THE UNIVERSITY OF MANITOBA

DEVELOPMENT OF A MICRO SCALE SIMULATION MODEL OF TRAFFIC FLOW ON A SELECTED SECTION OF PEMBINA HIGHWAY IN THE CITY OF WINNIPEG

by

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ABSTRACT

One of the main problems facing transportation planners in large urban centres today is that of coping with the existing road systems. Very few are the instances when a city can afford to destroy the old road system and its immediate environment to clear a path for a new transportation belt in a congested or semi-congested area of the city.

Planners must instead find the optimal manner of using the present road system and, if necessary, expanding the road in a manner involving the least cost for the maximum benefits. Due to the financial constraints imposed on city budgets, the planners must only implement changes which have a guaranteed beneficial effect.

A simulation model can aid in the planning of these changes by implementing the changes in a computer run and studying the resulting congestion. Whether the changes be ones of varying the existing signal lengths or adding a lane to the road, the model is a more economical manner of studying the effects of change rather than by real life implementation.

ACKNOWLEDGMENTS

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Introduction:

This thesis is composed of two main parts each of which deals with the development of a simulation model of traffic flow on a selected section of Pembina Highway. The first section deals with a computer based model which is written in the General Purpose Simulation System, GPSS, subroutine package on The University of Manitoba IBM 360/60 computer installation. The purpose of this computer based simulation model is to demonstrate the utility of such a model in planning changes in an existing road system such as the selected section of Pembina Highway. Changes in the lengths of traffic signals or in the configuration of the road can be tested by means of modification to the computer model as will be described later in the thesis. Traffic planners can then run the model with the changes introduced in order to study their effects without going to great expense or possible inconvenience to the users of the road. Despite the shortcomings of the model as it is presented in this paper in terms of practical use, it does point out the manner in which such a model may satisfy the needs of traffic planners to have a tool to experiment with possible changes at a particular intersection or series of intersections on an existing road system. In the first part of the thesis a number of changes in signal times, as well as in the size of the road, are tested by means of the computer simulation model and their effects in terms of queue lengths and waiting times are analysed. The computer based model of the thesis is referred to as a micro scale model. This term is used to describe the general orientation of the model as not being one of a large grid city-wide transportation networks, which is the normal situation modelled, but instead a localized series of city blocks being analysed. The model is concerned with the traffic at one intersection and how it affects the congestion at the next intersection, rather than with the more classical problems of origin-destination studies.

Whereas the first section of the thesis deals with the computer based simulation model which is constrained by the fact that it is computer based, the second section deals with the potential refinement of the simulation model through the use of mathematical sub-models which would alleviate the constraints. These models could be used in the main simulation model to increase its flexibility and make it more representative of the actual traffic flow on the selected section of Pembina Highway. This flexibility would be in terms of introducing hourly, daily and seasonal variations in traffic levels. The expanded simulation model would also be more representative of the actual traffic flow since it would be able to account for non-signalized as well as signalized intersections, car following theory and other factors not included in the presented simulation model.

Through the use of the simulation model potential changes in the road system can be evaluated in terms of shorter waiting times or decreased queue lengths. The improvements then must be considered in relation to the relative cost of each potential change and other socio-economic factors. However, it is not the purpose of this thesis to propose an optimal strategy to follow in the planning of future expansion and/or modification to the selected section of Pembina Highway. The purpose of this thesis is to present two models of the traffic flow on the selected section of Pembina Highway which could be used, with proper refinement, in the making of such a plan.

Description of the Model Zone:

Pembina Highway is a major artery in the road system of the southern portion of The City of Winnipeg. It serves as virtually the only link between the City's centre core and the outlying communities of Fort Garry, Fort Richmond, Parc La Salle, Saint Norbert and The University of Manitoba Campus.

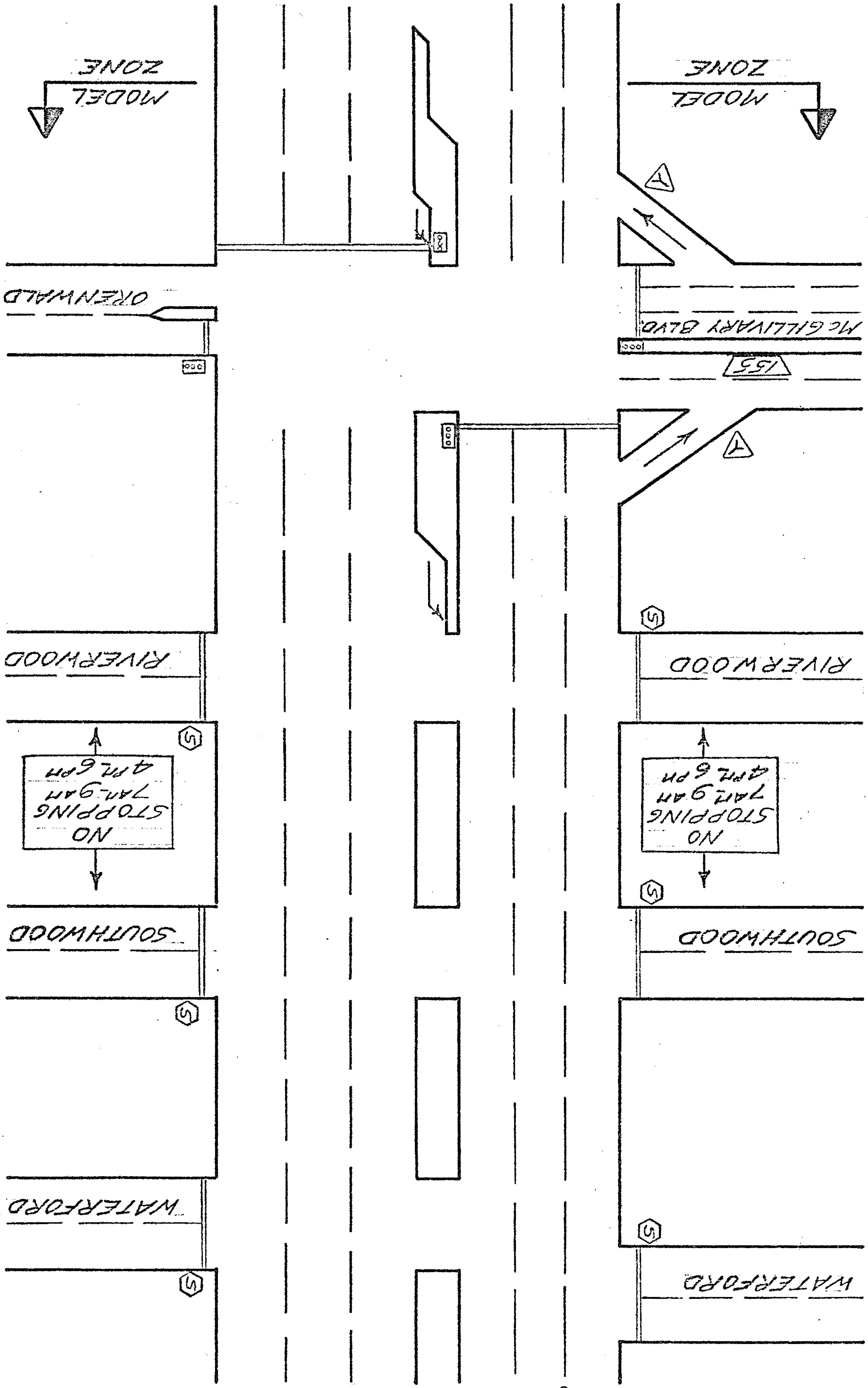
Due to the presence of the University and also large scale housing developments nearby, Pembina Highway has the unique feature of a bi-directional rush hour occurring twice a day. That is, the morning and afternoon rush hour traffic is not primarily travelling northwards and southwards respectively but has a high volume in both directions during both rush hours. This bi-directional rush hour imposes constraints on the adoption of several common combatants to the rush hour problem, such as, synchronized light changes or variable numbers of lanes of traffic.

The selected portion of Pembina Highway in its present form is found mapped out in Appendix A, while the same portion with a proposed lane addition is found in Appendix B. There is a centre island or median upon the entire length of the model zone as is the case for most of Pembina Highway. There are at present three southbound lanes of traffic, one of which is used as a parking lane during non-rush hours south of Windemere. There are also three northbound lanes up to Jubilee, of which one is used as a parking lane during non-rush hours south of Merriham. There are two northbound lanes from the Jubilee exit to south of Harrow where the road is divided into five lanes, two of which are for traffic turning left.

The southernmost intersection in the model zone is that of Pembina-MacGillivray-Oakenwald. At this intersection Pembina has one green light for northbound and southbound traffic to proceed through, there are no turning restrictions; northbound Pembina has a left turn storage lane and southbound Pembina has a right turn yield. Oakenwald has no turning restrictions and its own green light; similarly, MacGillivray has no turning restrictions and its own green light. There are five minor intersections before the next major crossing at Pembina-Point Road-Windemere. There is a no left turn restriction on northbound Pembina and although both northbound and southbound Pembina use the same green light, southbound Pembina has a left turn storage lane and flashing green light. Point Road has a right turn yield and uses the same green light as Windemere, neither street has any turning restrictions. There are three minor intersections before the Jubilee interchange, route 125 on the map. Northbound Pembina has a traffic signal at the Jubilee entrance, while the remaining interfaces between Pembina and Jubilee are standard exits and merges. The Pembina and Jubilee traffic is restricted in its ability to make turns by the semi-cloverleaf configuration of the intersection of the two streets. The next intersection is Pembina-Harrow where the northbound Pembina traffic cannot turn right at anytime and cannot turn left from 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. Pembina southbound traffic cannot turn left and Harrow traffic must turn right and also stop first. The next and most northerly intersection is Pembina-Stafford where the northbound Pembina traffic is broken down into five lanes, three straight and two turning left. Southbound Pembina cannot turn left and Stafford traffic must turn right. The Pembina northbound left turning lane shares a green light with the Stafford traffic, while the Pembina southbound and remaining northbound traffic have their own green lights.

As earlier mentioned the traffic at rush hours on Pembina Highway is heavy in both northerly and southerly directions. Therefore, the signal times at Pembina-Stafford change to the same sequence for morning or afternoon rush hours. At Pembina-Point Road-Windemere and Pembina-MacGillivray-Oakenwald the times are constant throughout the day, while at Pembina-Jubilee there are three signal times, one for morning rush hour, non-rush hour and afternoon rush hour.

Snow clearance along the selected section of Pembina Highway is excellent and thus all lanes are functional throughout the year. Within the model zone there is no housing immediately along Pembina Highway and thus traffic is generated from sattelite population densities. Due to the road structure in the area the traffic from these locations is handled mainly by the feeder routes, which are a part of the major intersections, and not by the minor roads along the selected section of Pembina Highway.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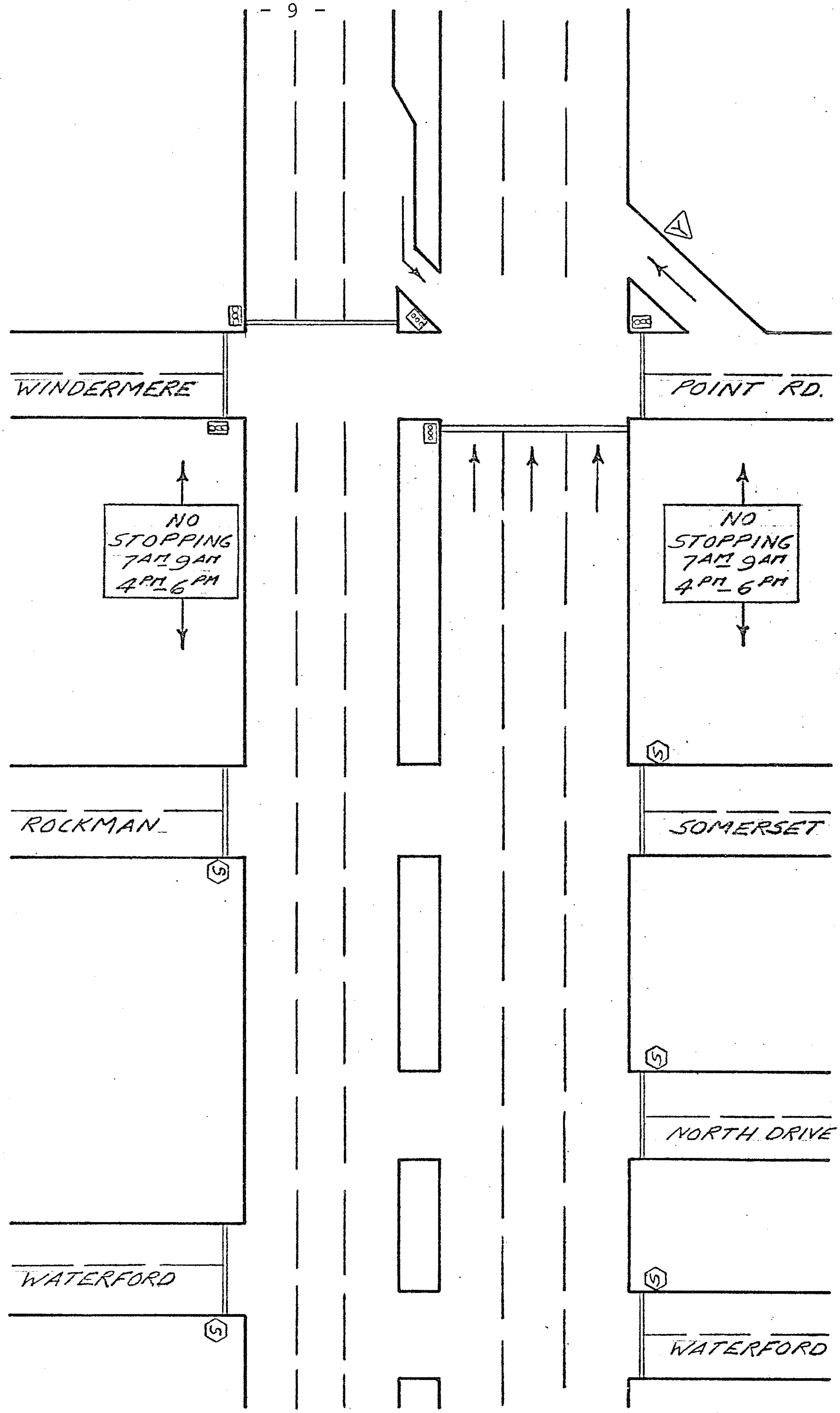
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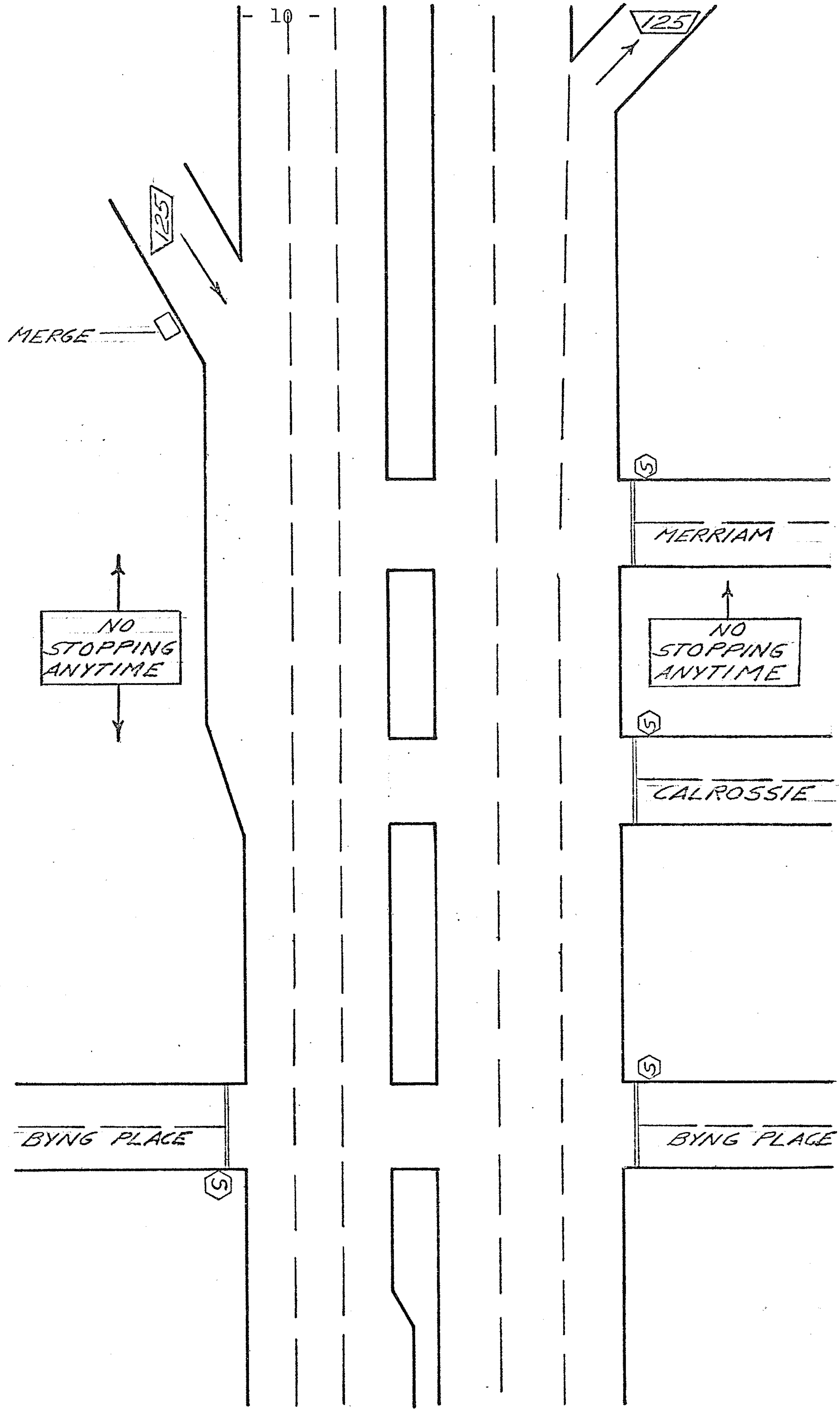
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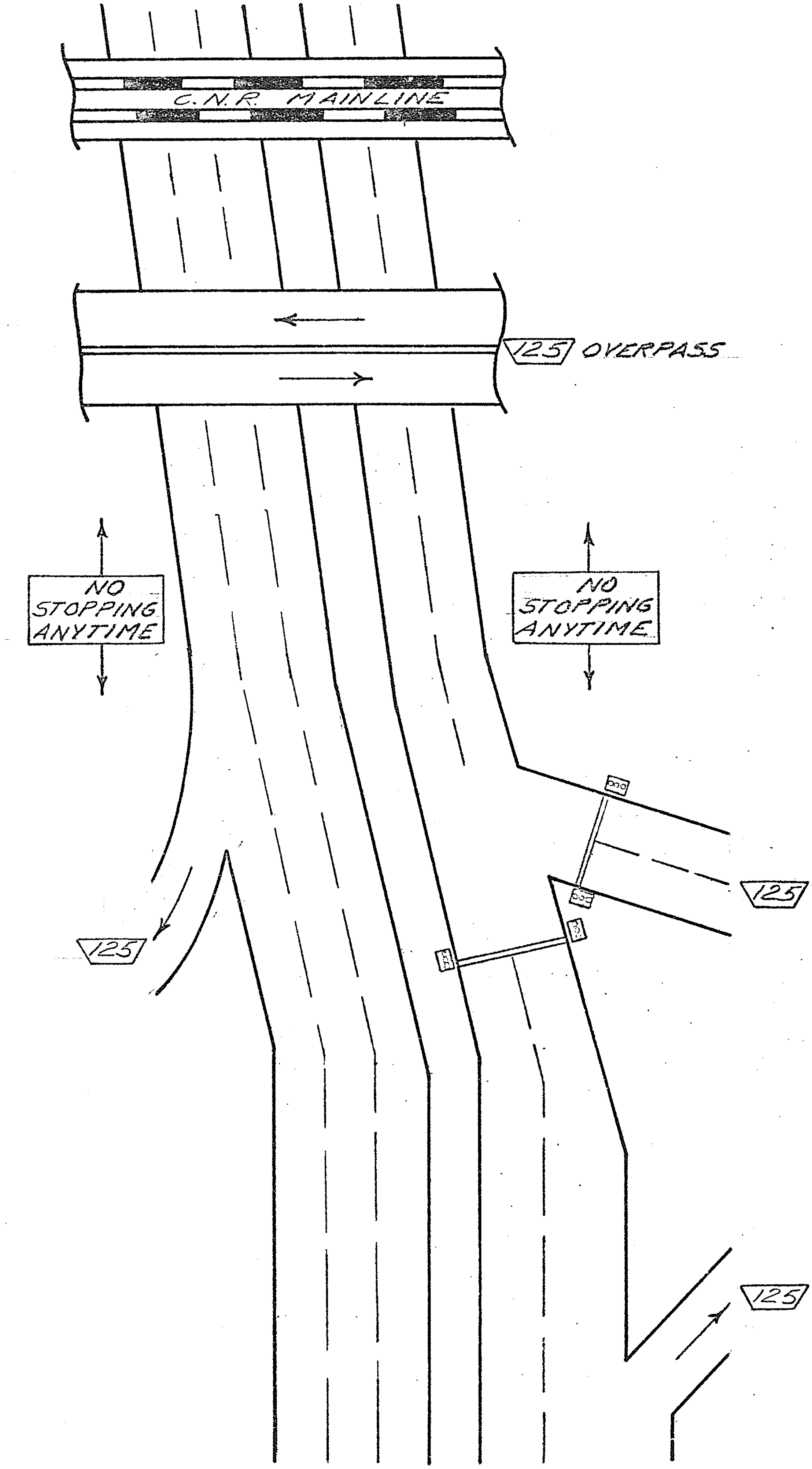
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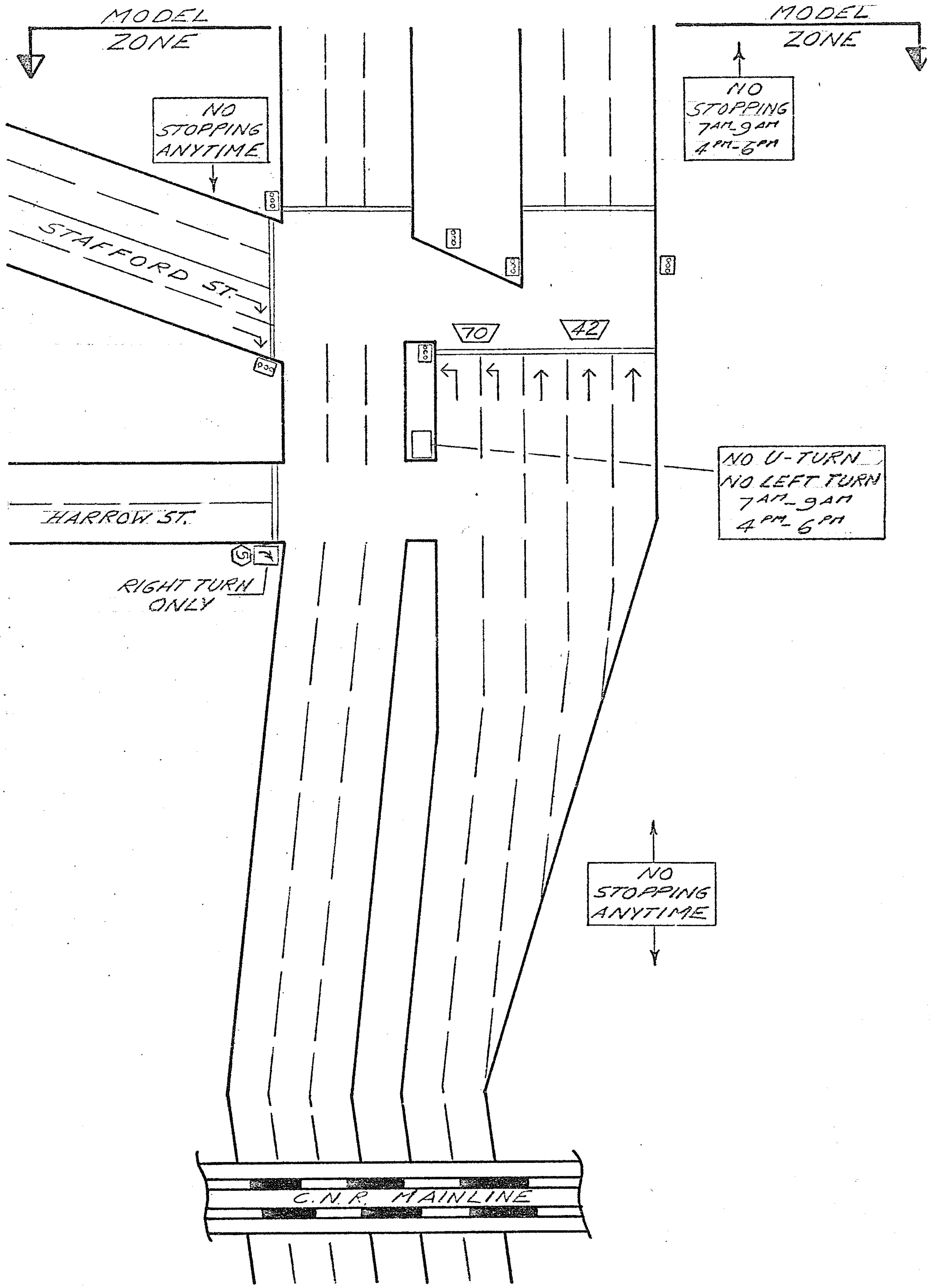
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Description of the Computer Based Simulation Model:

The computer based simulation model consists of a General Purpose Simulation System GPSS programme which is written for the IBM 360/65 installation at The University of Manitoba. Rather than dealing with a detailed description of the programme, this section of the thesis will concentrate on the more general features of the programme and refer the reader to Appendix C for a detailed listing of one variation of the programme and Appendix D for the corresponding flowchart.

Since the simulation programme was written in GPSS it would perhaps be beneficial to give a brief summary of the various transactions available in GPSS and used in the programme. Please refer to the first page of Appendix D for a listing of the transactions and their corresponding block symbols used in the flowchart found in the same Appendix.

The ADVANCE block is used to delay the progress of a transaction through the system. Within this simulation programme the ADVANCE block is used for two main purposes, to delay the change in a signal light, that is, to simulate the length of a red or green signal light at a particular intersection and to delay the advancement of an automobile through the road system, that is, to simulate the time taken for an automobile to depart from an intersection or the travel time between intersections. The length of the delay is specified in one of two ways, either as a constant value which does not change from transaction to transaction, or as a value which does vary to a certain extent from transaction to transaction. The former type of ADVANCE block has only one value specified, while the latter has two values, a mean and a modifier.

The DEPART block serves to remove a transaction from the queue specified in the block itself. In this simulation programme the DEPART block is used to simulate an automobile leaving a lineup at an intersection and proceeding into the traffic flow.

A GATE block serves as its name implies, to restrict the movement of a transaction through a system. A GATE block can be one of two types, GATE LR and GATE LS, depending upon whether the gate is considered to be initially in a reset or set state. This state, when coupled with the corresponding LOGIC block, will determine whether a transaction may pass through the gate, be sent on some specified alternate path or placed in a pushdown delay chain until the state of the GATE is changed by a corresponding LOGIC block. In this simulation GATE blocks are used in two areas which are closely related. In the signal control subroutines GATE blocks are used to determine the path of a transaction to be one of entering an ADVANCE block for the length of a red or green traffic light. Within the traffic simulation portion of the programme GATE blocks, corresponding to LOGIC blocks found in the signal control subroutines, are used to simulate the delay in an automobile caused by a red light and the possibility of an automobile to proceed through a green light.

The GENERATE block is the most fundamental block of any GPSS programme. This block is used to create transactions at specified intervals. Just as in the ADVANCE block these intervals may be of some constant value or may vary somewhat from transaction to transaction. In the former case one number is specified as the standard interarrival time or time between transactions, while the latter both a mean and a modifier is specified. In addion to these attributes a specification can be given in the GENERATE block as to the number of transactions to be created within one run of the GPSS programme. This last feature is used in the signal control subroutines where only one transaction is used to perform the switching function for one set of signals. The GENERATE block is also used throughout the programme to simulate the introduction of automobiles at varying time intervals into the road system from the side roads and at the southern and northern extremities of the selected section of Pembina Highway.

The LOGIC block operates as a switch in a GPSS programme. Whenever a transaction passes through a LOGIC block depending upon its nature, the switch is placed in a set state, a reset state or is inverted into the state opposite from which it was in, that is, set to reset or vice versa. These three types of LOGIC blocks are indicated as LOGIC S, LOGIC R and LOGIC I respectively. As mentioned earlier the LOGIC blocks in this simulation programme correspond to GATE blocks found both in the signal control subroutines and in the main traffic simulation area. A LOGIC block which is in a reset state will result in a corresponding GATE LR to be in an open state and a GATE LS to be in a closed state.

As indicated by the simulation programme found in Appendix C, the QUEUE block is the principal block used to gather information in this simulation. A QUEUE block gathers information about a transaction or a number of transactions while they are being held in the block. Unlike most blocks in GPSS a transaction does not leave a QUEUE block automatically but must be removed by means of a DEPART block. In this simulation QUEUE block serves two principal functions; they simulate the lineup of automobiles in various lanes of an intersection and they simulate an automobile crossing an intersection. The second function of the QUEUE block is present in this programme for mainly internal purposes in that an automobile wishing to enter a traffic flow from a yield, or by a right turn on a red light, can check to see if the intersection is free before entering the traffic flow. The first function of the QUEUE block is to accumulate statistics which are used in the analysis of the computer simulation and in the building of the mathematical model.

The RESET block in a GPSS programme sets the relative clock to zero, the maximum contents of the QUEUE blocks to the current contents and the total entry count of the QUEUE blocks to the current contents. The purpose of the RESET block is to be able to commence the tabulation of statistics in a system from some point in time when the system is fully active and closer to representing reality than its initial state. In this simulation programme the RESET block is encountered after the system has been operative for 1800 seconds or one-half hour. This figure was reached by considering the maximum travel time of one automobile through the system to be in the region of five to ten minutes so that the initial automobile generated at one extremity would be through the entire system as would many of those following. That is, all QUEUE blocks would be in 'normal' use. The RESET block prevents the accumulation of statistics or QUEUE blocks which are only accepting arrivals from side road inputs into the main traffic flow and not from continuing traffic along the main route.

The START block determines the length of the simulation run by indicating the number of termination counts which are to be encountered before ending the run. Every termination count reduces the value specified in the START block by one. Once the value is depleted the run is terminated and either a RESET block or END block is encountered. The function of the RESET block has been mentioned earlier and that of the END block is to exit from the GPSS system. In this simulation programme there are two START blocks, START 18 and START 72. The first run, as earlier mentioned, is to initialize the entire system before collecting statistics, while the second run is the simulation of a period of 7200 seconds or two hours during which statistics are collected.

A TERMINATE block is used to remove a transaction from the system. If a TERMINATE block has a value specified in it this value will be entered into the termination count whenever a transaction enters that TERMINATE block. In this simulation the TERMINATE block is used in two ways, first as a part of the simulation timer where a value of one is specified and also throughout the model where no value is specified. The later use of the TERMINATE block is meant to represent automobiles turning off Pembina Highway or leaving the selected section of Pembina Highway at either extremity.

The TEST block is used to determine the path of a transaction through the system by means of comparing the relationship between the values of the contents of two other blocks or one block and some specified value. The comparison can consist of less than, L, less than or equal, LE, equal, E, not equal, NE, greater than, G, or greater than or equal, GE. The TEST block can allow a transaction through if the condition of the block is satisfied, if not, send the transaction along on an alternate path if one is specified or place it in a pushdown delay chain. In this simulation the TEST block is used to determine if there is room in a storage lane, is an intersection empty and is there room on the other side of an intersection for an automobile to proceed.

The TRANSFER block is also used to change the path of a transaction in the system. The TRANSFER block can be of an unconditional mode in that all transactions follow one specified path, that is, proceed to a certain specified block, or a fractional selection mode in that a proportion of transactions go to one specified block while the remainder go to another. In this simulation the fractional mode is used to simulate the proportion of automobiles turning off Pembina Highway or onto Pembina Highway from a side road. The unconditional mode is used to have transactions leaving an intersection all enter the traffic flow to the next intersection.

However brief this summary of the principal blocks used in the GPSS programme has been, it is hoped that it will be of some use in understanding the following description of an individual intersection and then of the linking of a series of intersections.

The intersection which will now be described in detail is that of Pembina Highway and Stafford Street. The intersection is depicted in two parts of the computer listing found in Appendix C. The first portion of the listing which concerns this intersection is that of the signal control subroutine called STAFFORD SIGNALS and which consists of blocks thirty through thirty-nine. The GENERATE block creates one transaction and only one. This transaction passes through a LOGIC I block, which in the case of the first pass and all odd numbered passes, places the LOGIC switch labelled STA in a set position. The transaction proceeds to the GATE LS block which in the case of this pass is open due to the LOGIC labelled STA being in a set position and thus the transaction enters the ADVANCE 16 block where it is held for sixteen seconds. While the transaction is being held in this ADVANCE block it is simulating the length of the Pembina Highway northbound traffic's red light. Next, the transaction passes through the LOGIC S block which sets the LOGIC switch labelled STB.

Following this it enters an ADVANCE block where it is held for twenty-eight seconds, this is to simulate the occurrence of a straight through green arrow from Pembina Highway northbound traffic. Once the twenty-eight seconds have elapsed the transaction enters the TRANSFER block where it is directed back to the LOGIC I block which it proceeds through. In the case of the second pass and all even numbered passes the LOGIC switch labelled STA is placed in a reset condition. Next the transaction approaches the GATE LS block but since the corresponding LOGIC switch labelled STA is in a reset position the transaction takes the alternate route where it enters an ADVANCE block and is held for a variable length of time in a region specified by a means of fifty-three and a modifier of two seconds. This represents the length of a green light for Stafford traffic and Pembina Highway northbound traffic turning onto Stafford. The two ADVANCE blocks earlier mentioned combine to simulate the length of the green light for Pembina Highway southbound. Next the transaction passes through a LOGIC R block which resets the LOGIC switch labelled STB. The main purpose of this signal control subroutine and of the other three signal control subroutines is to co-ordinate the changes in the states of the various LOGIC switches which correspond to the various GATE blocks found in the main traffic simulation model.

The second portion of the computer listing which applies to the Pembina Highway and Stafford intersection consists of blocks 304 through 374. This area of the computer programme is simulating the traffic flow at the intersection. All transactions referred to are representing automobiles in the road system which have either been created at earlier intersections or are created at the intersection being studied. The first block which is encountered by a northbound transaction is a TRANSFER block using a fractional selection mode. The block directs fifty-six percent of the time to remain on Pembina Highway and forty-four percent of the time to turn onto Stafford. The figures used in this fractional mode TRANSFER block, as is the case with all such blocks in the programme, were found through analysis of historical traffic counts for the intersections being simulated. Next the traffic turning onto Stafford is considered, the transactions enter a TEST block which serves to decide which lane the transaction will enter. The decision is based solely on which lineup or QUEUE length is shorter. As a result of the TEST block the traffic enters either QUEUE 12 or QUEUE 26, both of which represent a left turn lane from Pembina Highway onto Stafford. While statistics are being collected on a transaction in the QUEUE, the transaction is attempting to pass through a GATE LR block which corresponds to the LOGIC switch STA once the switch is in a reset state as determined in the signal control subroutine, the transaction may proceed through the GATE and enter an ADVANCE block for one second to represent departure time in terms of a driver's and an automobile's reaction time. Statistics are then no longer kept about that transaction in the QUEUE block since a DEPART block is encountered. The transaction then enters a QUEUE block from which it is immediately removed by a DEPART block. This is to simulate traffic in the actual intersection and would be checked to be equal to zero before an automobile could make a right turn on a red light from Pembina southbound onto Stafford if such a turn were permitted. Finally, the transaction enters a TERMINATE block and is removed from the system since it has left the selected section of Pembina Highway.

The traffic remaining on Pembina is simulated by blocks 321 through 335. A transaction arrives at the first block from the fractional selection mode TRANSFER B block earlier mentioned. This transaction enters a TEST block to determine the shortest QUEUE length, next it enters that QUEUE and awaits the GATE LS block to be opened by the LOGIC switch labelled STB to be in a set condition. Next the transaction enters a one second ADVANCE block after which it is removed from the QUEUE and passes through the Pembina Highway northbound intersection before being removed from the system.

The simulation of southbound traffic, both on Pembina Highway and from Stafford, is somewhat different from the northbound cases. One of the main differences is that the transactions are being created just before the intersection. In the case of rush hour conditions the Pembina Highway southbound traffic has a transaction created by a GENERATE block every four seconds with a one second modifier, that is, every four plus or minus one second. Next the transactions enter a transfer block where ten percent of the time they take the outer lane. The remaining transactions enter a battery of TEST blocks in order to determine which of the three available traffic lanes have the shortest QUEUE length. The transactions then enter the preferred QUEUE and attempt to proceed through the GATE LS which is open when the LOGIC switch labelled STA is in a set condition. Once the transaction passes the GATE it enters a TEST block to determine if the corresponding QUEUE at the next intersection is backed up all the way to the present intersection. Due to the manner in which transactions select the shortest QUEUE length this condition of congestion implies that all lanes are equally or very nearly equally backed up. Next the transaction enters the one second ADVANCE block after which it is removed from the QUEUE and passes through the intersection. The curb lane has a percentage of its transactions terminate thus simulating automobiles turning off Pembina Highway. The remaining transactions in the curb lane and all transactions in the other two lanes are transferred to an ADVANCE block which simulates the travel time to the next intersection.

The Stafford traffic, like the Pembina Highway southbound traffic and also like all side roads in the simulation, creates transactions just before the intersection. Also like all side roads in the simulation, except those with right turn lanes or yields, the traffic on Stafford is considered to be in one QUEUE. The GENERATE block creates transactions which enter a QUEUE block, they then attempt to pass the GATE LR block which is open when the LOGIC switch labelled STA is in a reset condition. Next a check is made if there is room to turn onto Pembina Highway, that is, if the QUEUES at the next intersection do not stretch all the way back to Pembina Highway and Stafford. A one second ADVANCE block is encountered afterwhich statistics are no longer collected for the transaction at that QUEUE. The transaction then passes through the intersection and enters the southbound traffic flow by means of an ADVANCE block to simulate the travel time.

Although as can be seen from the maps in Appendices A and B, the computer listing in Appendix C and the GPSS flowchart in Appendix D, each intersection has unique characteristics in terms of the number of side roads, the signal control systems and the possibility of land expansion. However, despite these differences there are a number of general characteristics shared by all the intersections. The previous description of one intersection points out these characteristics, the manner in which a transaction takes the lane with the shortest QUEUE length, the way the GATE blocks in conjunction with the signal control subroutines simulate the traffic signals, the manner in which a departure time in terms of driver's and automobile's reaction time is included, the way in which traffic turning off or onto Pembina Highway is accounted for and, also, the way congestion at the next intersection is considered.

As previously stated, a description of a series of intersections will now be given. This description will be much more general than the previous one for an individual intersection. The major logic flow will be described rather than the path of an individual transaction. This policy has been adopted to avoid any further repetition to what has already been stated. This description will follow the pattern of the simulation programme itself in that it will first consider the northbound Pembina Highway from the southern extremity to the northern extremity of the selected section of Pembina Highway and then the southbound traffic on Pembina Highway passing through the model zone.

Pembina Highway traffic is generated just south of the Pembina Highway-MacGillivray-Oakenwald intersection. The traffic then enters a left turn storage lane, the curb lane, or one of the two straight through lanes depending upon the number of automobiles in the left turn storage lane. When the traffic signal is green, that is, the GATE is open, traffic will proceed northbound on Pembina Highway, then turn right onto Oakenwald and TERMINATE from the system or wait for the western half of the intersection to be clear and turn left onto MacGillivray and TERMINATE from the system.

Oakenwald traffic is broken down into a right turning lane and a straight through lane which also accounts for left turning traffic. The right turn lane will turn when the light is green or when the intersection is clear on a red light. This is determined by a TEST block which checks if QUEUE 2 which represents the intersection is clear. The traffic in the other lane awaits the Oakenwald green light and then terminates after leaving the QUEUE.

The MacGillivray traffic is considered to enter one QUEUE after being created. Once the GATE is open the MacGillivray traffic, like that of Pembina Highway and Oakenwald, checks to see that there is room to enter the traffic flow leading to the intersection.

All traffic entering this northbound traffic flow enters a fifty-nine second ADVANCE block to simulate travel time between intersections. These travel times were arrived at by empirical observations at different times during the day.

Following this ADVANCE block traffic is once again broken down into various lanes depending upon the percentage of traffic turning right and on the QUEUE lengths for the northbound traffic. When the GATE is open for Pembina Highway northbound traffic the transactions leave the QUEUES after a one second delay one after another until the GATE closes once again.

Point Road traffic has a right turn yield which involves a TEST block used to determine if the intersection is free before a transaction proceeds into the northbound traffic flow. Southbound and straight through traffic must check by means of a TEST block that one is not in another's way after passing through the GATE block. Furthermore, southbound traffic must check that it may turn without colliding with any Windemere traffic. Similarly, Windemere traffic encounters several TEST blocks of the same nature. Before testing for a right turn on red light, a transaction must have no transactions in the QUEUE before it, also before making a left turn onto Pembina Highway northbound, a TEST block is encountered to assume that there are no straight through Point Road automobiles in the intersection. Traffic which is proceeding onto Point Road from Windemere must check to see that no automobiles waiting to make a left turn onto Pembina Highway northbound are blocking its path.

The northbound transactions generated by Pembina Highway northbound traffic, Point Road right turning traffic and Windemere left turning traffic enter a forty-one second ADVANCE block to represent travel time up to the Jubilee exit where 20.6 percent of the traffic turns off onto Jubilee and leaves the system. The remaining transactions enter a ten second advance before checking for the shortest QUEUE lengths and once in the QUEUES wait for the GATE to open, thus simulating a green signal light. The Jubilee traffic also await the opening of its GATE and then enters the same northbound traffic flow as the Pembina Highway northbound traffic. The transactions in this flow enter a twenty-six second ADVANCE block before reaching the Harrow intersection. In non-rush hours nine percent of the transactions enter a QUEUE to turn left onto Harrow. The transactions in this QUEUE check to see if the western side of the Pembina Highway-Harrow intersection is open; if so, after a one second departure they proceed across the intersection and out of the system.

The transactions which remained on Pembina Highway entered a seven second ADVANCE before being separated by a TRANSFER block into traffic turning onto Stafford and traffic remaining on Pembina. The transactions in each case TEST for the shortest QUEUE lengths and then attempt to pass through their respective GATE, afterwhich they enter a one second ADVANCE block before leaving the QUEUE block, passing through the intersection and terminating.

The southbound Pembina Highway and Stafford southbound traffic have already been described in terms of their activities at the actual intersection. Following the intersection the transactions enter an eight second ADVANCE block. Following this 1.1 percent of the transactions terminate and the remainder proceed into the southbound traffic flow.

Southbound traffic is also generated from Harrow Street where it enters a QUEUE, then by means of a TEST block checks to see that the intersection is open and, if so, after a one second ADVANCE block leaves the QUEUE and enters the southbound traffic flow already mentioned. The transactions in this flow enter a twenty-seven second ADVANCE block to simulate the travel time before the Jubilee exit where 23.7 percent of the transactions TERMINATE. The remaining transactions enter a ten second ADVANCE block after which they are joined by transactions created by the Jubilee southbound traffic. Then the transactions enter a thirty-three second ADVANCE block followed by a series of TRANSFER and TEST blocks which place 2.6 percent of the traffic in the curb lane, 2 percent in a left turn storage lane and the remainder in the lane with the shortest QUEUE length.

Next the standard procedure for straight through traffic of waiting for the GATE to open, checking for future congestion, allowing for traffic to turn off and the use of one second ADVANCE blocks representing departure time is followed. The left turning traffic checks to see that the GATE is open and if there is no oncoming traffic before crossing the intersection and terminating oncoming traffic is delayed after the opening of the GATE by means of a flashing green light for the southbound traffic. The remaining transactions as well as other southbound transactions generated from Point Road and Windemere enter a sixty-one second ADVANCE block to represent the travel time.

The transactions are then assigned to various QUEUES by means of a series of TRANSFER and TEST blocks. The transactions turning right do not reach the signals since they TERMINATE from the system by means of a right turn yield. The left turning traffic blocks the centre lane due to the lack of a left turn storage lane. However, this has little effect on that lane's QUEUE length due to the manner in which transactions are placed in the shortest QUEUE. Once the transactions are in their respective QUEUES they wait for the GATE to be opened representing a green signal light. In the case of left turning traffic they TEST for the eastern side of the intersection to be clear before terminating. The centre lane traffic checks that no left turning traffic is blocking its way and, if not, proceeds in the standard fashion before terminating just beyond the intersection.

Throughout the foregoing description of the computer based simulation model a number of assumptions used in the formation of the model were referred to directly or indirectly. These assumptions were made in order to make the programme more manageable or were imposed as a result of the constraints placed on the programmer using GPSS. A brief listing of the key assumptions used in the programme will now be given. As earlier mentioned the geographic layout in the area bordering on the selected section of Pembina Highway is of such a nature that a high dependence is placed on feeder routes connecting Pembina Highway and the population pockets rather than a series of small side roads leading from a population area onto Pembina Highway. It is due to this higher use of feeder routes that the role of side roads has been deemphasized. Therefore, in the simulation model, due to size constraints imposed by GPSS, it was assumed that the effects of such non-signalized side roads to be negligible and thus were not accounted for in the programme. A simulation of the effect on that traffic flow of Pembina Highway of automobiles entering from such side roads would have required a large expansion of the simulation programme which was already at its limit in terms of core usage. A second assumption which was made in the programme was that an automobile approaching an intersection would choose the rightmost lane if it were to turn right, the leftmost lane if it were to turn left and the lane with the shortest queue length if it were to proceed on the same road after the intersection. This decision process was adopted for the sake of simplicity in developing the programme. As a result of this method of having automobiles choose their lane of travel it was possible to study the waiting times at a representative queue for each direction of travel at an intersection, rather than attempting to collect data for all queues which would not be permissible in GPSS due to the number of queues. A third key assumption is that the start up or reaction time before departure for an automobile leaving a queue is a constant value of one second. This assumption was made in light of the fact that in a real life situation the first car has a much greater delay time than the final cars in the queue and that each car in the queue has a proportionately lesser delay time. It was also taken into account that the expected queue lengths based on preliminary runs were always found to have a value of less than ten automobiles. These two facts, decreasing leaving time and short queue lengths, indicated that an assumption of a constant departure time would give a close enough approximation of reality in the computer simulation. An expansion of the delay time to being dependent on an automobile's position in the queue would have necessitated a reduction in other areas of the programme. The fourth fundamental assumption made in the computer simulation model is that of all cases having a standard travel time between intersections. This assumption was used for the sake of simplicity in developing the programme. Without the addition of a linear car following delay subprogramme within the model a randomly distributed series of travel times could result in automobiles "passing" one another in the same lane or two automobiles arriving in a queue at the same instant. Therefore, in order to avoid these problems without developing a simulation subprogramme for linear car following delays, which would be of the magnitude of another thesis, a constant travel time was introduced.

In addition to these key assumptions a number of minor ones were also made. These consisted of assuming an automobile to make a right turn on a red light where permissible, if it were the first automobile in the queue and the intersection were empty. A similar assumption in terms of the intersection being empty and the automobile being first in the queue was made for automobiles entering from a yield lane or a side road with a stop sign.

Throughout the description of the computer simulation I have been rather vague about the numerical inputs used in the simulation programme. This was done in order to keep the description as general as possible. A complete listing of the numerical values for the various simulation runs representing different times of day and varying conditions can be found in tables A, B, C.1, C.2, C.3 and D which follow this section of the thesis.

TABLE A

TRAVEL TIME BETWEEN

INTERSECTIONS *

IN SECONDS

NORTHBOUND

MacGillivray-Oakenwald & Point Road-Windemere	59
Point Road-Windemere & Jubilee Exit	41
Jubilee Exit & Jubilee Entrance	10
Jubilee Entrance & Harrow	26
Harrow & Stafford	7

SOUTHBOUND

Stafford & Harrow	8
Harrow & Jubilee Exit	27
Jubilee Exit & Jubilee Entrance	10
Jubilee Entrance & Point Road-Windemere	33
Point Road-Windemere & MacGillivray-Oakenwald	61

* Based upon empirical observations taken at three different times in one week. Road conditions varying from wet to dry. Total number of observations for each travel time was 9.

TABLE B

PERCENTAGE TRAFFIC TURNING

AT EACH INTERSECTION *

	Left	Right
Pembina-MacGillivray-Oakenwald		
Pembina Southbound	1.0	19.9
Pembina Northbound	9.4	1.7
MacGillivray Eastbound	60.1	30.8
Oakenwald Westbound	44.7	27.7
Pembina-Point Road-Windemere		
Pembina Southbound	7.2	2.6
Pembina Northbound	N/A	1.0
Point Road Westbound	12.5	79.8
Windemere Eastbound	80.2	9.7
Pembina-Jubilee		
Pembina Northbound	N/A	20.6
Pembina Southbound	23.7	N/A
Pembina-Harrow		
Pembina Northbound	9.0	N/A
Pembina Southbound	N/A	1.0
Pembina-Stafford		
Pembina Northbound	44.0	N/A
Pembina Southbound	N/A	1.0

---

* Based upon historical traffic counts over the past five years supplied by The City of Winnipeg Transportation Planning Department. Total number of traffic counts for each intersection was 12.

TABLE C.1

SIGNAL TIMES AT EACH INTERSECTION

IN SECONDS

PRESENT CONDITIONS *

	Morning	Mid-Day	Afternoon
Pembina Green at MacGillivray-Oakenwald	63	63	63
Oakenwald Green	13	13	13
MacGillivray Green	18	18	18
Pembina Green at Point Road-Windemere	56	56	56
Pembina Southbound Flashing Green at Point Road-Windemere	12	12	12
Point Road & Windemere Green	27	27	27
Pembina Northbound Green at Jubilee	57	37	73
Jubilee Green	22	23	27
Pembina Northbound Red at Stafford	16	19	16
Pembina Northbound No Turning Green at Stafford	28	15	28
Pembina Northbound and Stafford Green	53	28	53

---

* Based upon empirical observations over the course of one week. Observations at 8:30 A.M., 12:30 P.M. and 5:30 P.M. Total number of observations for each time of day at each intersection was 30.

TABLE C.2

SIGNAL TIMES AT EACH INTERSECTION

IN SECONDS

SHORTENED CYCLE *

	Morning	Mid-Day	Afternoon
Pembina Green at MacGillivray-Oakenwald	32	32	32
Oakenwald Green	7	7	7
MacGillivray Green	9	9	9
Pembina Green at Point Road-Windemere	28	28	28
Pembina Southbound Flashing Green at Point Road-Windemere	6	6	6
Point Road-Windemere Green	14	14	14
Pembina Northbound Green at Jubilee	29	19	37
Jubilee Green	11	12	14
Pembina Northbound Red at Stafford	8	10	8
Pembina Northbound No Turning Green at Stafford	14	8	14
Pembina Northbound and Stafford Green	27	14	27

* Found by taking one half of Table C.1 Values

TABLE C.3

SIGNAL TIMES AT EACH INTERSECTION

IN SECONDS

LENGTHENED CYCLE *

	Morning	Mid-Day	Afternoon
Pembina Green at MacGillivray-Oakenwald	95	95	95
Oakenwald Green	20	20	20
MacGillivray Green	27	27	27
Pembina Green at Point Road-Windemere	84	84	84
Pembina Southbound Flashing Green at Point Road-Windemere	18	18	18
Point Road-Windemere Green	41	41	41
Pembina Northbound Green at Jubilee	86	56	110
Jubilee Green	33	35	41
Pembina Northbound Red at Stafford	24	29	24
Pembina Northbound No Turning Green at Stafford	42	23	42
Pembina Northbound and Stafford Green	80	42	80

* Found by Taking one and one half of Table C.1 Values

TABLE D

INTERARRIVAL TIMES OF AUTOMOBILES

IN SECONDS

FOR EACH TRAFFIC GENERATION POINT

PRESENT POPULATION */EXPANDED POPULATION **

	Morning	Mid-Day	Afternoon
Pembina Northbound at MacGillivray-Oakenwald	4,2/3,2	4,1/3,1	3,1/2,1
Oakenwald	33,12/25,9	43,9/32,7	35,12/26,8
MacGillivray	19,12/14,9	12,1/9,1	7,2/5,2
Point Road	22,20/17,15	40,5/30,4	27,3/20,2
Windemere	30,13/23,10	98,5/74,4	38,26/29,20
Jubilee Northbound	7,2/5,2	16,2/12,2	11,2/8,2
Pembina Southbound at Stafford	4,1/3,1	5,0/4,0	4,1/3,1
Stafford	8,1/6,1	13,2/10,2	4,1/3,1
Harrow	17,9/13,7	16,3/12,2	9,1/7,1
Jubilee Soutbound	9,4/7,3	20,2/15,2	14,8/11,6

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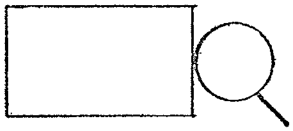
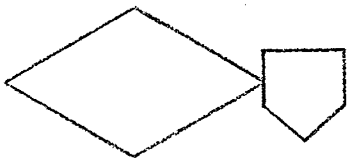
* Based upon historical traffic counts obtained from The City of Winnipeg Transportation Planning Department. Total number of traffic counts for each intersection was 12.

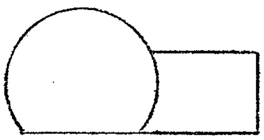
** Based upon reducing the interarrivals by taking three-quarters of their former value.

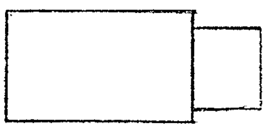
LEGEND OF BLOCK SYMBOLS
(USED IN THE GPSS FLOWCHART)

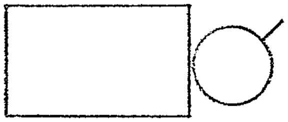

ADVANCE BLOCK

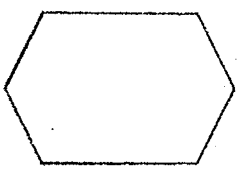

DEPART BLOCK


GATE BLOCK, CONNECTOR CONTAINS INDE
MAIN BLOCK CONTAINS INITIAL STATE

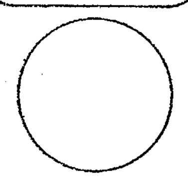

GENERATE BLOCK

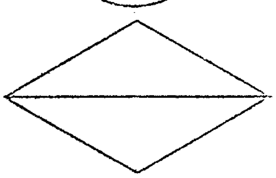

LOGIC BLOCK, CONNECTOR CONTAINS INDEX
MAIN BLOCK CONTAINS FUNCTION

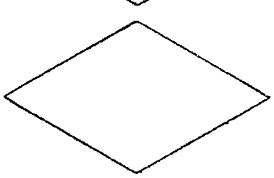

QUEUE BLOCK


RESET BLOCK


START BLOCK


TERMINATE BLOCK

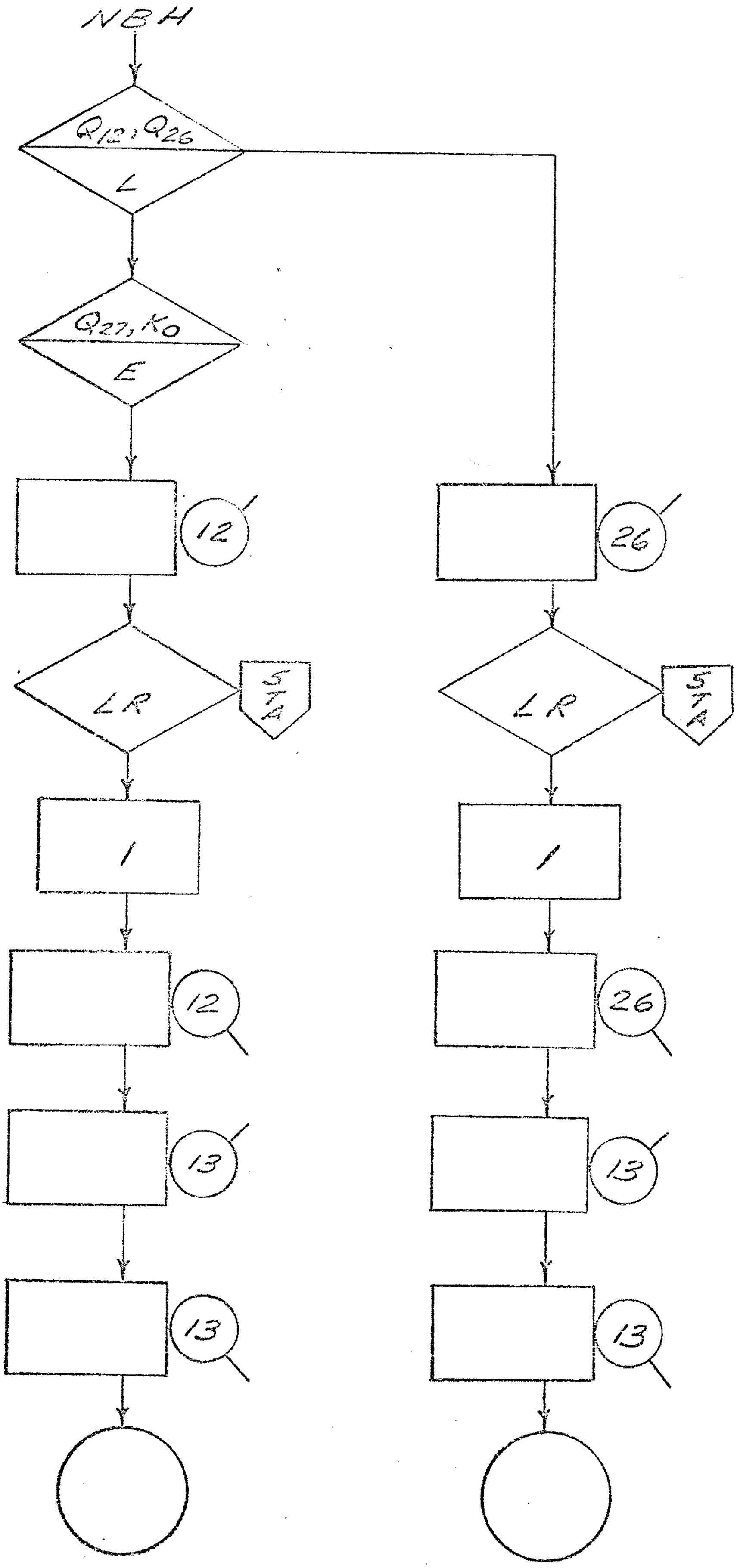

TEST BLOCK


TRANSFER BLOCK

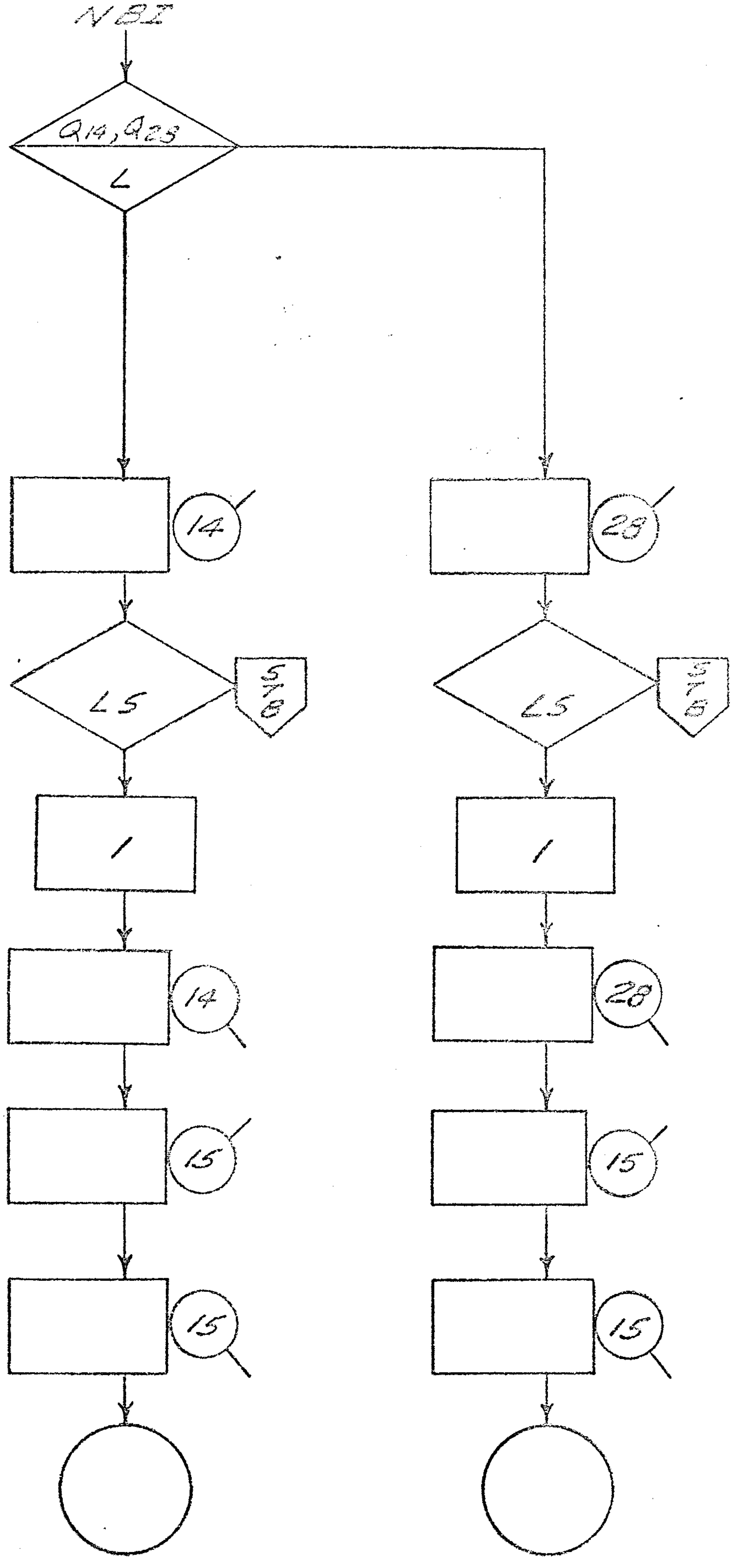

INFORMATION PATH


TRANSACTION PATH

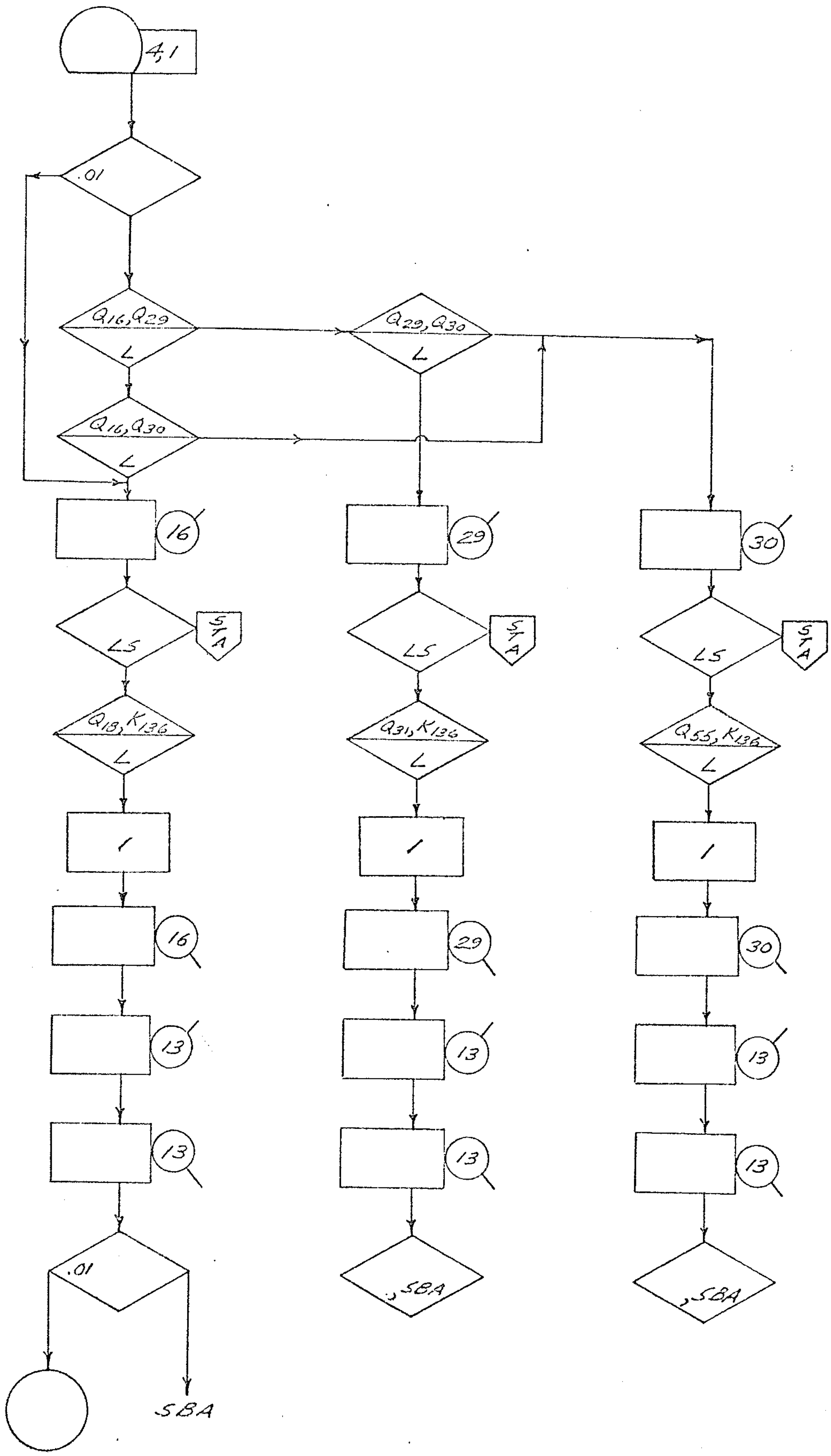
PEMBINA NORTH BOUND TRAFFIC TURNING ONTO STAFFORD



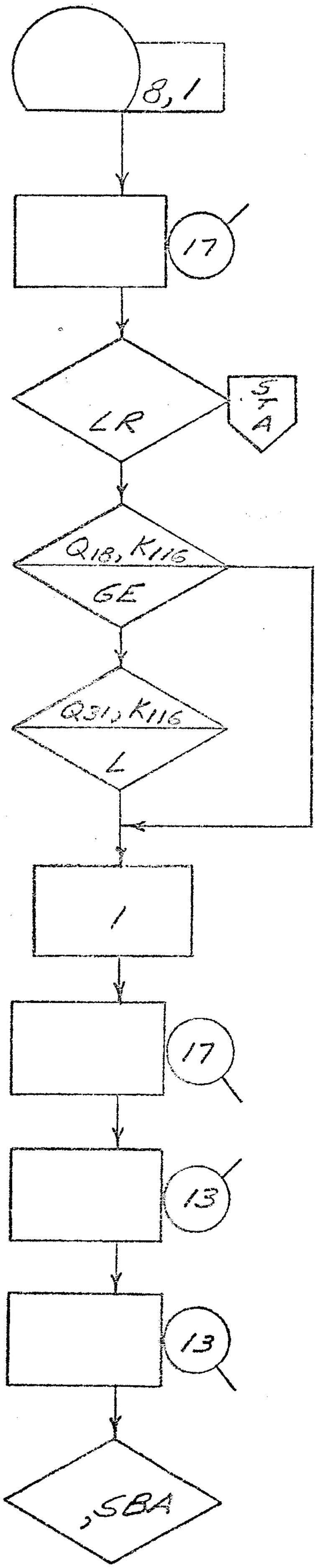
PEMBINA NORTH BOUND TRAFFIC
REMAINING ON PEMBINA



PEMBINA SOUTH BOUND TRAFFIC
APPROACHING STAFFORD



STAFFORD SOUTH BOUND TRAFFIC



Variations of the Computer Based Simulation Model:

In order to simulate the traffic flow on the selected section of Pembina Highway at different times of day and under varying conditions, a number of modifications to the programme had to be implemented. These modifications were of many different forms ranging from the mere changing of the mean and modifier values of certain GENERATE or ADVANCE blocks to the rewriting of entire sections of the programme.

This section of the thesis will deal with the general nature of the variations and give some idea of the type of modifications used to simulate the road system at different times of day and under varying conditions of population, signal lengths and road size.

The primary programme simulated the selected section of Pembina Highway in the mid-day time period, that is, without the no stopping 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. being in effect and under present conditions, that is, with the historically based values for the GENERATE statements as found in Table D and similarly for the ADVANCE statements used in the signal subroutines as found in Table C.1. Next a series of runs to simulate varying signal light lengths along the road system. Throughout all these runs the GENERATE values were those based on the historical data. These runs made use of the values found in Tables C.2 and C.3 for the ADVANCE blocks in the signal control subroutines in the following manner. The Pembina Highway times were lengthened, that is, the first, fourth, fifth, seventh, tenth and eleventh values of the middle column of Table C.3 were used in the appropriate ADVANCE blocks. The next run consisted of using the Pembina Highway times for Table C.2 with all other times being those of Table C.1. This simulated the shortening of the length of the signals on Pembina Highway. Then the effect of lengthening of the side road signal times was simulated by using the second, third, sixth, eight and ninth values of the middle column of Table C.3, while using the Table C.1 values for the remaining ADVANCE blocks. Next the side road times were shortened by using the Table C.2 values. Following this a run was made with Pembina Highway times lengthened, Table C.3, and side road times shortened, Table C.2. Then both sets of signal times were shortened and finally both lengthened using all Tables C.2 and C.3 values respectively.

Following this series of runs the signal times were returned to their original values of Table C.1. The next situation which was simulated was that of an expanded road system under mid-day conditions. A number of individual QUEUES had to be added to the programme at the Pembina-MacGillivray-Oakenwald intersection for both Pembina northbound and southbound traffic; similarly at the Pembina-Point Road-Windemere intersection and for northbound traffic only at the Pembina-Jubilee intersection. The programme was then run with the present population levels for the GENERATE blocks and the present signal times for the ADVANCE blocks of the signal control subroutines. After this run the GENERATE statement values were changed to those of a higher population as found in Table D.

Next the programme was modified to represent rush hour conditions with the removal of one QUEUE for northbound Pembina Highway traffic at the Pembina-Jubilee intersection and southbound traffic at the Pembina-Point Road-Windemere intersection. These lane changes, just as in the modifications for mid-day expansion, involved the changing of values in certain TEST blocks or rewriting certain decision systems in the programme. With this restructured programme the morning and afternoon rush hours were simulated under present conditions of traffic levels and signal lengths, under the conditions of varying signal lengths in the same pattern as outlined for the mid-day and in the case of the morning rush hour with the present signal lengths and the GENERATE block values for higher traffic levels as found in Table D.

Once again the programme had to be restructured in order to simulate the rush hour conditions on an expanded road system. This was accomplished by adding a QUEUE for northbound and southbound traffic at the Pembina-MacGillivray-Oakenwald and Pembina-Point Road-Windemere intersections and also for northbound traffic only at the Pembina-Jubilee intersection. Then by the use of the appropriate values from Table C.1 and Table D. both morning and afternoon rush hours were simulated with the present traffic levels and traffic signal lengths.

These were the final runs made with the simulation model and a copy of the programme in this state is presented in Appendix C. The rush hours could not be simulated with the increased traffic levels or the expanded road system since the computer core allocated to GPSS would have been exceeded. The same problem prevented any simulation of the afternoon rush hour with the higher traffic levels.

An analysis of the results of these various computer runs follows.

Analysis of Results of the Computer Simulation Runs:

The complete set of results for the computer simulation runs can be found in Appendix E to this thesis. One copy of this appendix is available upon request. Due to the size of this appendix, well over seven hundred and fifty pages, this section will present a summary of the main effects on traffic flow, in terms of expected waiting times brought about by varying the conditions on the selected section of Pembina Highway.

The previous section of the thesis outlined the various simulation runs which were made to represent varying conditions along the selected section of Pembina Highway. Among those variations were ones concerned with changing the lengths of traffic signals on either Pembina Highway or the side roads. It is the results of these runs which will now be discussed.

The relationship which will be mentioned is that concerned with the percentage of a traffic light cycle, red plus green, which is green. This percentage can be looked upon as $PGC = \frac{G}{R + G} \times 100$ where G and R represent the length of a green and red light respectively. It was found through trial runs that in order to gain the full effect of changes in PGC and cycle length on the delay at an intersection the two factors should be changed in conjunction with one another. Two major trends were investigated, that of decreasing the PGC while increasing the cycle length and decreasing the PGC while decreasing the cycle length. The resulting effects of these changes on traffic flow in terms of expected waiting time, E[W], were studied for each intersection at various levels of input, see Tables E.1, E.2 and E.3. The results of these various runs were found to be consistent for all intersections and at all levels of input used. What is meant by the results being consistent is not that the E[W] were all found to have the same values but, instead, that the trends in E[W] versus PGC relationships with shortening the light cycle and increasing PGC and with lengthening the light cycle and increasing PGC were found to be consistent for all intersections and at all input levels. An example of these trends is given on Graph 1 found at the end of this section.

Although the results of the computer simulation runs are limited to three points for each curve and thus cannot be used for the formulation of strict quantitative results, the trends exhibited in the results are consistent with the traffic flow characteristics at an intersection.

A general formulation of the type of relationships exhibited by the curves is that of a modified negative exponential function such as,

$$E[W] = e^{-f(PGC,C)}$$

where PGC is the percentage of cycle green, C is the cycle length,

f(PGC,C) is a function of both the PGC and the cycle length. As mentioned the results do not permit the formulation of strict quantitative results in terms of further defining the function f(PGC,C) which is an integral part of the main function in that it reveals the manner in which PGC and C determine E(W) through their own interrelationships.

The results do indicate that the policy which would lead to minimizing the delay or E(W) at an intersection when only one direction of travel is considered would be one of increasing PGC while shortening the traffic signal cycle length. It must be noted that this policy is related to only one direction of traffic being considered. However, the purpose of any intersection is to provide a means of controlling traffic flows which cross one another at some point. Therefore, in addition to considering the effects of any policy regarding signal cycle lengths on traffic travelling in one direction, the effects on side road traffic must also be studies. An increasing PGC on one direction will result in decreasing the PGC for the cross road direction. Since the better method of increasing PGC for the main road, in terms of lowering E(W), would be to do so while shortening the cycle length, the side road would be found to have a decreasing PGC with the cycle length being shortened. This factor will lead to increasing the E[W] on the side road, while decreasing the main road E[W]. Graph 1 represents the E[W] versus PGC for southbound Pembina traffic at Point Road, while Graph 2 represents the E[W] versus PGC for Point Road traffic at Pembina. It can be seen from these two graphs that by increasing the PGC for Pembina Southbound from the present value of 72 to 83 the E[W] drops from 6 to 3, or by fifty percent and the Point Road E[W] increased from 26 to 32, or by twenty three percent, since the PGC decreases from 26 to 17 because PGC on Pembina southbound plus PGC for Point Road equals one hundred. The purpose of this analysis, just as that of the thesis, is not to point out the ideal signal times to be implemented. There are a number of policy questions, such as should the road serving the immediate community or the main artery serving travellers through the community receive priority in terms of shortest delay, which must be answered when a decision is being made to set the time lengths. This analysis was given in order to point out the usefulness of a computer simulation model to analyse the effect of various signal lengths or the delay of automobiles at an intersection. Several factors, as well as the percentage change in delay, must be taken into account before a decision would be made regarding the length of the signal cycles or PGC values at an intersection. The E[W] value which is increasing must not become so large a value that drivers will disobey the signal lights from sheer frustration of waiting so long. The effect of changes at one intersection upon the traffic behaviour at the next intersection must also be considered. There would be little use in minimizing E[W] at one intersection if in so doing the E[W] at a following intersection was increasing at a rapid rate. There are also questions regarding load factor of an intersection and the theoretical versus practical usage rate of an intersection which would have to be answered. A number of these factors will be considered in more detail later in the thesis. The object of this thesis is not to consider these various factors and thus not to find an optimal signal cycle or PGC for the intersections on the selected section of Pembina Highway. However, the computer simulation model does point out how such a simulation programme can determine the effect of decisions made in light of factors such as those just mentioned on the actual traffic flow, whether it be in terms of the average queue length at an intersection or the average delay at an intersection as was the case in this model. The benefit of this result can be best appreciated if one considers the high cost of obtaining data on the delay at an actual intersection and the tremendous value that such data would have in making a decision concerning the signal cycle of a particular intersection.

Aside from the usefulness of a computer simulation model for evaluating the effect of changes in signal cycles in terms of queue lengths, delay times and other measures of performance for an intersection's behaviour, the model has also brought out two results regarding the capacity of the selected section of Pembina Highway. The first result is in regard to the present road experiencing a higher level of traffic than that which it is now serving. It was found that the degree of congestion at the signalized intersection in terms of E[W] did not increase proportionately when the interarrival times of automobiles being generated into the system were taken as 3/4 of the historically based levels. It can be stated that the E[W] values were at almost the same levels with either traffic levels. The most plausible explanation for this phenonemon is that the present light cycles are longer than the traffic levels require. Although the computer model does not explictly indicate that traffic flows through the system in groups or platoons of automobiles, the manner in which the bulk of traffic arriving at an intersection is made up of automobiles travelling along the main road which could only depart from the previous intersection during certain specific periods coupled with the constant travel time between intersections has resulted in the traffic flowing in groups through the system. Increasing the traffic volume could have resulted in one of two events, either the groups or platoons would be larger in size and, therefore, take longer to flow through the intersection, or else the entire platoon would not have been able to pass through the intersection causing a build-up in congestion with the arrival of each new platoon. This aspect of platoons will be explored in some detail in the mathematical model to follow. It is only presented here as a quantitative argument to point out how the present light cycles are longer than the present traffic volumes need and, in fact, long enough to handle the increased traffic levels. The result of the simulation model with higher traffic levels indicate that traffic signal capacities are considerably longer than the demands the present traffic level places upon them where the signal capacity is the number of automobiles, or size of platoon, which may proceed through the intersection during one green light.

The second computer simulation result regarding capacity is concerned with the aspect of increasing the size of the main road. It was found that in terms of E[W] there was no noticeable change in overall traffic congestion when the simulation model was expanded to represent the selected section of Pembina Highway with a one lane expansion along all of its route, except when passing under the two overhead crossings immediately north of Jubilee. At some intersections at certain times of the day the E[W] values were lower with the expanded road, however, at other intersections and/or different times the values were the same or even somewhat greater with the expanded road. However, there were only six out of forty-two observations where the change in E[W] was greater than ten percent and of these six most values were very small so that a change of 1 in E[W] resulted in a twenty-five or thirty-three percent change from the initial value.

This result demonstrates first of all how a computer simulation model is able to evaluate a decision such as road expansion in terms of its effect on traffic flow in the same manner as the PGC and cycle length decisions could be evaluated. This result also shows how road expansion on its own is not a guaranteed solution to reducing the delay of automobiles at an intersection. Road expansion decisions must be made in light of numerous other factors including the signal light decisions, intersection capacities, how frequently is the road congested and so on. It must be noted that a simulation model, such as the one developed in this thesis, cannot be considered to be an all inclusive method of making decisions in the area of traffic engineering but rather can be used as a tool to aid the engineer in reaching a decision. This simulation model has demonstrated the manner in which a model can aid in evaluating potential choices of PGC and cycle length, decisions on road expansion or evaluating the effect on the present road system of greater traffic volumes.

A computer simulation model which could actually be used in making decisions regarding changes in a road system would have to be much more refined in terms of traffic engineering concepts than the model presented here. However, the purpose of this thesis is to point out how a simulation model could be used in traffic planning decisions and not to build a model which could be used in its present state to make such decisions.

In both this section of the thesis and the one describing the computer simulation model, reference was made to a number of assumptions used in the formulation of the programme and some of the programme's shortcomings in terms of representing the actual traffic flow. The last section of the thesis will attempt to take some of these factors into account by outlining how a series of mathematical models could be used to refine the simulation model.

TABLE E.1

EXPECTED WAITING TIMES
E[W]

QUEUE / RUN NO.	1	2	3	4	5	6	7	8	9	10
A	12	12	14	21	5	5	6	19	12	13
B	25	34	11	22	25	41	13	32	23	23
C	32	46	16	32	32	47	17	47	33	31
D	12	13	10	16	8	10	7	19	12	12
E	26	42	11	22	32	44	13	37	24	33
F	25	41	10	25	29	47	13	37	27	27
G	4	3	6	7	2	2	2	5	4	5
H	22	36	10	19	25	39	12	33	23	22
I	13	16	10	15	10	13	7	18	11	13
J	2	2	3	4	1	1	2	3	2	2
K	25	38	12	25	25	38	12	38	26	25
L	11	13	9	14	9	11	6	16	11	11
M	6	6	8	13	3	3	3	11	6	6
N	6	6	8	13	3	2	4	12	8	7

TABLE E.2

EXPECTED WAITING TIMES
E[W]

QUEUE \ RUN NO.	11	12	13	14	15	16	17	18	19	20
A	5	3	7	8	2	2	3	6	13	13
B	22	42	11	23	28	43	15	34	22	23
C	33	48	17	33	32	47	16	48	33	32
D	6	7	8	13	4	4	4	8	11	15
E	27	32	9	23	32	62	10	47	23	29
F	33	44	10	21	31	44	11	40	27	29
G	5	4	8	11	3	2	3	7	6	6
H	13	21	6	10	14	24	7	19	13	13
I	10	13	11	14	6	10	6	18	10	12
J	4	3	6	5	2	2	3	5	4	4
K	10	17	3	10	10	18	3	17	10	13
L	11	12	10	13	6	8	6	16	11	11
M	7	5	9	13	3	2	4	10	7	7
N	5	5	7	10	2	2	3	11	5	6

TABLE E.3

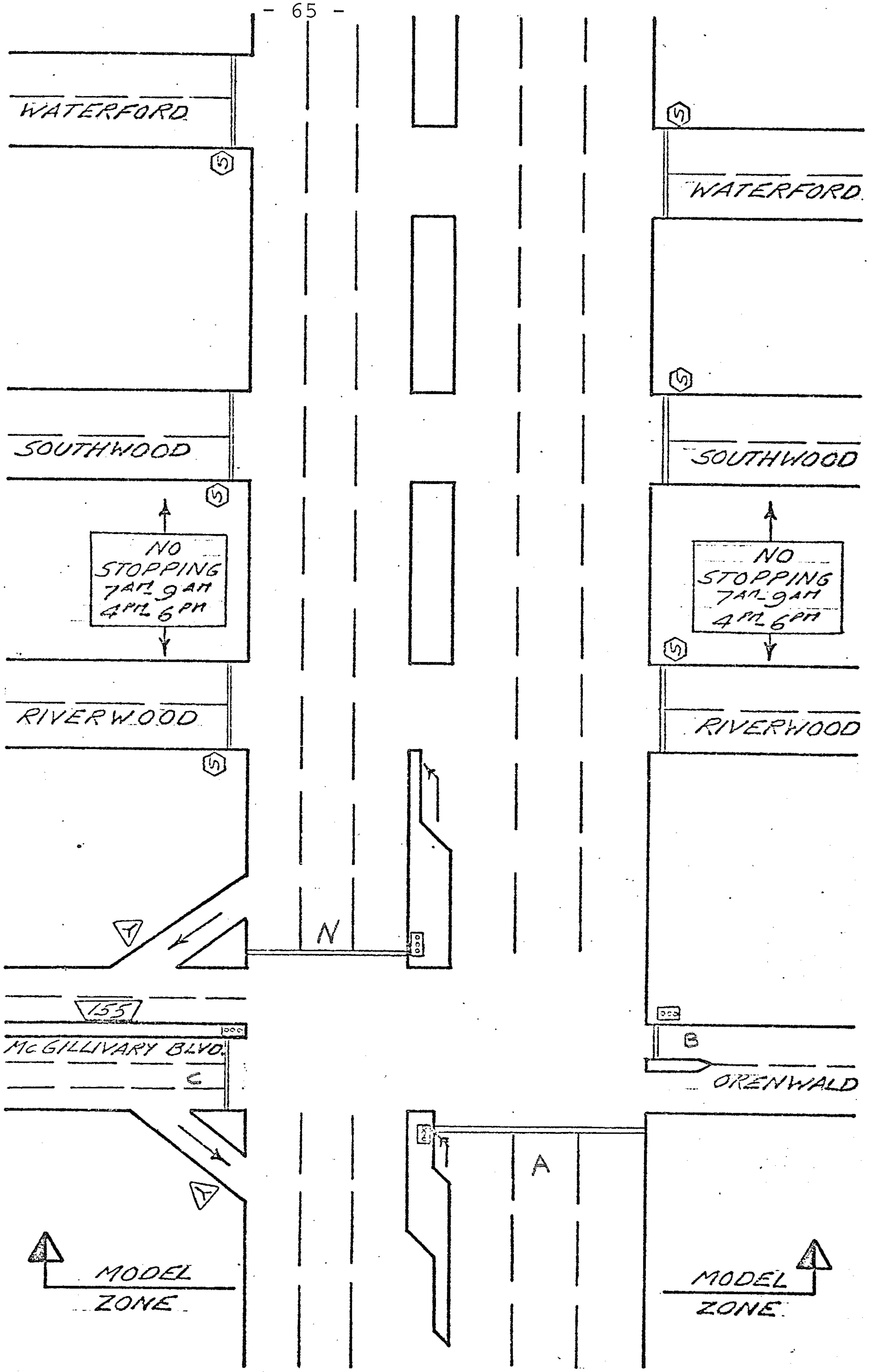
EXPECTED WAITING TIMES
E[W]

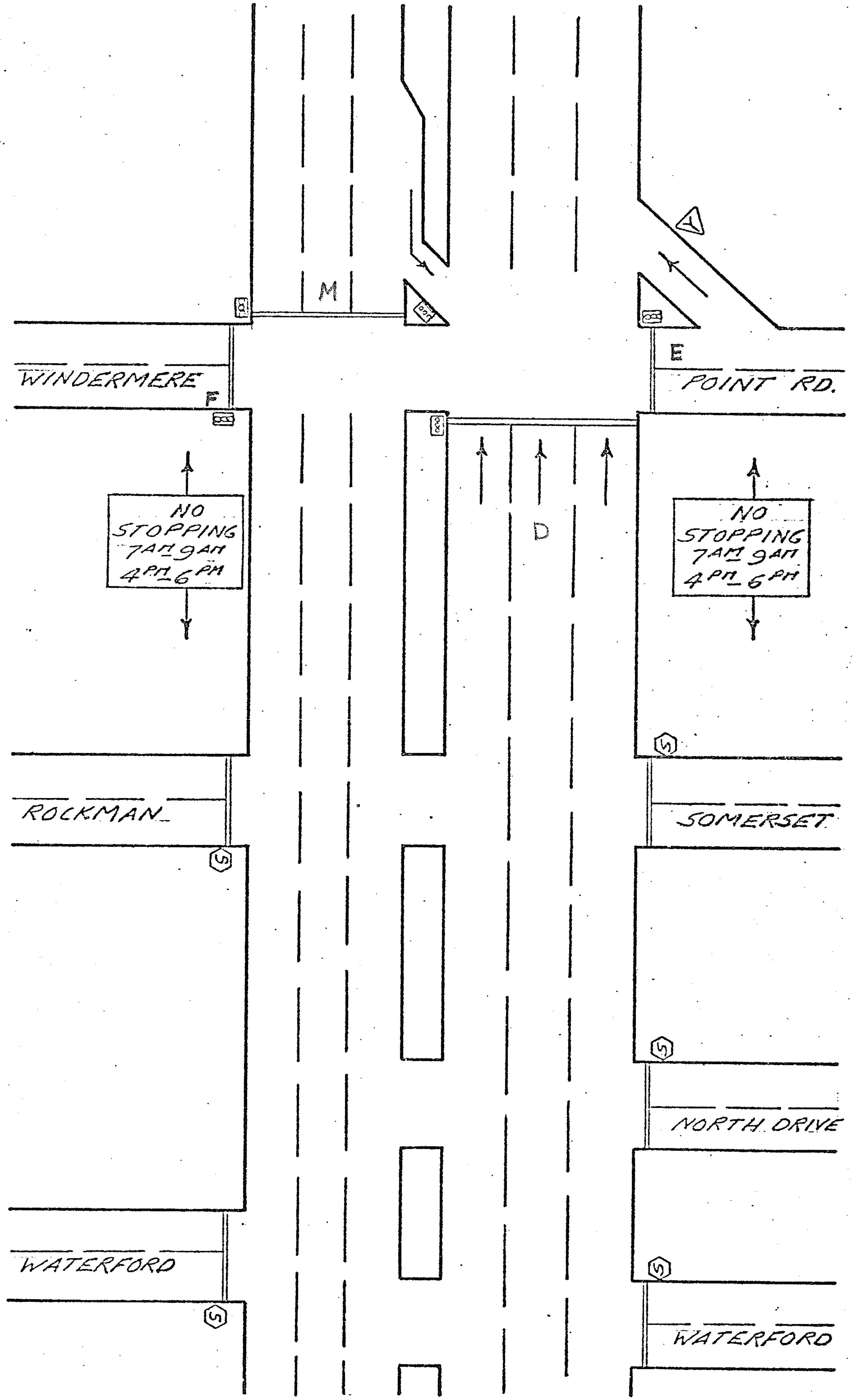
RUN NO.	21	22	23	24	25	26	27	28	29
QUEUE									
A	13	12	14	21	6	6	7	21	14
B	22	35	12	21	23	40	11	35	24
C	32	48	18	32	32	48	17	48	33
D	14	14	11	27	7	8	7	13	12
E	29	33	10	19	27	55	14	36	27
F	26	44	11	21	29	43	12	36	25
G	4	3	7	8	2	2	3	6	6
H	28	46	12	24	32	50	15	41	27
I	15	15	10	19	10	14	7	16	12
J	3	2	3	4	1	1	2	3	2
K	25	38	12	25	25	38	12	38	24
L	11	13	9	14	8	11	6	16	11
M	8	6	9	12	3	2	4	10	5
N	7	6	8	13	3	3	4	10	5

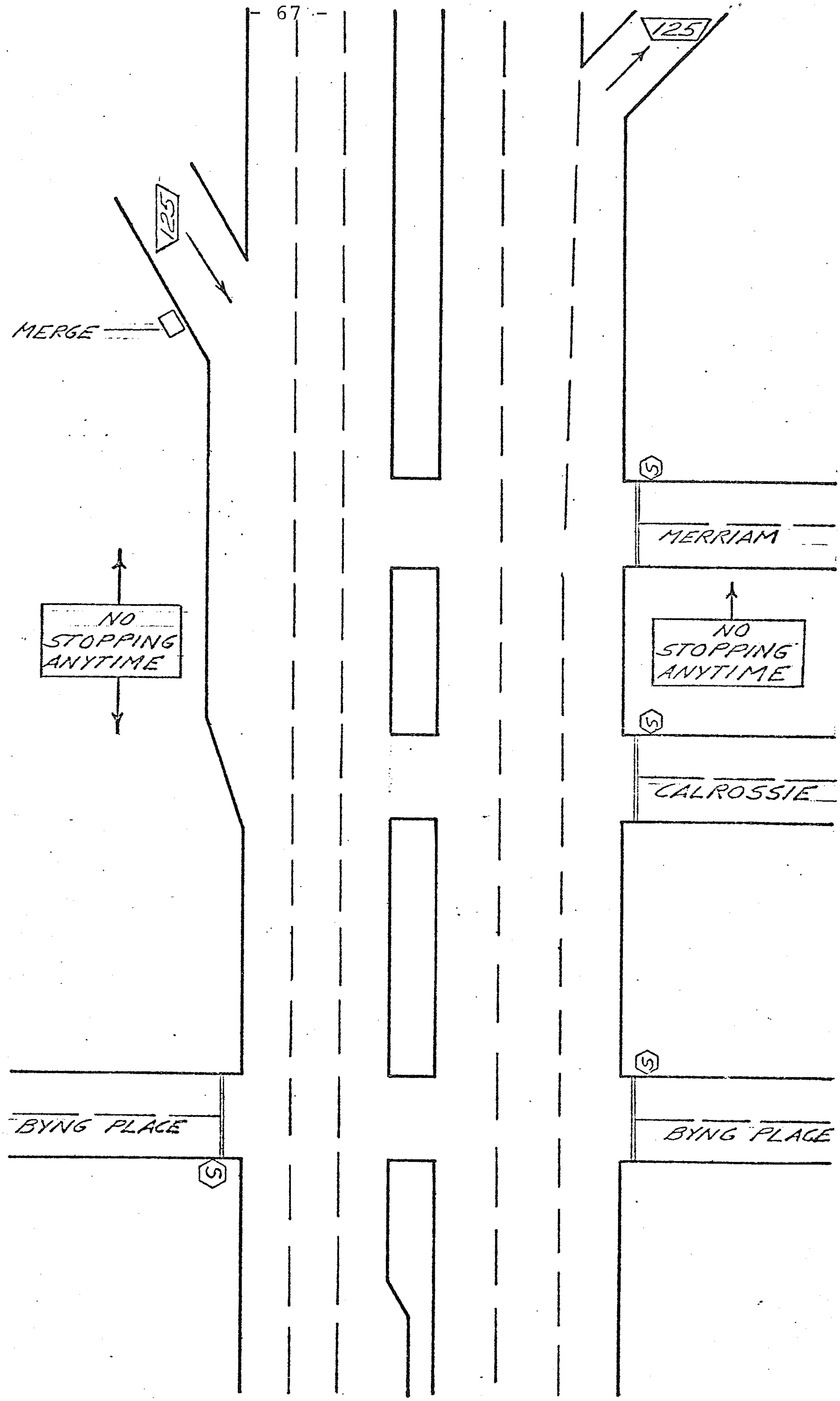
INDEX FOR

TABLES E.1, E.2, E.3

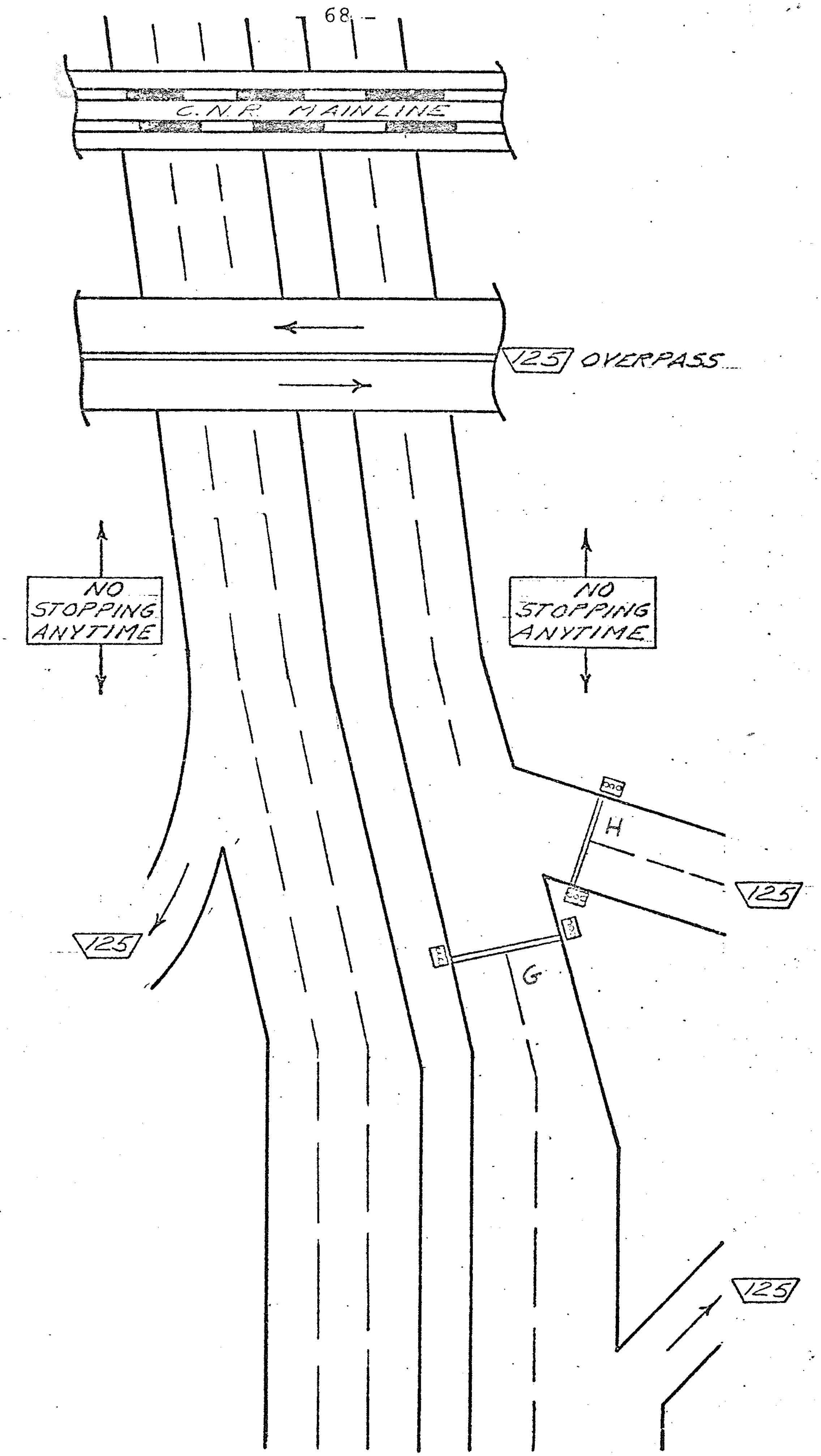
QUEUE	A	Pembina northbound traffic at MacGillvray - Oakenwald
	B	Oakenwald traffic
	C	MacGillivray traffic
	D	Pembina northbound traffic at Point Road - Windemere
	E	Point Road traffic
	F	Windemere traffic
	G	Pembina northbound traffic at Jubilee
	H	Jubilee traffic
	I	Pembina northbound traffic turning onto Stafford
	J	Pembina northbound traffic
	K	Pembina southbound traffic to Stafford
	L	Stafford traffic
	M	Pembina southbound traffic to Point Road - Windemere
	N	Pembina southbound traffic at MacGillivray - Oakenwald

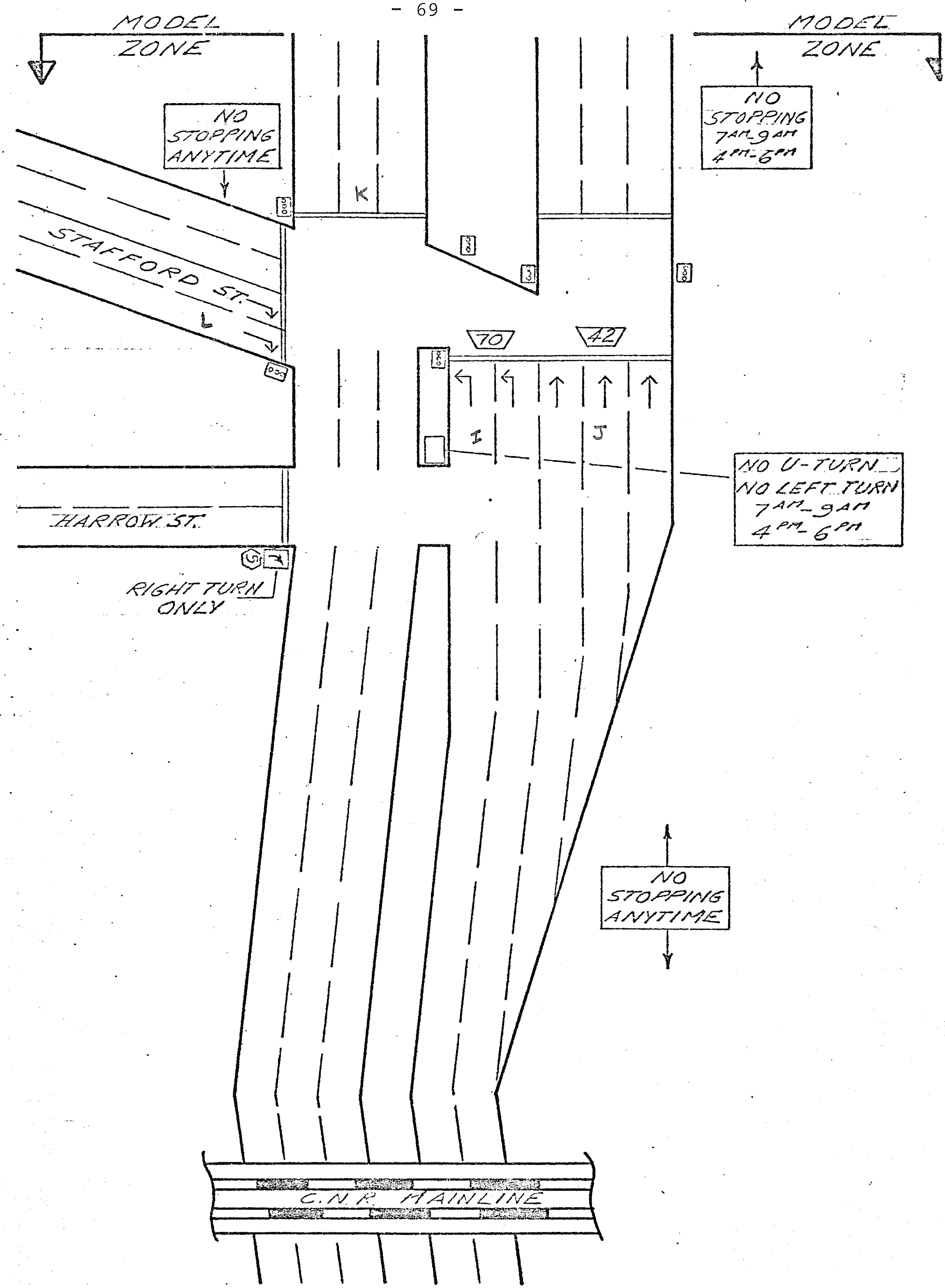

WATERFORD
WATERFORD
SOUTHWOOD
SOUTHWOOD
NO STOPPING 7AM-9AM 4PM-6PM
NO STOPPING 7AM-9AM 4PM-6PM
RIVERWOOD
RIVERWOOD
N
155
McGILLIVARY BLVD.
C
B
ORENWALD
A
MODEL ZONE
MODEL ZONE


M
F
E
WINDERMERE
POINT RD.
NO STOPPING 7AM 9AM 4PM 6PM
NO STOPPING 7AM 9AM 4PM 6PM
D
ROCKMAN
SOMERSET
NORTH DRIVE
WATERFORD
WATERFORD



125
125
MERGE
NO STOPPING ANYTIME
MERRIAM
NO STOPPING ANYTIME
CALROSSIE
BYNG PLACE
BYNG PLACE


C.N.R. MAINLINE
125 OVERPASS
NO STOPPING ANYTIME
NO STOPPING ANYTIME
H
125
125
G
125



MODEL ZONE
MODEL ZONE
NO STOPPING ANYTIME
NO STOPPING 7AM-9AM 4PM-6PM
K
STAFFORD ST.
L
70
42
I
J
NO U-TURN
NO LEFT TURN
7AM-9AM
4PM-6PM
HARROW ST.
RIGHT TURN ONLY
NO STOPPING ANYTIME
C.N.R. MAINLINE

MORNING RUSH HOURS

Present Traffic Levels:

Run No. 1 Present signal lengths

2 Pembina green signal lengths increased

3 Pembina green signal lengths decreased

4 Side road green signal lengths increased

5 Side road green signal lengths decreased

6 Pembina green signal lengths increased and side road green signal lengths decreased

7 Pembina and side road green signal lengths decreased

8 Pembina and side road green signal lengths increased

Increased Traffic Levels:

9 Present signal lengths

Present Traffic Levels:

10 Road expanded by one lane, present signal lengths

MID-DAY

Present Traffic Levels:

Run No.	11	Present signal lengths
	12	Pembina green signal lengths increased
	13	Pembina green signal lengths decreased
	14	Side road green signal lengths increased
	15	Side road green signal lengths decreased
	16	Pembina green signal lengths increased and side road green signal lengths decreased
	17	Pembina and side road green signal lengths decreased
	18	Pembina and side road green signal lengths increased
	19	Present signal lengths on expanded road

Higher Traffic Levels:

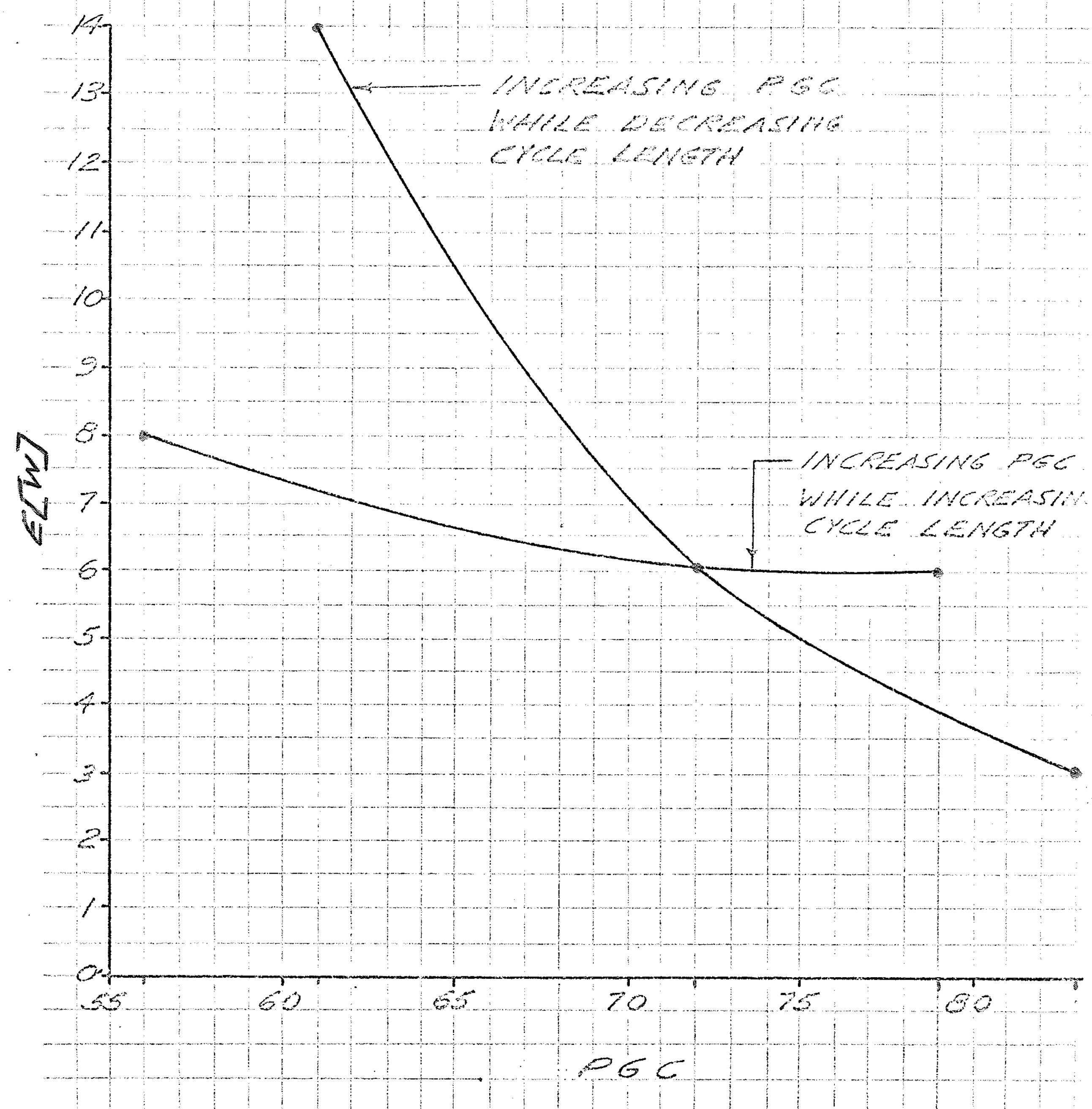
	20	Present signal lengths on expanded road

AFTERNOON RUSH HOUR

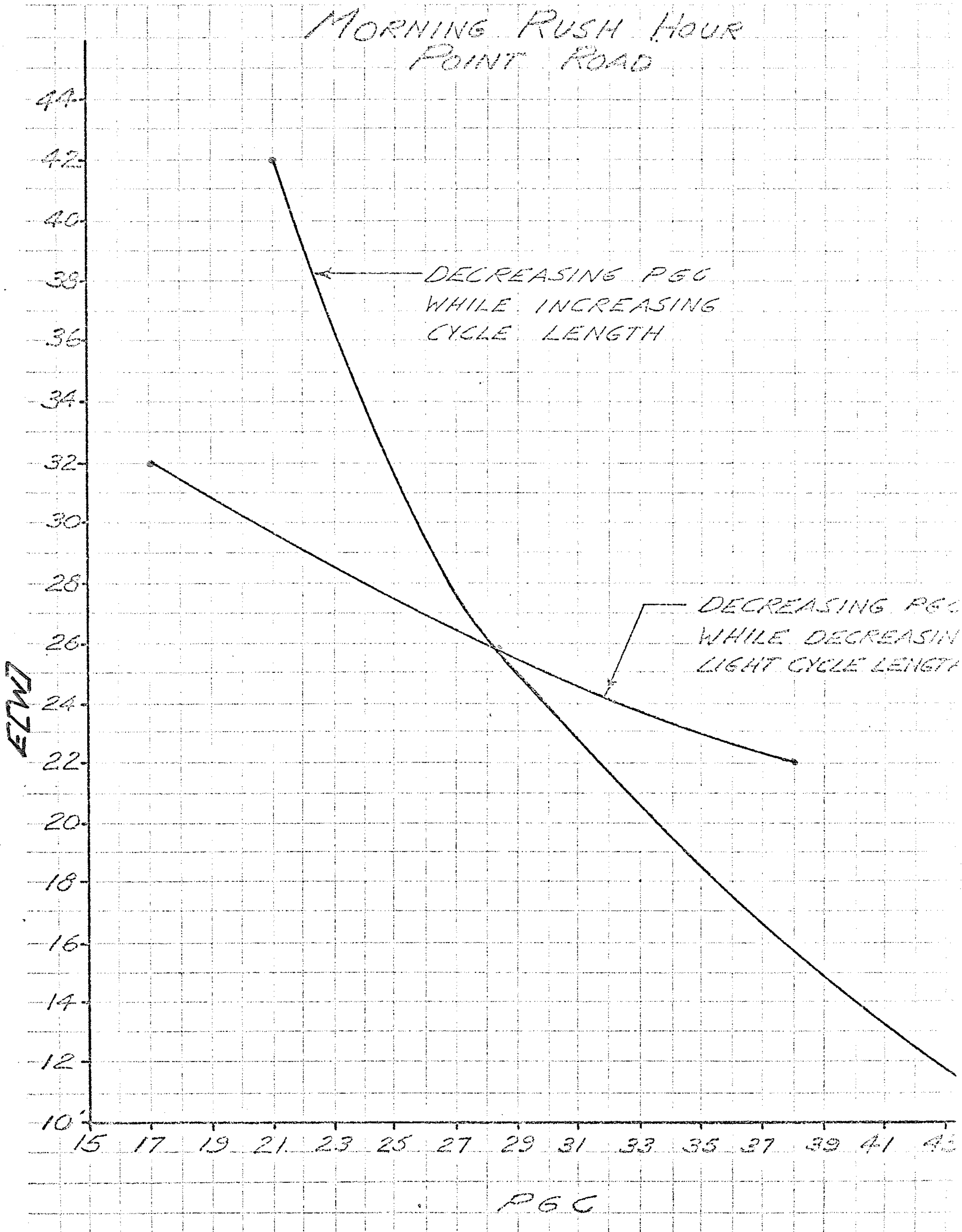
Present Traffic Levels:

Run No.	21	Present signal lengths
	22	Pembina green signal lengths increased
	23	Pembina green signal lengths decreased
	24	Side road green signal lengths increased
	25	Side road green signal lengths decreased
	26	Pembina green signal lengths increased and side road green lengths decreased
	27	Pembina and side road green signal lengths decreased
	28	Pembina and side road green signal lengths increased
	29	Present signal lengths on expanded road

MORNING RUSH HOUR
PEMBINA SOUTH BOUND
AT
POINT ROAD - WINDEMERE



GRAPH NO. 1
E[W] vs. PGC



GRAPH NO. 2
E[W] vs. PGC

Verification of Results:

The results that were obtained through the various simulation runs were verified in two different ways. First the results of any typical run were investigated in terms of what confidence intervals could be associated with the resulting expected waiting times of automobiles at the various intersections which were simulated. Next the qualitative nature of the results were looked over by members of The City of Winnipeg Engineering Department to see if they portrayed the actual situation which would occur in the event of the changes being made.

The representative queues of automobiles on Pembina Highway will now be listed, along with their estimated $\sigma_{\bar{X}}$, that is, their standard deviation of E(W) for every 2nd interval of a series of 24 five minute intervals, divided by the square root of 12.

	$\sigma_{\bar{X}}$ (estimated)
Northbound at MacGillivray	.50 seconds
Southbound at MacGillivray	.66
Northbound at Point Road	.85
Southbound at Point Road	.52
Northbound at Jubilee	.78
Northbound onto Stafford	.74
Southbound at Stafford	.59
Northbound at Stafford	.28

If we wish the results to be reliable within two seconds, that is, the E(W) to be within two seconds at a 98% confidence level than $2.33\,\sigma_{\bar{X}} = 2$ or $\sigma_{\bar{X}} = 2/2.33 = .86$ seconds. Since the estimates of $\sigma_{\bar{X}}$ are all less than .86 seconds it can be said that the results are within 2 seconds at a 98% confidence level. The $\sigma_{\bar{X}}$ values were not presented for the side road queues because the number of transactions recorded differ from the number of automobiles simulated per lane on the side roads due to the combination of several lanes into one, the presence of yields and right turns on red lights. The Pembina Highway queues which were used represent a lane in the centre of the traffic flow which is not affected by these factors.

The second step in the verification of results involved going down to the City Engineers and speaking with them about the results which were obtained regarding the effect of expected waiting times or changing the traffic signals, the traffic volume and road capacity. The Engineers who were interviewed expressed confidence in the results in that the trends exhibited in the graphs regarding signal light changes were what should be expected, as were the tabular results regarding changing traffic volumes or road capacities. Since the road had been set up in terms of capacity and signal systems for a higher volume of traffic, double that which was experienced on the road at the time of the change, the results of signals being of over capacity and so on were what the engineers would expect. The length of the expected waiting time at intersections in terms of number of traffic signal cycles at rush hours as compared to at non-rush hours were considered to be in line with what presently occurs at the intersections under the present conditions along this section of Pembina Highway.

Having heard about the capacity of the road by being much larger than present traffic volume a selected intersection of the model zone was isolated from the remainder of the programme and given higher traffic levels than were possible with the complete programme. The intersection chosen was that of Pembina-MacGillivray-Oakenwald. Six different traffic volumes were simulated for the intersection for morning rush hour conditions, that is, the no stopping zones are in effect.

The runs and the resulting expected waiting times were as follows,

Traffic Volume as a % of Present Volume	E(W) Pembina North-bound	Pembina South-bound	MacGillivray Eastbound	Oakenwald Westbound
100%	12	6	32	21
125%	13	7	33	24
150%	15	8	35	26
200%	18	10	37	28
250%	32	25	46	35
400%	95	45	248	150

It can be seen from these results that the capacity of the road does accommodate traffic up to a certain level, in this instance, approximately 200% of the present traffic volumes. Above this level the expected waiting times at the various intersections increase at an exorbitant rate so that the E(W) fall in the range of eight times the presently experienced ones.

These results tend to verify the qualitative statements regarding the capacity of the road system made by the engineers interviewed.

Potential Refinement of the Simulation Model Through Mathematical Sub-Models:

The purpose of this section of the thesis is to study possible refinements of the computer based simulation model in order to make it more flexible in terms of applicability and more realistic in terms of simulating the traffic flow on the selected section of Pembina Highway.

There are four main factors which will be considered in this section of the thesis, forecasting of traffic levels, non-signalized side road effects, car following theory and synchronization of signal lights at the various intersections. Rather than developing mathematical formulations for each of these factors, use will be made of existing theories on the subjects in order to describe them. Once each has been described a general statement as to where in the simulation model the actual sub-model or theory could be used and also to what extent it would improve the model will be given. This approach has been taken since the focus of this thesis has been on the development of the simulation model earlier presented and this section is included to indicate the areas in which the computer simulation model can be refined to better represent the actual traffic flow.

The first factor which will be discussed is concerned with the forecasting of traffic levels at input points, feeder routes and the extremities of the main road in the road system. The presented simulation model makes use of traffic levels, in terms of interarrival times, which are based on rather sparse data. It is due to this lack of data that the model was run to simulate three parts of the day, morning rush hour, mid-day and afternoon rush hour, with the traffic levels remaining constant during a particular simulation run. If a good deal more data than was available could be obtained it would be possible to simulate the traffic flow for a great many more times of the day, some of which would lead to peak traffic volumes. This expanded data base which would be in the form of hourly figures of interarrival times of automobiles or in some form which could be converted to interarrival times with observations for each weekday and season, would be used in the following manner. Assume that there are n hourly observations h in a day, j daily observations d in a week, k weekly observations w in a season and l season observations s in a year, then by means of a moving-average method[1] the variations in traffic levels caused by the time of day could be calculated. First n hour

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[1] W.A. Spur and C.P. Bonini, Statistical Analysis for Business Decisions, Richard D. Irwin, Homewood, Illinois, 1967 pp. 502-532.

moving averages would be calculated and then compared to the observed value of the (n/2) - 1 hour from the first hour included in the moving average.

That is, $\frac{h_1 + h_2 + \dots + h_n}{n}$ would be compared to $h_{1 + \frac{n}{2} - 1}$ and $\frac{h_2 + \dots + h_n + h_{n+1}}{n}$ would be compared to $h_{2 + \frac{n}{2} - 1}$ observations, etc.

Note: A. n/2 must be an integer and thus fractional values must be rounded off.

B. n + 1 is the first hour's observation for the second day.

Next the h observation is divided into the corresponding moving average, thus giving a percentage value. Through the computation of moving averages over several days a number of percentage values for each hour of the day are computed. The modified mean of each of these series of percentages for a particular hour are found by averaging all values in the series except the highest and lowest in order to minimize the effect of irregular factors. Finally, each modified mean is multiplied by 100 n/(sum of the modified means).

The resulting percentages are the modifying means for each hour of the day which are used to transform a standard interarrival time to one representing a particular hour of the day. The same procedure is followed to obtain modifiers for the day of the week and seasonal variations or inter-arrival times. Although the method of determining the time of day, day of week or seasonal variations on the traffic levels is quite straightforward as presented here, it is also a very expensive process. The expense is in terms of obtaining and tabulating the data necessary to calculate the modifiers.

The main purpose of a forecasting model, such as the one outlined above, or more sophisticated ones, namely Census Method II or Exponential Smoothing is greater flexibility. This flexibility is in terms of being able to simulate the traffic flow, not only for the three discrete time points in a day, but to be able to simulate for each hour in a day. In addition to this hour of day flexibility, the forecasting model would also enable simulation of the traffic flow to take into account variations for the day of the week and season. Through the use of such a forecasting model the simulation model would become more realistic in that it would be simulating the traffic flow without assuming the morning rush hour traffic levels do not vary from one hour to another and that all traffic levels are the same from day to day or season to season for any particular rush hour.

The next area of improvement which will be discussed is that of a traffic flow or car following sub-model. As earlier mentioned the computer based simulation chose to adopt a constant travel time for all automobiles travelling between the same two intersections. This procedure was followed for the sake of ease in building the model and also due the size constraint imposed upon the computer simulation model by the GPSS language.

A review of the theories advance in regard to traffic flow, or more specifically car following, indicates that their application would be very limited in regard to the present simulation model which is mainly concerned with traffic congestion or potential congestion. The theory advanced by Chandler, Herman and Montroll[2] as well as that advanced by Herman, Montroll, Potts and Rotherty[3] are chiefly concerned with stability in the traffic flow on lengthy uninterrupted sections of a road. This stability is in reference to an even or uniform flow of automobiles with respect to speed, spacing, acceleration and deceleration. When instability arises in the traffic flow it can be of two forms as pointed out by Lee[4], local or asymptotic

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[2] R.E. Chandler, R. Herman and E.W. Montroll, Traffic Dynamics: Studies in Car Following:, "Operations Research", Vol.6,1958

[3] R. Herman, E.W. Montroll, R.B. Potts and R.W. Rotherty, Traffic Dynamics: Analysis of Stability in Car Following, "Operations Research", Vol. 7,1959.

[4] G. Lee, A Generalization of Linear Car Following Theory, "Operations Research", Vol. 14,1966

Local instability refers to the lack of response of a following car to the movements of the leader and thus resulting in a collision, while asymptotic instability is a chain reaction of a lead car action with increasing amplitude until a collision occurs somewhere down the line. Lee's paper is chiefly concerned with the development of equations which upon solution express a following vehicle's speed as a function of the lead vehicle's time history of relative speed. This aspect of vehicular speed is a very important point of traffic studies on major road systems with reference to analyzing causes of accidents. However, the inclusion of such theory in the model formulation of the selected section of Pembina Highway would not be worthwhile when comparing the slight changes in arrival rates at an intersection with the cost of accumulating statistics on driving behaviours that would be required and the large expansion in the simulation model in terms of building new subroutines which would be compatible with the main programme's language and which could perform integration and differentiation.

Although the aforementioned theory tends to constrain the presented simulation model, the theories presented by Chandler, Herman and Montroll and by Herman, Montroll, Potts and Rotherty have some features which would be of use in the refining of the simulation model. The features which are being referred to are those concerned with the spacing of automobiles in the traffic flow. The spaces between the automobiles which could be referred to as intergaps are of great value when considering traffic delayed at non-signalized crossings of the main road. Chandler, Herman and Montroll present a method[5] of calculating these intergaps by actually calculating the position of the n'th automobile relative to a moving scale on which the lead and/or following automobile's position is also calculated. The rule given is as follows:-

$$X_{n-1} = X_n + b + TV_n + L_{n-1} \qquad (1)$$

where X_i is the position of the i'th vehicle. The distance between X_n and X_{n-1} vehicles is then

$$X_{n-1} - X_n = b + TV_n + L_{n-1} \qquad (2)$$

where b is the distance between vehicles at rest.

V_n is the velocity of the n'th vehicle

T is the time constant relating to the areas driving habits in terms of distance allowed for a given number of miles per hour - e.g., 10 feet for each 10 miles per hour. $T \approx 10$ ft/(14 ft/sec) $\approx$ 2/3 of a second.

L_n is the length of the vehicle n.

In terms of the selected section of Pembina Highway a formula such as the one presented above could be used to calculate the

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[5]R.E. Chandler, R. Herman and E.W. Montroll, op.cit.

expected intertraffic gaps in heavy traffic. The information which would be needed is a distribution of the speed of automobiles in heavy traffic, the distance between automobiles at rest and the length of vehicles. All three items could be easily obtained through studies of traffic flows, overhead photos of a grid intersection and survey of automobile specifications. One additional piece of information which would be needed and which would be the most difficult to obtain is that of the distance versus speed factor that drivers follow. This information would be needed to obtain a value for T.

Therefore, even though the aspect of a linear car following model is not highly suited to the simulation model, a small portion of the theory behind the model can be used to determine the size of gaps between automobiles. These gaps will be now shown to be an important factor in the expansion of the simulation model to one including non-signalized as well as signalized side roads.

The purpose of the simulation model is to represent the delays or congestion on the selected section of Pembina Highway. In order to fully represent these delays the simulation model must take into account the non-signalized as well as signalized intersections. A number of theories or models have been developed for the situation of a non-signalized intersection on a main road. In most cases these models have been developed for the situation of a single lane main highway with a continuous traffic flow, whereas the selected section of Pembina Highway is a multi-lane road with non-continuous traffic flow due to the presence of signal control systems at numerous locations along its path. The traffic flow is non-continuous in the sense that the automobiles travel in groups or platoons due to the characteristics of a signal control system and due to the rather short distances between the signalized intersections. The former factor causes the traffic on the main road, which is the main component of the traffic flow, to only pass through the intersection during specified periods and the latter prevents the cars from being able to spread out into a continuous flow before grouping together at the next intersection.

Despite the fact that the traffic flow is not the same as that accounted for in the papers by Haight[6], Oliver and Brisbee[7], Weiss[8] and Weiss and Maradudin[9], they do point out

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[6] R.A. Haight, Mathematical Theories of Traffic Flow, Academic Press, New York, 1963.

[7] R.M. Oliver and E.G. Brisbee, Queueing for Gaps in High Flow Traffic Streams, "Operations Research" Vol. 10,1962

[8] G.H. Weiss, The Intersection Delay Problem with Correlated Gap Traffic Streams, "Operations Research", Vol. 10, 1962.

[9] G.H. Weiss and A.A. Maradudin, Some Problems in Traffic Delay "Operations Research", Vol. 10, 1962.

the theory involved in formulating a model for side road traffic delay at non-signalized intersections based on the theory of gap acceptance. In the paper by Weiss two equations are presented which could be used to determine the mean delay time incurred upon an automobile which arrives on a side road at a non-signalized intersection at time t = 0. They are

$$\bar{t} = \int_0^\infty t\left[a_0(t) + \frac{1-\bar{\alpha}_0}{\bar{\alpha}}\, a(t)\right] dt + \bar{t}_0 \quad (3)$$

$$\bar{t}_0 = \frac{1}{\bar{\alpha}} \int_0^\infty t\left[\bar{\alpha}\, \psi_0(t) + (1-\bar{\alpha}_0)\, \psi(t)\right] dt \quad (4)$$

where:

$$a_0(t) = \varphi_0(t)\, \alpha(t)\, \rho(t)\, \eta(t)$$

$$a(t) = \varphi(t)\, \alpha(t)\, \rho(t)\, \eta(t) \quad (5)$$

$$\bar{\alpha} = \int_0^\infty \alpha(x)\, \varphi(x)\, dx \quad (6)$$

(7)

$$\bar{\alpha}_0 = \int_0^\infty \alpha(x)\, \varphi(x)\, dx \quad (8)$$

$\varphi(t)$ - density fnc. that gap is of length t.

$$\varphi_0(t) = \left(\frac{1}{\mu}\right) \Phi(t) \quad (9)$$

$$\mu = \int_0^\infty x\, \varphi(x)\, dx \quad \text{mean headway} \quad (10)$$

$$\Phi = \int_t^\infty \varphi(x)\, dx \quad \text{probability gap is t or greater} \quad (11)$$

$\alpha(t)$ probability of leaving intersection with a gap of length t present

$\rho(t)$ probability of looking for a second gap when first was of length t

$$\eta(t) = \int_0^\infty \varphi(x)\, g(t,x)\, dx \quad (12)$$

probability that an acceptable gap is followed by an even more acceptable one.

$g(t, x)$ probability that gap x in length is more desirable than gap t in length

$$\psi_0(t) = \varphi_0[1 - \alpha(t)] \tag{13}$$

and $$\psi(t) = \varphi[1 - \alpha(t)]. \tag{14}$$

It can be seen from these equations that in order to calculate the delay at a non-signalized intersection a good deal of data would be needed in terms of the probability of specific gap sizes occuring, the probability of drivers entering the traffic flow given specific gap sizes and so forth. Some of this data could be found by means of the studies earlier mentioned in relation to equations 1 and 2, while other probability densities, such as the probability densities of turning down a gap of length t or the probability densities of entering the traffic flow upon the occurrence of a gap of length x, would have to be calculated from information gained through studies in driver behaviour.

It should also be noted that the above calculations are designed to find out the mean delay time of an automobile arriving at an intersection at time equal to zero with a continuous flow. Modifications would have to be made to the equations to find results in terms of a non-continuous flow of traffic which is the situation in the model zone. The necessary changes would involve a complete reworking of certain equations so as to introduce the possibility of no traffic on the main road, that is, between platoons or groups of automobiles, or for the gap sizes within the platoons at different times of the day such as rush hours or non-rush hours.

Despite the increased complexity involved in introducing the delays at non-signalized intersections in the simulation model the benefit of having a complete simulation of the selected section of a specific road sector would make the expansion worthwhile. However, due to the size of the task in introducing these side road delays in terms of collecting data to derive the necessary probability densities and the amount of work involved in formulating the basic simulation model this aspect of the model will be given as a direction in which the model must be expanded to become more realistic.

Another factor which could be considered in the simulation model is that of synchronization of traffic signals along the road system. This synchronization could result in entire platoons of automobiles being able to travel through the selected section of Pembina Highway without having to stop for a red light at a signalized intersection. It has been previously mentioned that an inhibiting factor in the synchronization of the signal lights along the selected section of Pembina Highway was the bi-directional nature of the rush hour traffic. One manner of studying the idea of traffic signal synchronization is by graphical analysis whereby the road system is presented in a space-time diagram. This method is employed in a paper by Little[10]. Through such a diagram it is possible to determine the maximum bandwidth, a factor related to the size of a platoon, able to pass uninterrupted by red lights along the road system. Two examples of such time space diagrams follow this section of the thesis, figures 1 and 2. Since the rush hour traffic on the selected section of Pembina Highway is bidirectional it would be ideal to be able to have a large bandwidth, that is, greater than one-half of the green light at each intersection, to be able to move through the system in both directions. The two space time diagrams given are representative of the presently used signal system on Pembina Highway in terms of signal lengths during morning rush hours. The space time diagrams propose a sequencing of signals at each intersection on the selected section of Pembina Highway. The sequencing proposed consists of setting the signal controls at each intersection so that at some time = 0 the Pembina signals at MacGillivray turn red, those at Point Road turn green for southbound by beginning to flash, those at Jubilee turn red and the Pembina northbound straight through green arrow just turns green. After time = 0 the signal controls at each intersection would

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[10]J.D.C. Little, The Synchronization of Traffic Signals, "Operations Research", Vol. 14, 1966

operate with their standard cycle lengths. It was assumed that the traffic in a platoon would travel at a constant speed between two signalized intersections and that this speed would be lower in areas of reducing number of lanes from Point Road to Jubilee and Jubilee to Stafford for northbound traffic. It was further assumed that the speeds of traffic in the less congested and more congested sectors of the road in terms of number of lanes would be taken as 27 and 24 miles per hour respectively. With the use of these assumptions, the distances between the intersections and the signal times at each intersection, figures 1 and 2 were drawn. An attempt was made at using two values of bandwidths b and b' which were 40 and 30 seconds respectively. It goes without question that the higher the value of the bandwidth the better the situation in that larger platoons in terms of more automobiles will be able to flow through the system. It was found that a bandwidth of b was too large to be handled at Jubilee for northbound traffic and at MacGillivray for southbound traffic. The b' bandwidth was found to be able to flow through all intersections smoothly without encountering any red lights.

This study into the synchronization of signal lights appears to suggest that a policy of synchronizing the signal lights on the selected section of Pembina Highway would help to alleviate congestion at the intersections.

However, it must be remembered that the proposed synchronization was based on the assumption of constant speed, below the speed limit, no hesitation in a platoon when approaching a signalized intersection which will only be turning green upon the platoon's arrival, the presence of empty queues at an intersection where the platoon arrives and that a platoon is of such a size that it only takes 30 seconds to cross an intersection.

Further inspection points out a number of problems which would tend to interfere with the ideal operation of the synchronization of the signal system. First is that traffic does not travel at a constant rate in rush hour conditions; it travels as quickly as it safely can and thus shows a good deal of fluctuation, second is that a platoon will show some hesitation on the part of a certain number of its members when approaching an intersection where the light has not yet turned green and, third, the most important problem that is encountered is that queues will not always be empty at a signalized intersection when a platoon comes upon it. This third factor arises from various causes, side road inputs into the traffic system between platoons, oversized platoons arriving at a critical intersection, one which can only handle the 30 second platoon and platoons arriving too early at an intersection.

the first cause of inputs from side roads into the traffic system between platoons will have an effect on platoons which arrive at the start of a green light such as north-bound ones at Jubilee, or southbound ones at Stafford or Point Road. The extent to which these inputs effect the traffic flow is dependent upon the size of the inputs. At the Jubilee intersection it can be expected to be quite severe since one of the inputs is very high, Point Road, and there are only two queues at Jubilee. There is also the possibility of the side road traffic following the platoon through a green light and thus not causing a queue to block the next platoon. This possibility exists as a result of the signal cycles along the selected section of Pembina Highway not being used to their capacity as pointed out in the section of the thesis analyzing the results of the computer runs. However, there will still be a certain number of automobiles arriving from side road inputs on a red light and queuing up in the path of the next platoon. When the platoon arrives it will be delayed by the start up time of the queued automobiles and of its own automobiles which were slowed down. This will take up a certain part of the green light and quite possibly result in an inability to have the entire platoon clear the interesection. This will leave a queue at the intersection which supplemented by side road inputs will impede the way of the next platoon. In the event of an oversized platoon arriving at a critical intersection with an empty queue, such as southbound at MacGillivray, a certain portion of the platoon will be unable to clear the intersection. This will result in a queue forming up for the next green light. This factor would not have a severe effect on the next platoon provided the built up queue could be cleared in the portion of the green light preceding the arrival of the platoon. However, it would result in a larger queue awaiting the platoon at an intersection along the route designed to have a platoon arrive at the beginning of a red signal. The third factor of platoons arriving too early at an intersection would result in a delay time for the platoon in excess of that incurred by the awaiting queue. This situation could develop at Jubilee if a northbound platoon arrived 10 seconds early which is possible as can be seen from figure 1 where the b width bandwidth's left hand solid line arrives for the last 10 seconds of the red signal. It should be noted that the first and third factors have a high likelihood of occurring at Jubilee which would result in heavy queue build ups at the intersection.

The idea of a signal synchronization model could be introduced into the computer simulation model by means of co-ordinating the phase in which the signal control subroutines commence operation. However, due to the fact that the two main factors leading to problems in the synchronization have been overlooked in many respects during the programme, uneven traffic speed and inputs from all side roads, a simulation model presenting a synchronized light system would perhaps be closer to representing the ideal traffic flow than the real life one.

In addition to the forecasting model, traffic flow model, non-signalized side road delay model and traffic signal synchronization model, the computer simulation model could have been expanded to also include other factors, such as, varying traffic speeds, load factor, theoretical capacities of intersections and other factors related to traffic engineering. This section of the thesis has presented a series of models which could be added to the computer simulation model so as to refine its ability to simulate the real life situation on the selected section of Pembina Highway. Diagram 4 at the end of this section of the thesis is a flowchart of the expanded simulation model showing the manner in which the various sub-models would be related to one another. The numbers listed with the various sub-models are the pages of the thesis where the sub-models can be found in their expanded form. A flowchart of the necessary data formation and maintenance system required to operate the expanded simulation model is given in Diagram 5 at the end of this section. This data base is the same one that was outlined earlier when the forecasting, car following and non-signalized side road delay models were discussed.

FLOWCHART OF EXPANDED SIMULATION MODEL

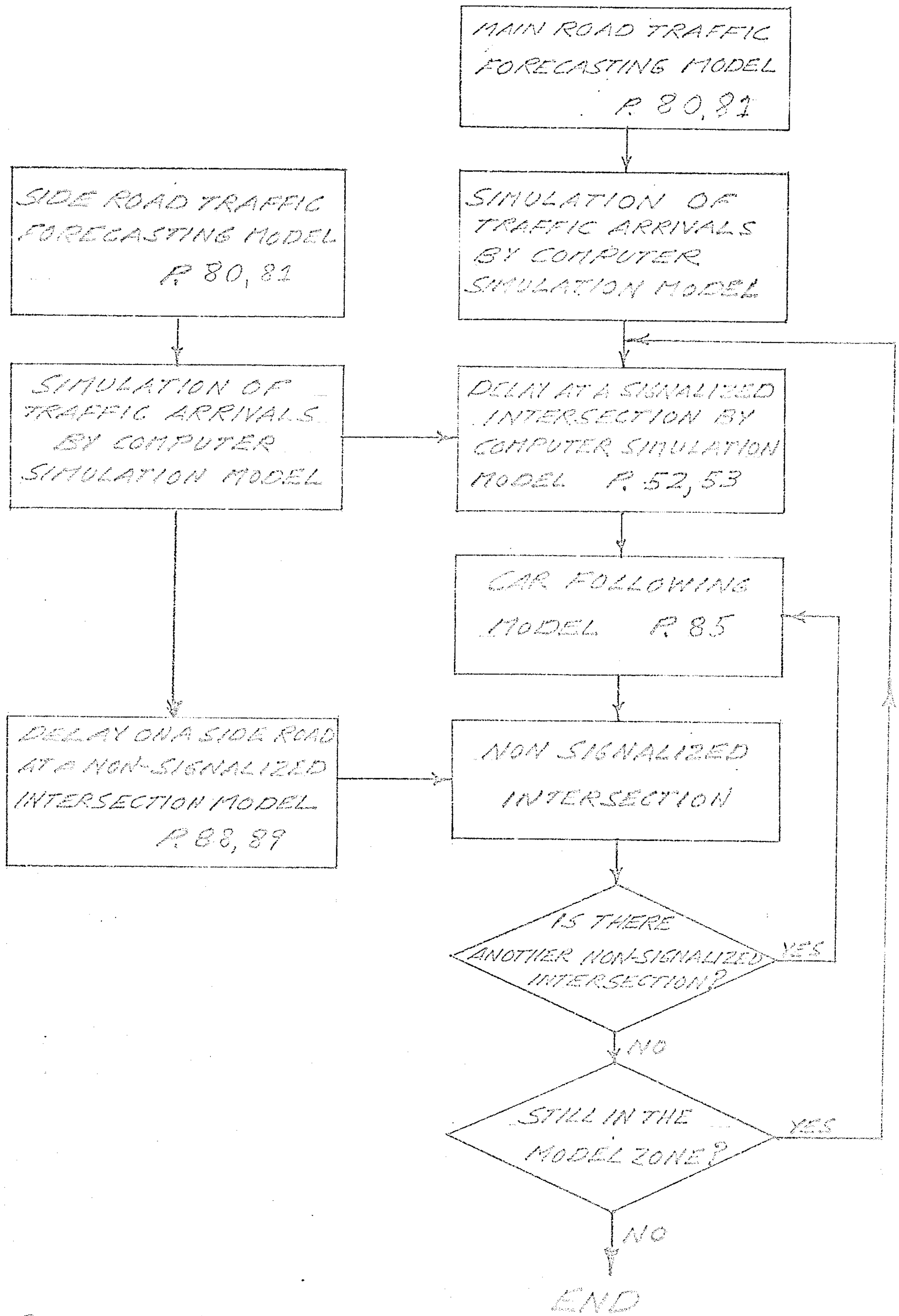

DIAGRAM 4

FORMATION AND MAINTENANCE OF DATA BASE

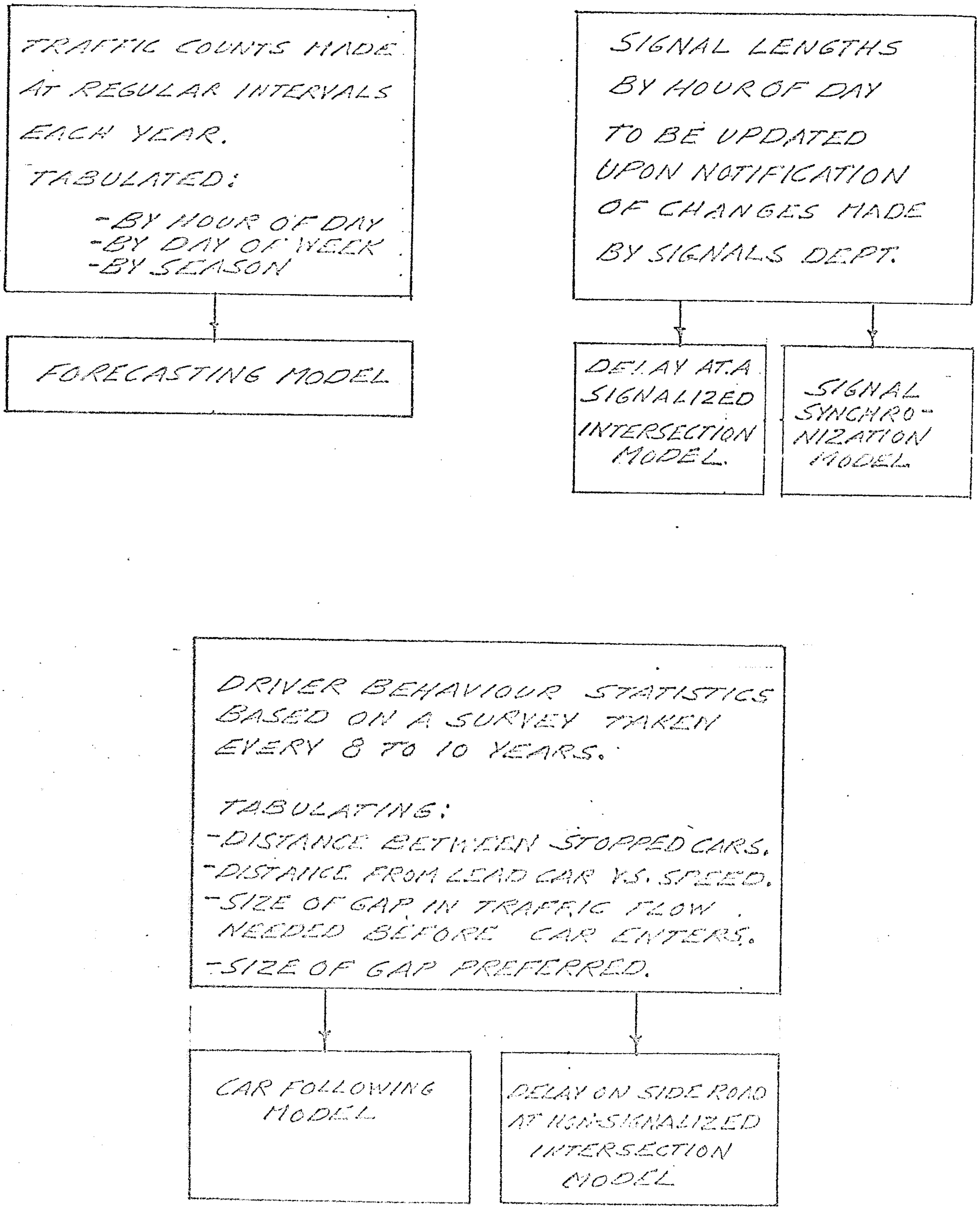

DIAGRAM 5

MORNING RUSH HOUR
NORTHBOUND TRAFFIC ON PEMBINA
SPACE-TIME DIAGRAM

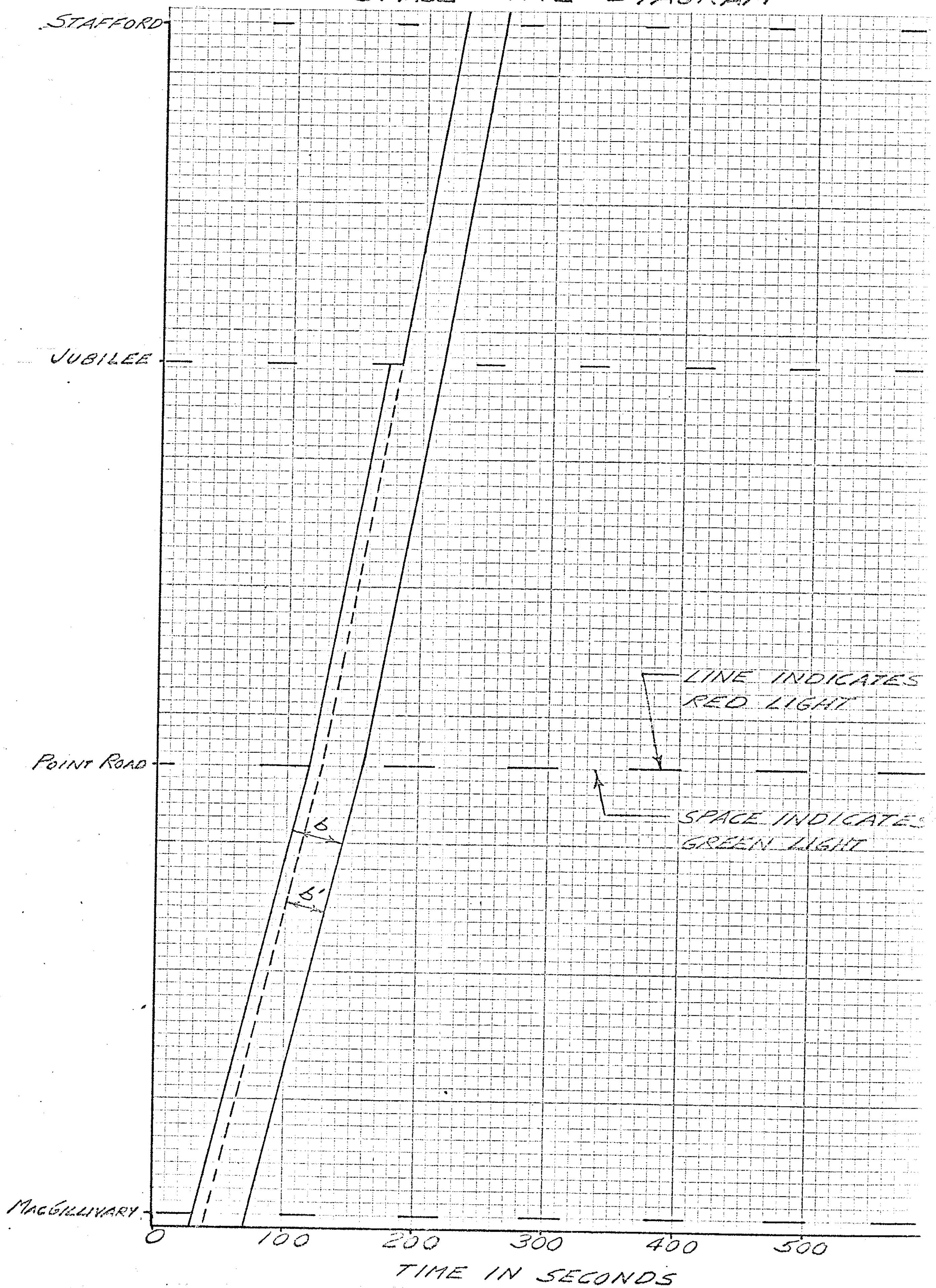

FIGURE 1

MORNING RUSH HOUR
SOUTHBOUND TRAFFIC ON PEMBINA
SPACE-TIME DIAGRAM

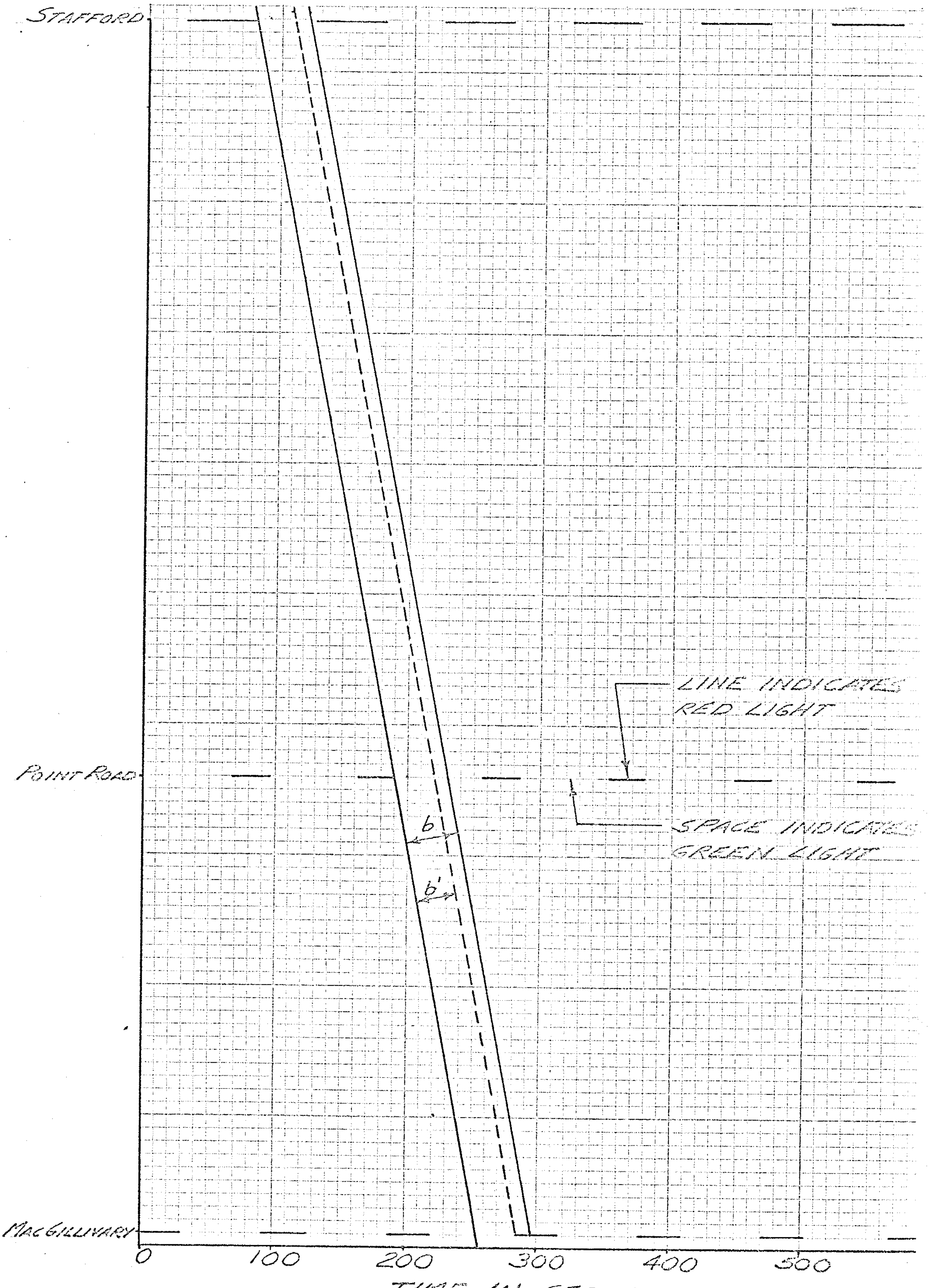

FIGURE 2

Conclusion:

This thesis has presented a study on the development of a micro-scale simulation model for a selected section of Pembina Highway. This study was conducted in two ways. First a computer based simulation model written in GPSS was developed and used to simulate the traffic flow on Pembina Highway under varying conditions of signal lengths, traffic volumes and road structure. Through these simulation runs it was found that the capacity of the signal systems in the model zone were above the traffic volumes and that by increasing the percentage green per cycle, while decreasing the cycle length the expected delay of automobiles at signalized intersections would be reduced. It was also concluded that the present road was not being used to capacity in terms of the simulated traffic volumes and thus an expansion of the road system in terms of a lane expansion would not be a sure method of reducing the congestion at the signalized intersections of the road system. The second part of the study was devoted to four models, forecasting, traffic flow, non-signalized intersection traffic delays and signal synchronization, which could be added to the main simulation model. The merit of each model in terms of added complexity versus cost versus benefit was looked into. The purpose of this section of the thesis was to propose paths which could be followed in the refinement of the simulation model. It was found that the forecasting model would be a great asset despite the high cost of data collection, the traffic flow model would be of use in part, the side road delay model would definitely refine the simulation model despite the increased complexity involved and the signal synchronization model would be of questionable merit due to some of the assumptions made in the main computer simulation model.

Perhaps the most important conclusion of the thesis is that it serves to point out the great number of problems and side issues involved in the simulation of a complex situation such as a traffic engineering problem concerning the traffic flow on a major artery.

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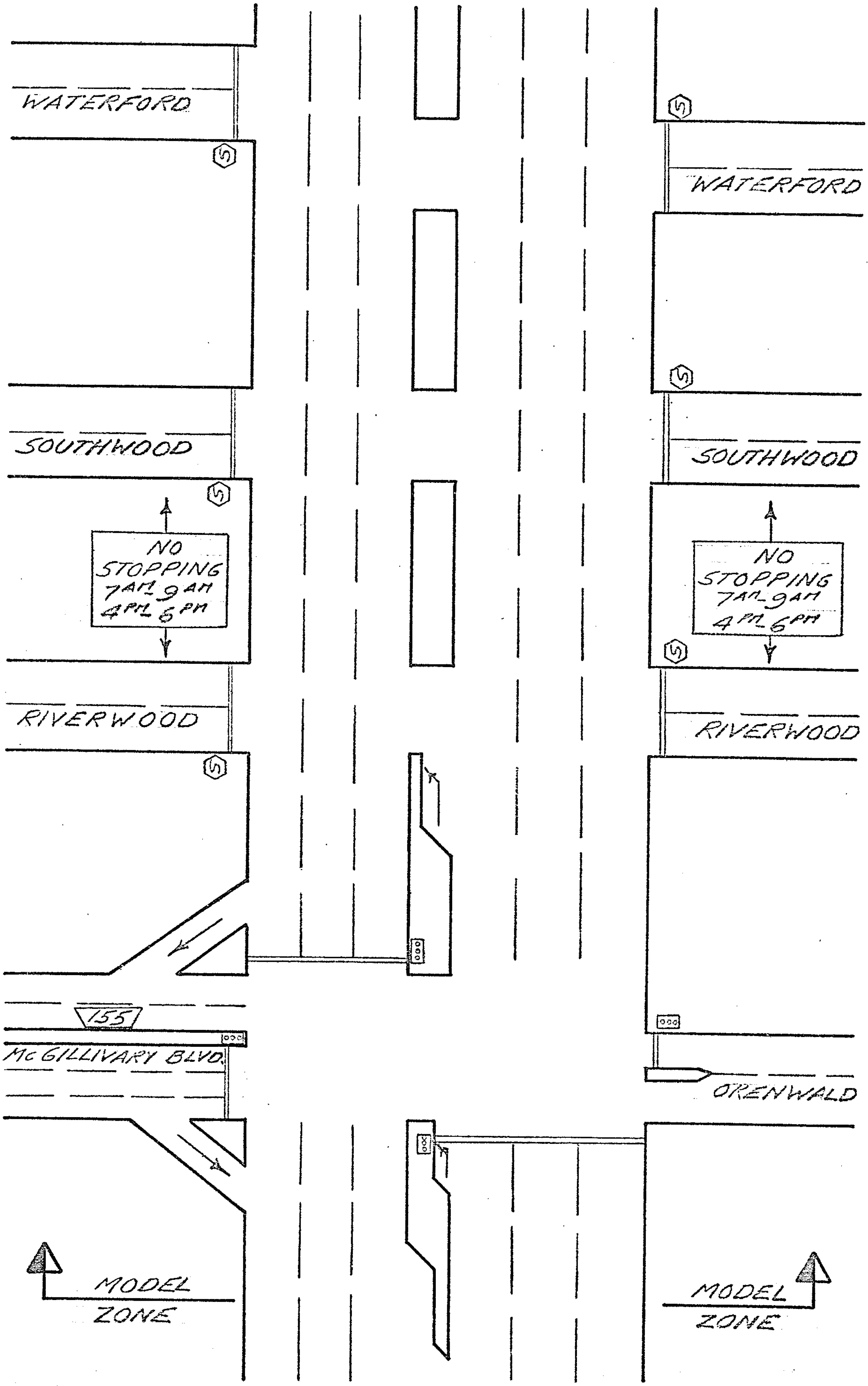
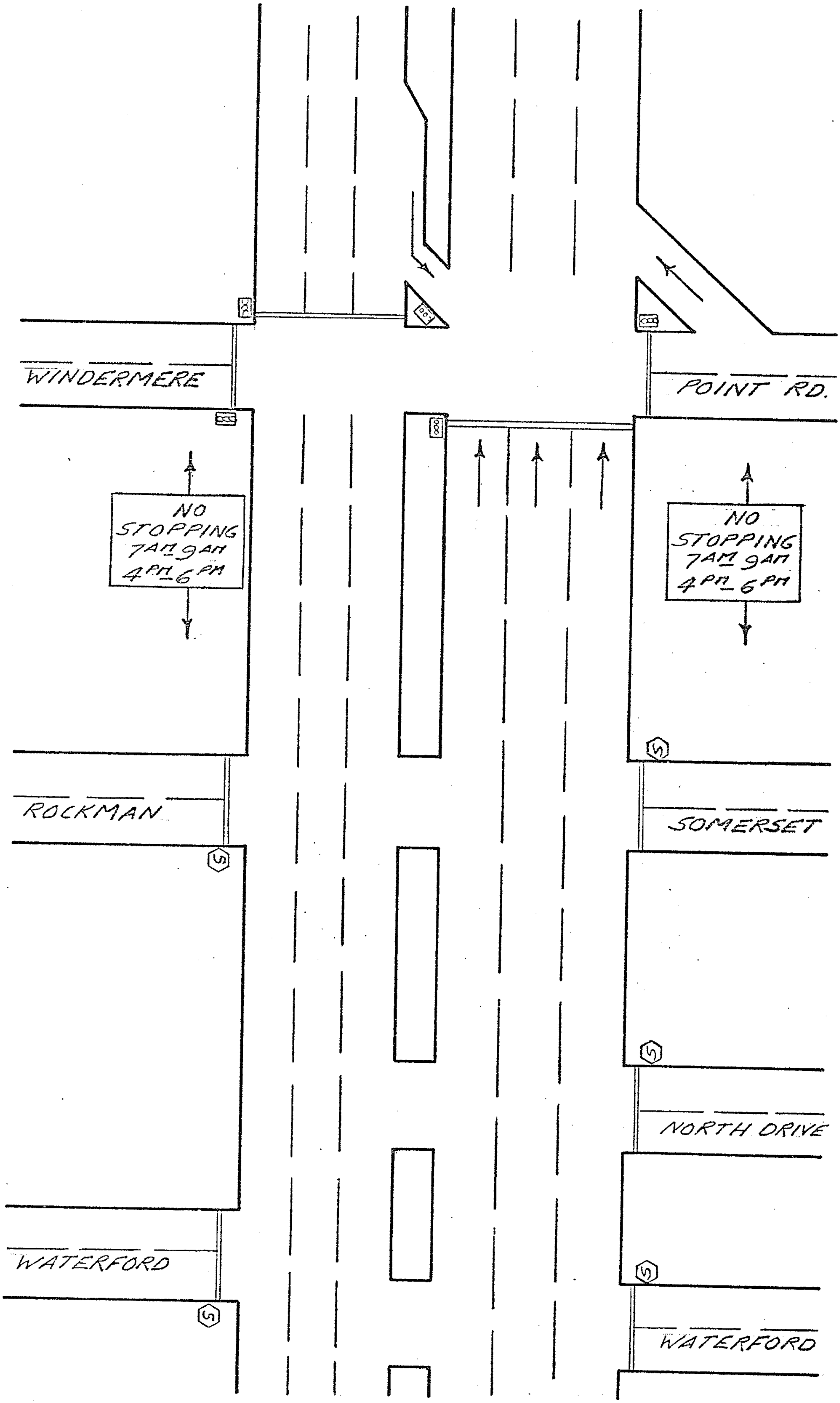
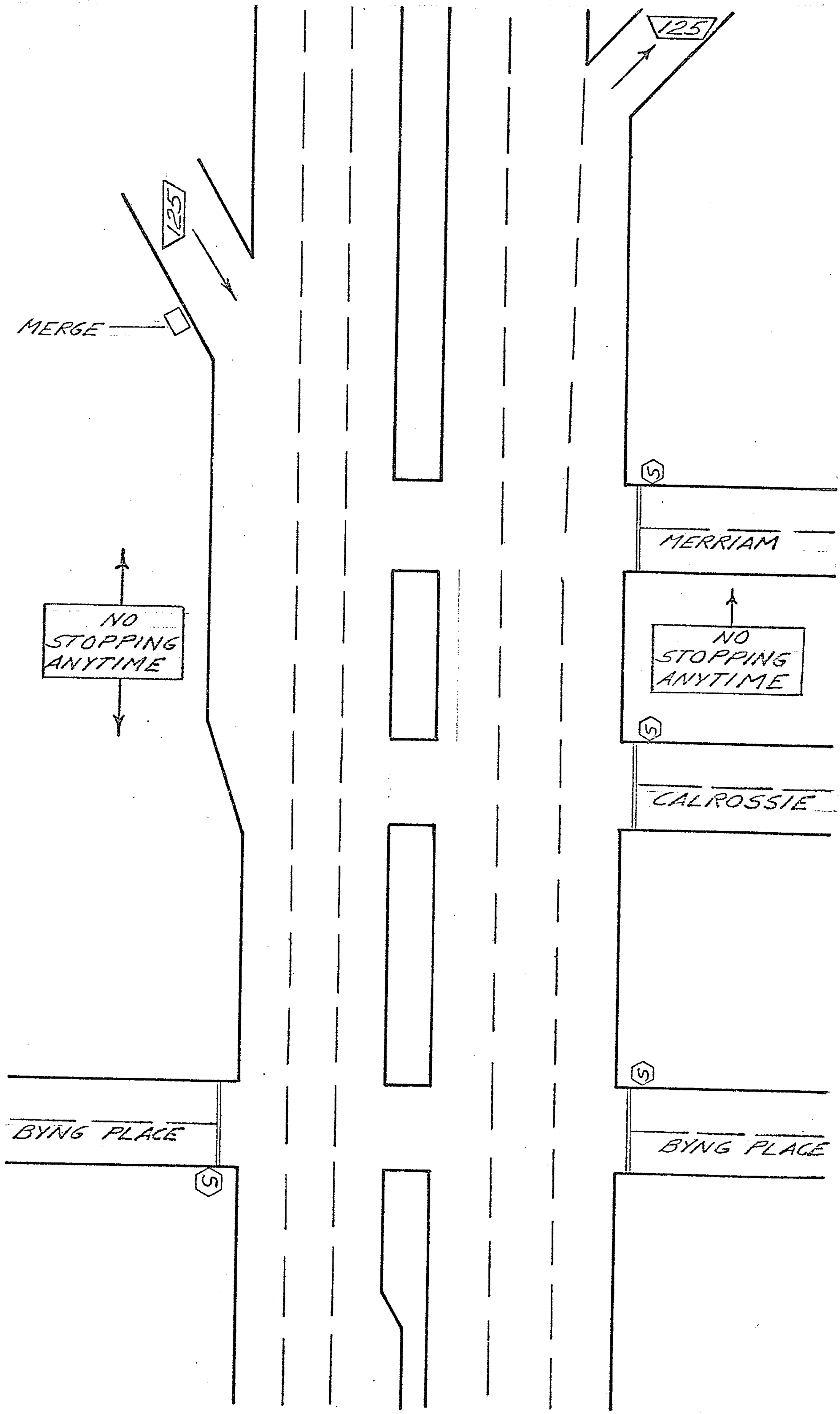
APPENDIX A

MAP OF THE
SELECTED PORTION OF PEMBINA HIGHWAY
IN ITS PRESENT FORM



WATERFORD
WATERFORD
SOUTHWOOD
SOUTHWOOD
NO STOPPING 7AM-9AM 4PM-6PM
NO STOPPING 7AM-9AM 4PM-6PM
RIVERWOOD
RIVERWOOD
155
McGILLIVARY BLVD.
ORENWALD
MODEL ZONE
MODEL ZONE


WINDERMERE
POINT RD.
NO STOPPING 7AM - 9AM 4PM - 6PM
NO STOPPING 7AM - 9AM 4PM - 6PM
ROCKMAN
SOMERSET
NORTH DRIVE
WATERFORD
WATERFORD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125
MERGE
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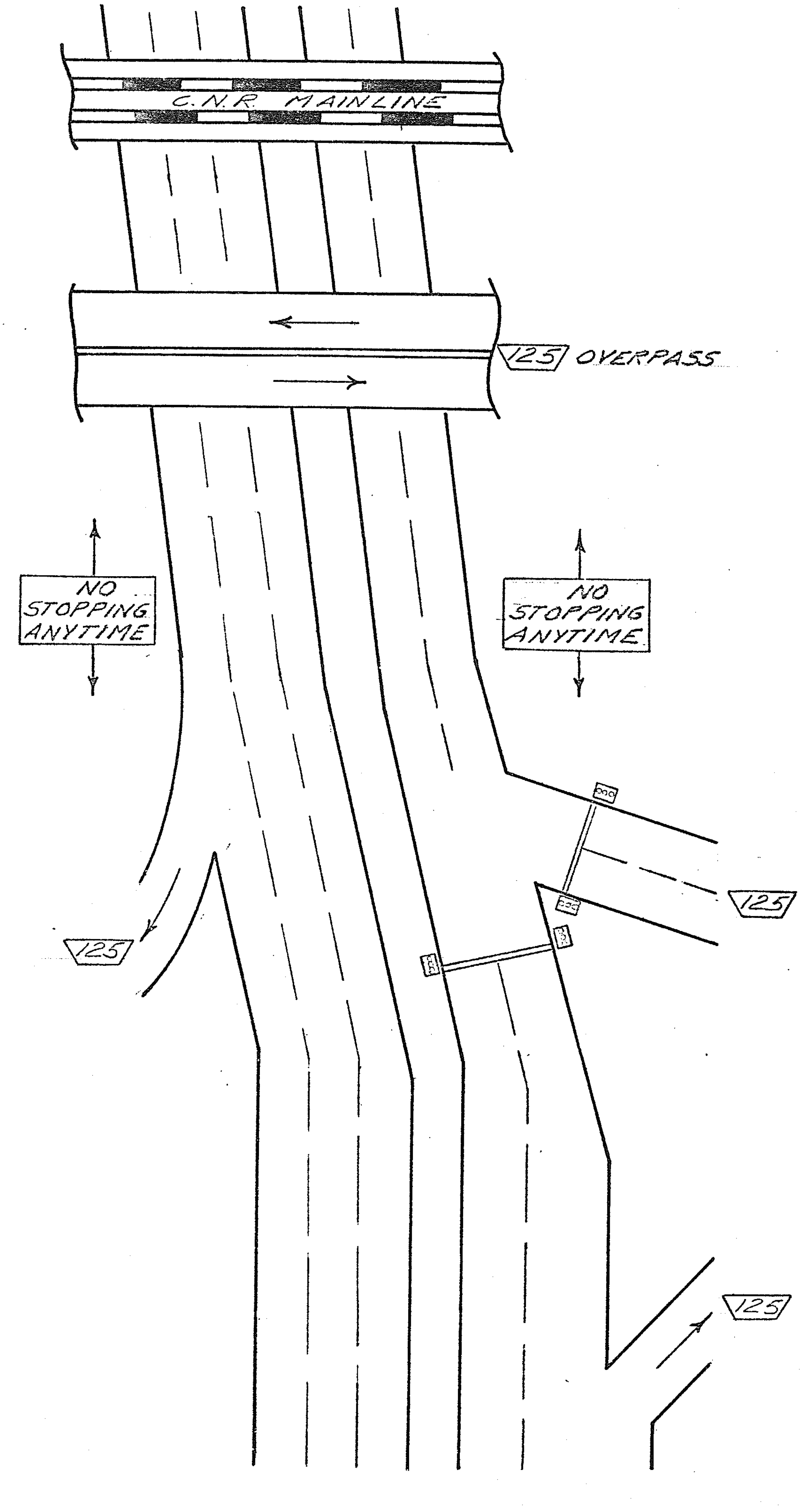
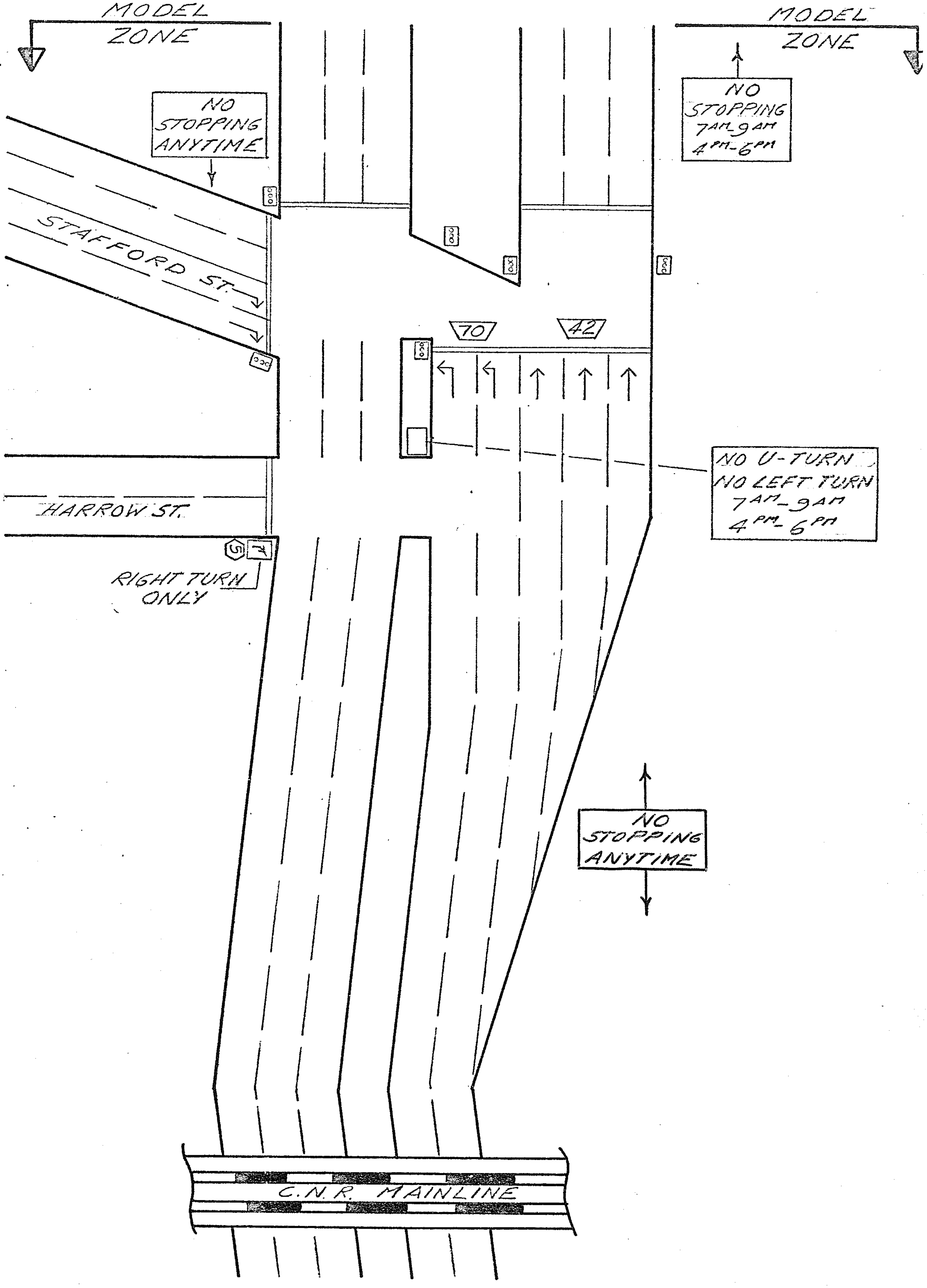
MERRIAM
NO STOPPING ANYTIME
CALROSSIE
BYNG PLACE
BYNG PLACE

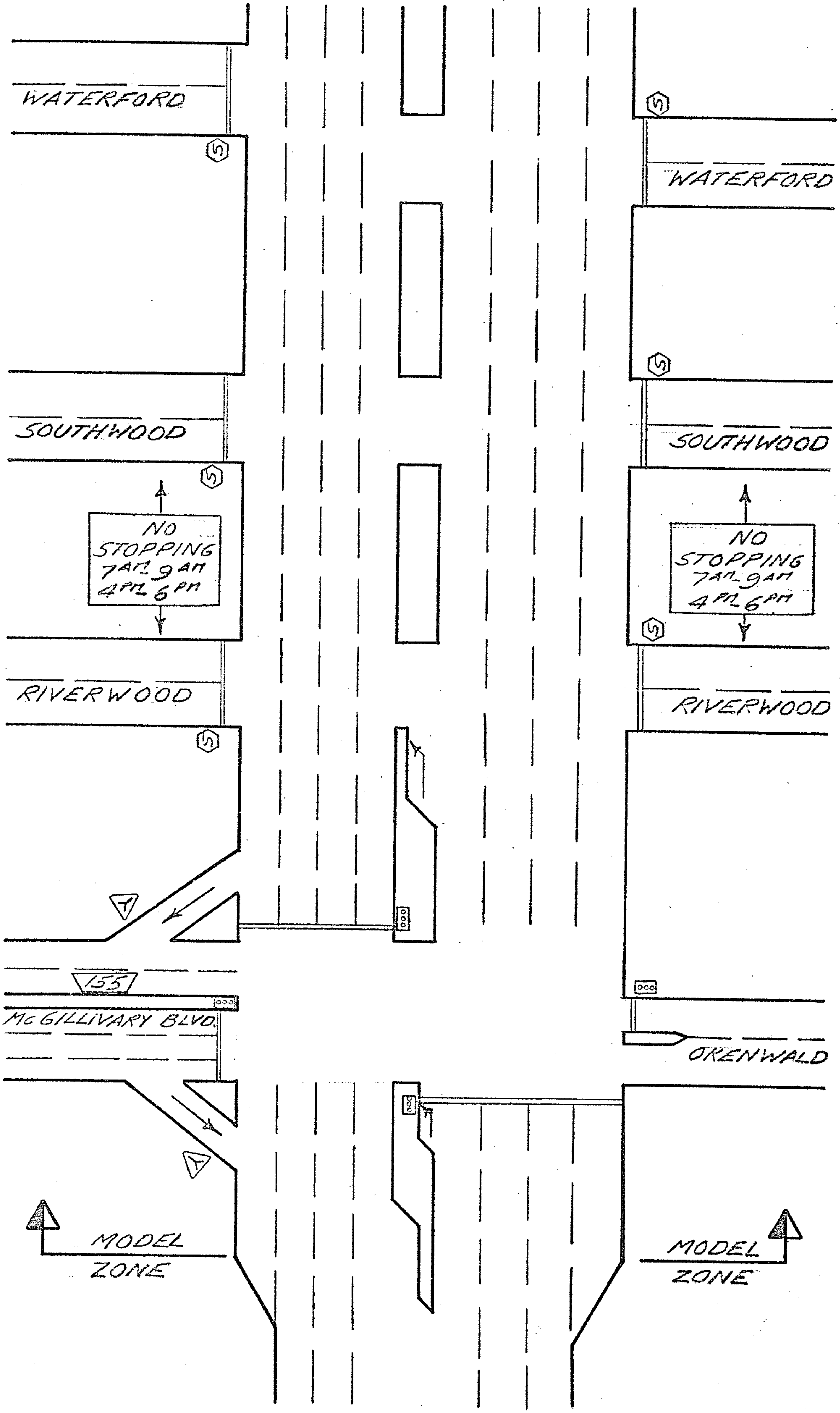


C.N.R. MAINLINE
125 OVERPASS
NO STOPPING ANYTIME
NO STOPPING ANYTIME
125
125
125

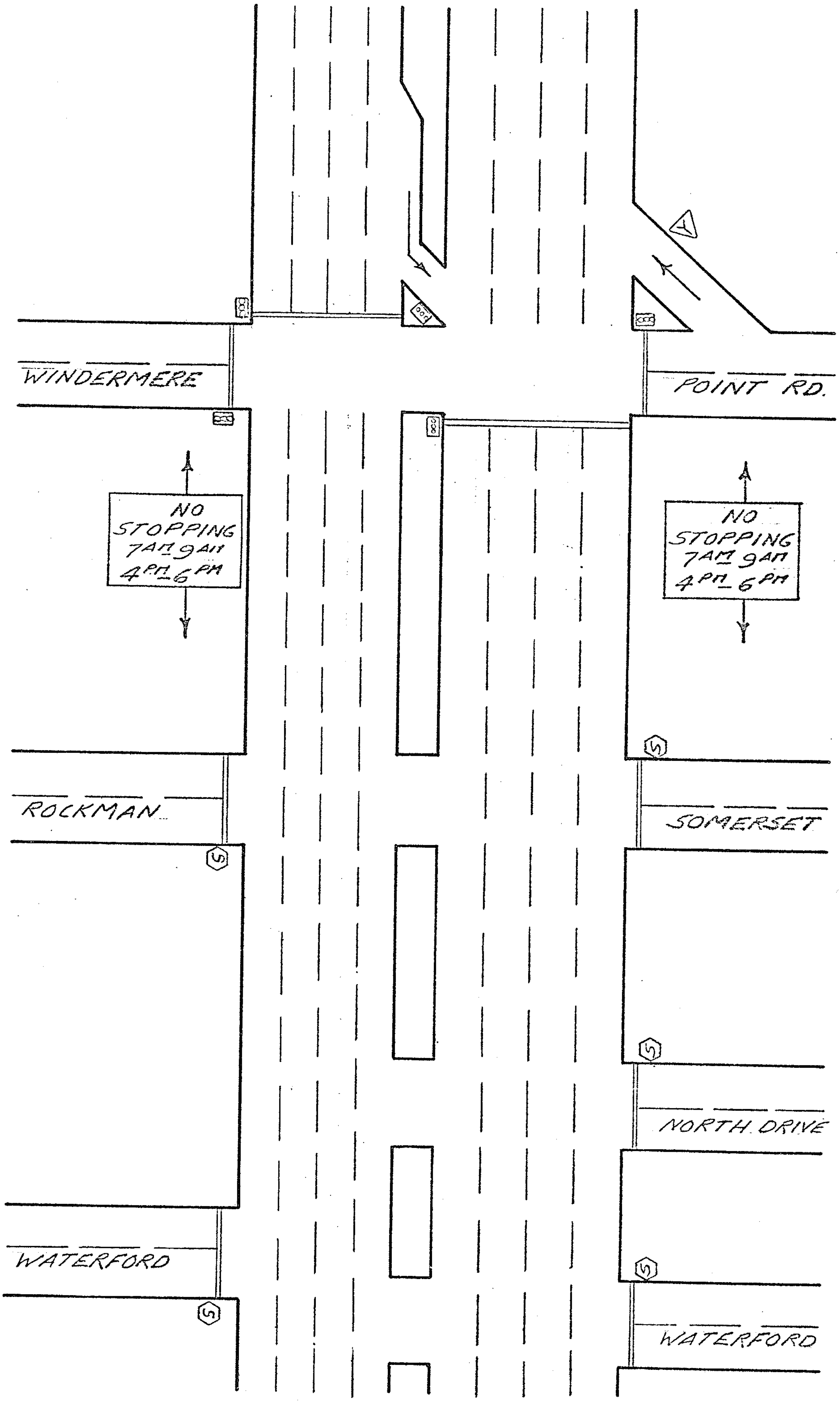

MODEL ZONE
MODEL ZONE
NO STOPPING ANYTIME
NO STOPPING 7AM-9AM 4PM-6PM
STAFFORD ST.
70
42
NO U-TURN
NO LEFT TURN
7AM-9AM
4PM-6PM
HARROW ST.
RIGHT TURN ONLY
NO STOPPING ANYTIME
C.N.R. MAINLINE

APPENDIX B

MAP OF THE
SELECTED PORTION OF PEMBINA HIGHWAY
WITH PROPOSED LANE EXPANSION



WATERFORD
WATERFORD
SOUTHWOOD
SOUTHWOOD
NO STOPPING 7AM-9AM 4PM-6PM
NO STOPPING 7AM-9AM 4PM-6PM
RIVERWOOD
RIVERWOOD
155
McGILLIVARY BLVD.
OKENWALD
MODEL ZONE
MODEL ZONE


WINDERMERE
POINT RD.
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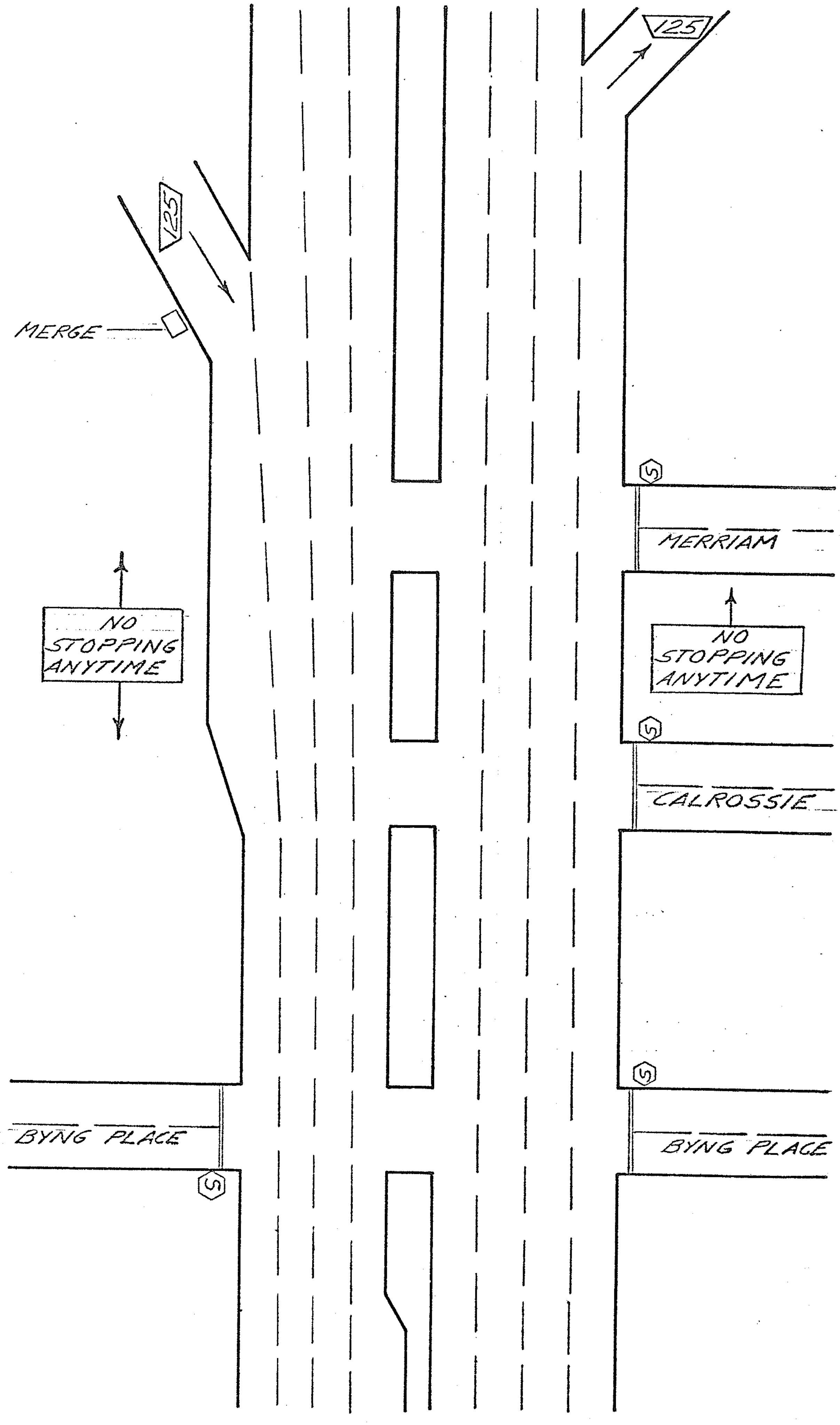
ROCKMAN
SOMERSET
NORTH DRIVE
WATERFORD
WATERFORD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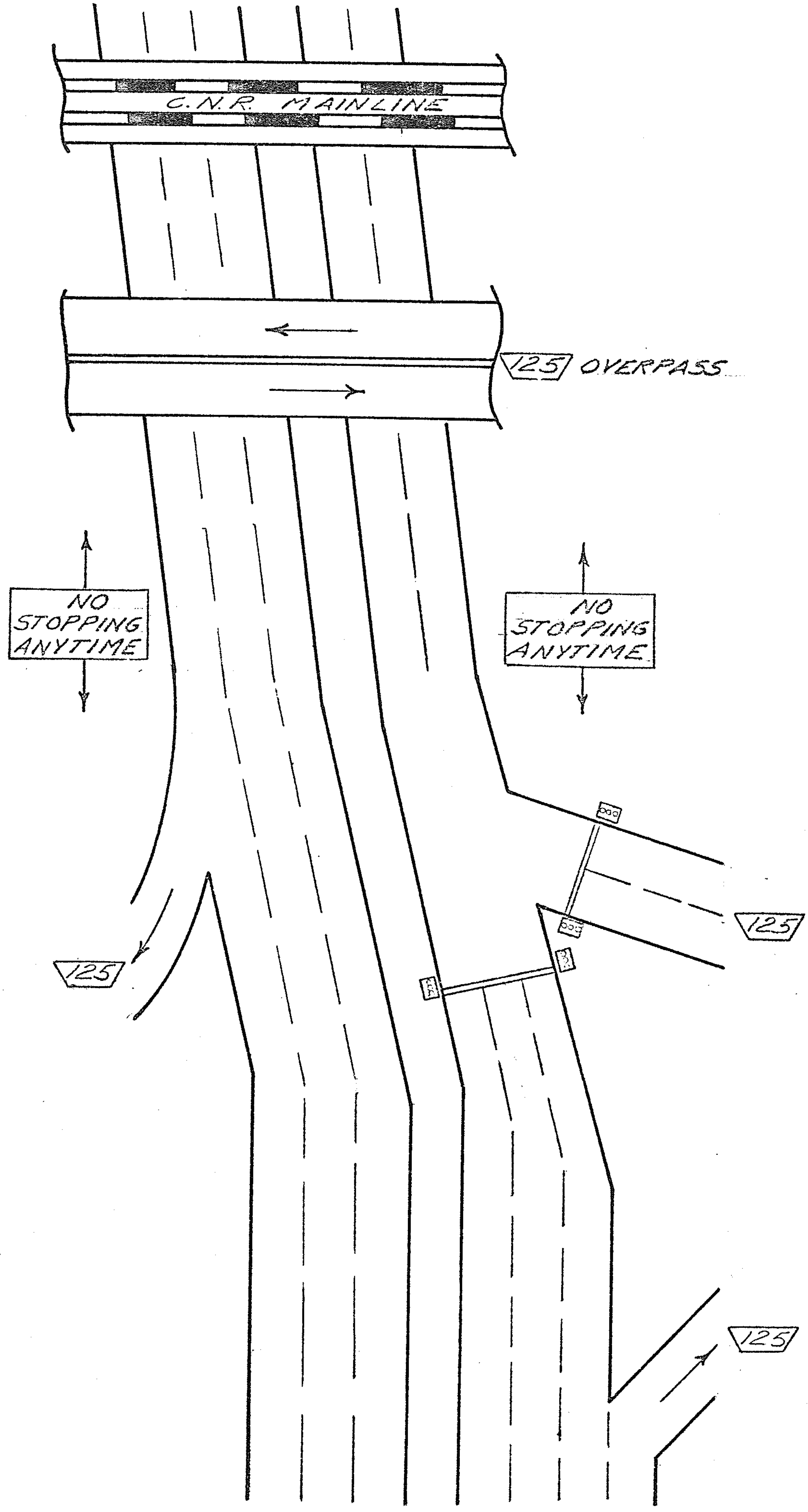
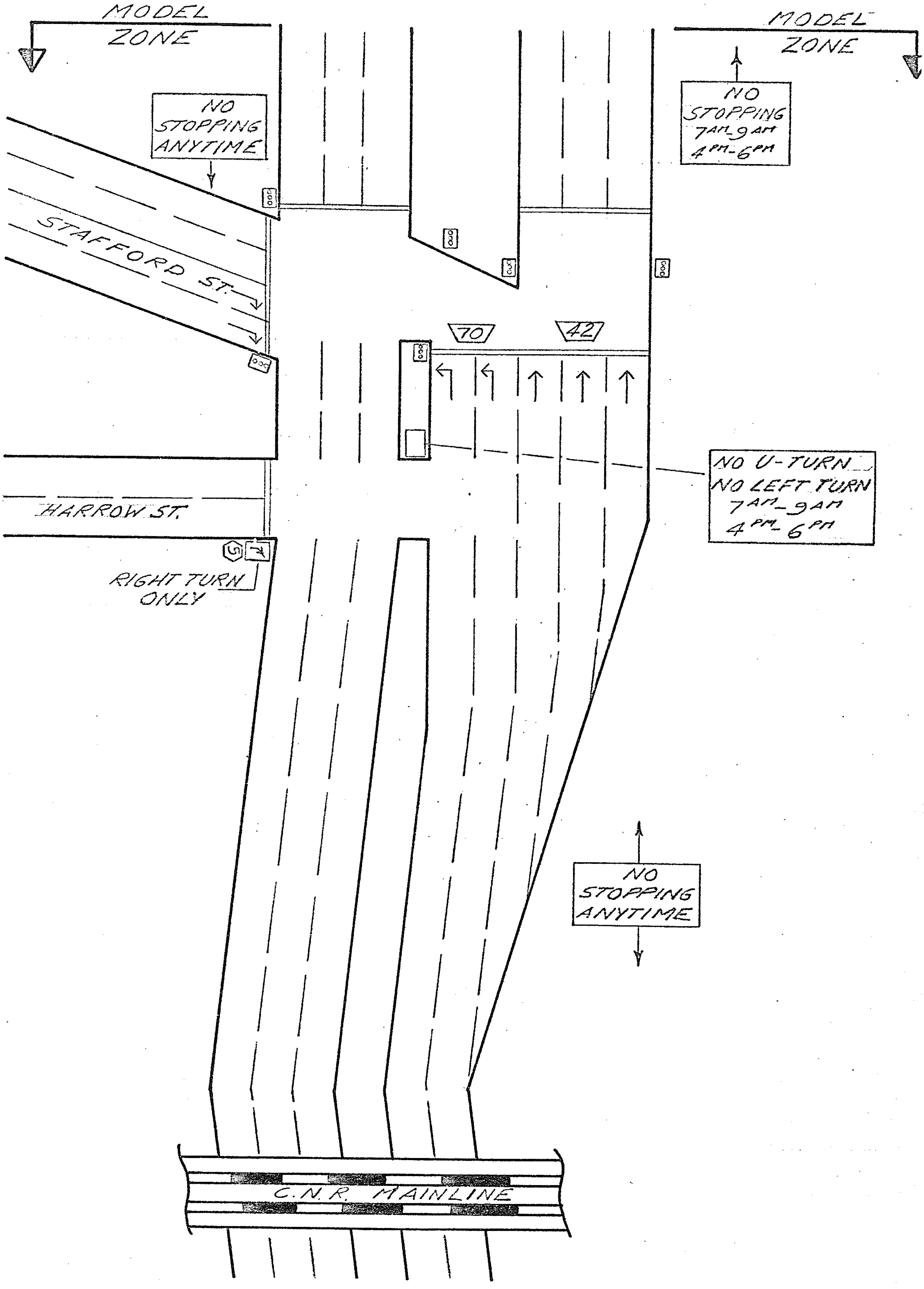
125
MERGE
MERRIAM
NO STOPPING ANYTIME
NO STOPPING ANYTIME
CALROSSIE
BYNG PLACE
BYNG PLACE



C.N.R. MAINLINE
125 OVERPASS
NO STOPPING ANYTIME
NO STOPPING ANYTIME
125
125
125


MODEL ZONE
MODEL ZONE
NO STOPPING ANYTIME
NO STOPPING 7AM-9AM 4PM-6PM
STAFFORD ST.
70
42
NO U-TURN NO LEFT TURN 7AM-9AM 4PM-6PM
HARROW ST.
RIGHT TURN ONLY
NO STOPPING ANYTIME
C.N.R. MAINLINE

APPENDIX C

GPSS SIMULATION PROGRAM FOR MORNING RUSH HOUR CONDITIONS ON SELECTED PORTION OF PEMBINA HIGHWAY WITH PROPOSED LANE EXPANSION

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G          COMMENTS
        *      SIMULATE
         A     QTABLE     1,1,10,10
         B     QTABLE     3,1,10,10
         C     QTABLE     4,1,10,10
         D     QTABLE     5,1,10,10
         E     QTABLE     7,1,10,10
         F     QTABLE     8,1,10,10
         G     QTABLE     9,1,10,10
         H     QTABLE     11,1,10,10
         I     QTABLE     12,1,10,10
         J     QTABLE     14,1,10,10
         K     QTABLE     16,1,10,10
         L     QTABLE     17,1,10,10
         M     QTABLE     18,1,10,10
         N     QTABLE     19,1,10,10
  1            GENERATE   100
  2            TERMINATE  1
        * MACGILLIVARY SIGNALS
  3            GENERATE   1,0,0,1
  4      LMA   LOGIC I    MAA
  5            GATE LS    MAA,RPM
  6            ADVANCE    63,2
  7            TRANSFER   ,LMA
  8      RPM   ADVANCE    13,2
  9            LOGIC S    MAB
 10            ADVANCE    18,2
 11            LOGIC R    MAB
 12            TRANSFER   ,LMA
        * POINT ROAD SIGNALS
 13            GENERATE   1,0,0,1
 14      LPR   LOGIC I    PRA
 15            GATE LS    PRA,GPR
 16            ADVANCE    12
 17            LOGIC S    PRB
 18            ADVANCE    56,2
 19            LOGIC R    PRB
 20            TRANSFER   ,LPR
 21      GPR   ADVANCE    27,2
 22            TRANSFER   ,LPR
        * JUBILEE SIGNALS
 23            GENERATE   1,0,0,1
 24      LJU   LOGIC I    JUB
 25            GATE LS    JUB,JUG
 26            ADVANCE    57,2
 27            TRANSFER   ,LJU
 28      JUG   ADVANCE    22,2
 29            TRANSFER   ,LJU
        * STAFFORD SIGNALS
 30            GENERATE   1,0,0,1
 31      LST   LOGIC I    STA
 32            GATE LS    STA,STG
 33            ADVANCE    16
 34            LOGIC S    STB
 35            ADVANCE    28
 36            TRANSFER   ,LST
```

```
37    STG    ADVANCE     53,2
38           LOGIC R     STB
39           TRANSFER    ,LST
      * PEMBINA N.B. TRAFFIC GENERATION APPROACHING MACGILLIVARY-OAKENWALD
40           GENERATE    4,2
41           TRANSFER    .017,TES2,QCN
42    TES2   TRANSFER    .094,TES1,QBN
43    TES1   TEST L      Q1,Q20,TET2
44           TEST G      Q41,Q1,TET3
45           TEST L      Q57,Q1,QCN
46           TRANSFER    ,TET4
47    TET2   TEST L      Q20,Q41,TET3
48           TEST L      Q57,Q20,CAN
49           TRANSFER    ,TET4
50    TET3   TEST L      Q57,Q41,TTT2
51    TET4   QUEUE       57
52           GATE LS     MAA
53           TEST L      Q58,K70
54           ADVANCE     1
55           DEPART      57
56           QUEUE       2
57           DEPART      2
58           TRANSFER    ,NBA
59    TTT2   QUEUE       41
60           GATE LS     MAA
61           TEST L      Q42,K70
62           ADVANCE     1
63           DEPART      41
64           QUEUE       2
65           DEPART      2
66           TRANSFER    ,NBA
67    CCN    QUEUE       1
68           GATE LS     MAA
69           TEST L      Q5,K70
70           ADVANCE     1
71           DEPART      1
72           TRANSFER    .034,NEX1,TEA
73    NEX1   QUEUE       2
74           DEPART      2
75           TRANSFER    ,NBA
76    CAN    QUEUE       20
77           GATE LS     MAA
78           TEST L      Q23,K70
79           TEST L      Q22,K7
80           ADVANCE     1
81           DEPART      20
82           QUEUE       2
83           DEPART      2
84           TRANSFER    ,NBA
85    CBN    QUEUE       22
86           GATE LS     MAA
87           TEST E      Q21,K0
88           ADVANCE     1
89           DEPART      22
90           QUEUE       21
91           DEPART      21
92    TEA    TERMINATE
```

```
      * OAKENWALD N.B. TRAFFIC GENERATION
 93           GENERATE    33,12
 94           TRANSFER    .277,NEX2,NEX3
 95    NEX2   QUEUE       3
 96           GATE LR     MAA
 97           GATE LR     MAB
 98           ADVANCE     1
 99           DEPART      3
100           QUEUE       2
101           DEPART      2
102    TEB    QUEUE       21
103           DEPART      21
104           TERMINATE
105    NEX3   QUEUE       35
106           TEST L      Q5,K70
107           TRANSFER    BOTH,NEX4,NEX5
108    NEX4   GATE LR     MAA
109           GATE LR     MAB
110    NEX6   ADVANCE     1
111           DEPART      35
112           TRANSFER    ,NBA
113    NEX5   TEST E      Q2,K0
114           TRANSFER    ,NEX6
      * MACGILLIVARY E.B. TRAFFIC GENERATION
115           GENERATE    19,12
116           QUEUE       4
117           GATE LR     MAA
118           GATE LS     MAB
119           TEST GE     Q5,K70,XYZ3
120           TEST GE     Q23,K70,XYZ3
121           TEST GE     Q42,K70,XYZ3
122           TEST L      Q58,K70
123    XYZ3   ADVANCE     1
124           DEPART      4
125           QUEUE       21
126           DEPART      21
127           TRANSFER    .601,TEC,NBA
128    TEC    TERMINATE
      * PEMBINA N.B. TRAFFIC APPROACHING POINT ROAD-WINDEMERE
129    NBA    ADVANCE     59
130           TRANSFER    .010,TES3,QEN
131    TES3   TEST L      Q5,Q23,TAT2
132           TEST G      Q42,Q5,TAT3
133           TEST L      Q58,Q5,QEN
134           TRANSFER    ,TAT4
135    TAT2   TEST L      Q23,Q42,TAT3
136           TEST L      Q58,Q23,QEN
137           TRANSFER    ,TAT4
138    TAT3   TEST L      Q58,Q42,TTT4
139    TAT4   QUEUE       58
140           GATE LS     PRA
141           GATE LS     PRB
142           TEST GE     Q9,K84,TAT5
143           TEST GE     Q24,K84,TAT5
144           TEST L      Q43,K84
145    TAT5   ADVANCE     1
146           DEPART      58
```

```
147           QUEUE      6
148           DEPART     6
149           TRANSFER   ,NBC
150    TTT4   QUEUE      42
151           GATE LS    PRA
152           GATE LS    PRB
153           TEST GE    Q9,K84,SSS1
154           TEST GE    Q24,K84,SSS1
155           TEST L     Q43,K58
156    SSS1   ADVANCE    1
157           DEPART     42
158           QUEUE      6
159           DEPART     6
160           TRANSFER   ,NBC
161    GEN    QUEUE      5
162           GATE LS    PRA
163           GATE LS    PRB
164           TEST GE    Q9,K84,TAT9
165           TEST GE    Q24,K84,TAT9
166           TEST L     Q43,K84
167    TAT9   ADVANCE    1
168           DEPART     5
169           TRANSFER   .990,TEA,NEX7
170    NEX7   QUEUE      6
171           DEPART     6
172           TRANSFER   ,NBC
173    QDN    QUEUE      23
174           GATE LS    PRA
175           GATE LS    PRB
176           TEST GE    Q24,K84,TAT6
177           TEST GE    Q9,K84,TAT6
178           TEST L     Q43,K84
179    TAT6   ADVANCE    1
180           DEPART     23
181           QUEUE      6
182           DEPART     6
183           TRANSFER   ,NBC
184    TEE    TERMINATE
      * POINT ROAD W.B. TRAFFIC GENERATION
185           GENERATE   22,20
186           TRANSFER   .798,NEY6,NEY7
187    NEY7   QUEUE      38
188           TEST L     Q9,K84
189           TEST E     Q6,K0
190           ADVANCE    1
191           DEPART     38
192           TRANSFER   ,NBC
193    NEY6   TRANSFER   .620,NEY8,NEY9
194    NEY8   QUEUE      39
195           TEST L     Q33,K70
196           GATE LR    PRA
197           TEST E     Q61,K0
198           ADVANCE    1
199           DEPART     39
200           QUEUE      61
201           DEPART     61
202           TRANSFER   ,SBE
```

```
203    NEY9   QUEUE       7
204           GATE LR     PRA
205           TEST E      Q39,K0
206           ADVANCE     1
207           DEPART      7
208           QUEUE       6
209           DEPART      6
210           QUEUE       61
211           DEPART      61
212           TERMINATE
      * WINDEMERE E.B. TRAFFIC GENERATION
213           GENERATE    30,13
214           TRANSFER    .C97,NEX9,NEY1
215    NEX9   TRANSFER    .802,NEY4,NEY5
216    NEY5   QUEUE       8
217           GATE LR     PRA
218           TEST E      Q36,K0
219           TEST E      Q37,K0
220           ADVANCE     1
221           DEPART      8
222           QUEUE       61
223           DEPART      61
224           QUEUE       6
225           DEPART      6
226           TERMINATE
227    NEY1   QUEUE       36
228           TEST L      Q19,K70
229           TRANSFER    BOTH,NEY2,NEY3
230    NEY2   TEST E      Q61,K0
231           ADVANCE     1
232           DEPART      36
233           TRANSFER    ,SBE
234    NEY3   GATE LR     PRA
235           ADVANCE     1
236           DEPART      36
237           QUEUE       61
238           DEPART      61
239           TRANSFER    ,SBE
240    NEY4   QUEUE       37
241           GATE LR     PRA
242           TEST L      Q24,K84
243           TEST E      Q6,K0
244           ADVANCE     1
245           DEPART      37
246           QUEUE       61
247           DEPART      61
248           TRANSFER    ,NBC
      * PEMBINA N.B. TRAFFIC APPROACHING JUBILEE EXIT
249    NBC    ADVANCE     41
250           TRANSFER    .794,TEI,NBE
251    TEI    TERMINATE
      * PEMBINA N.B. TRAFFIC APPROACHING JUBILEE ENTRANCE
252    NBE    ADVANCE     10
253           TEST L      Q9,Q24,TTT5
254           TEST L      Q43,Q9,TTT6
255    TTT9   QUEUE       43
256           GATE LS     JUB
```

```
257            TEST L      Q27,K42,TTT7
258            TEST L      Q12,K53
259            TEST L      Q26,K53
260            TRANSFER    ,TTT8
261    TTT7    TEST L      Q28,K53
262            TEST L      Q14,K53
263    TTT8    ADVANCE     1
264            DEPART      43
265            QUEUE       10
266            DEPART      10
267            TRANSFER    ,NBF
268    TTT5    TEST L      Q24,Q43,TTT9
269            TRANSFER    ,GEN
270    TTT6    QUEUE       9
271            GATE LS     JUB
272            TEST L      Q28,K53
273            TEST L      Q14,K53
274            ADVANCE     1
275            DEPART      9
276            QUEUE       10
277            DEPART      10
278            TRANSFER    ,NBF
279    GEN     QUEUE       24
280            GATE LS     JUB
281            TEST L      Q27,K42
282            TEST L      Q12,K53
283            TEST L      Q26,K53
284            ADVANCE     1
285            DEPART      24
286            QUEUE       10
287            DEPART      10
288            TRANSFER    ,NBF
       * JUBILEE N.B. TRAFFIC GENERATION
289            GENERATE    7,2
290            QUEUE       11
291            GATE LR     JUB
292            TEST L      Q27,K42,ZZZ1
293            TEST GE     Q12,K53,XYZ2
294            TEST GE     Q26,K53,XYZ2
295    ZZZ1    TEST GE     Q28,K53,XYZ2
296            TEST L      Q14,K53
297    XYZ2    ADVANCE     1
298            DEPART      11
299            QUEUE       10
300            DEPART      10
301            TRANSFER    ,NBF
       * PEMBINA N.B. TRAFFIC APPROACHING HARROW
302    NBF     ADVANCE     26
       * PEMBINA N.B. TRAFFIC DIRECTIONAL BREAKDOWN
303    NBG     ADVANCE     7
304            TRANSFER    .550,NBH,NBI
       * PEMBINA N.B. TRAFFIC TURNING ONTO STAFFORD W.B.
305    NBH     TEST L      Q12,Q26,GGN
306            TEST E      Q27,K0,GGN
307            QUEUE       12
308            GATE LR     STA
309            ADVANCE     1
```

```
        DEPART      12
        QUEUE       13
        DEPART      13
        TERMINATE
CGN     QUEUE       26
        GATE LR     STA
        ADVANCE     1
        DEPART      26
        QUEUE       13
        DEPART      13
        TERMINATE
* PEMBINA N.B. TRAFFIC REMAINING ON PEMBINA
NBI     TEST LE     Q14,Q23,CHN
        QUEUE       14
        GATE LS     STB
        ADVANCE     1
        DEPART      14
        QUEUE       15
        DEPART      15
        TERMINATE
CHN     QUEUE       28
        GATE LS     STB
        ADVANCE     1
        DEPART      28
        QUEUE       15
        DEPART      15
        TERMINATE
* PEMBINA S.B. TRAFFIC GENERATION
        GENERATE    4,1
        TRANSFER    .010,TES4,QAS
TES4    TEST L      Q16,Q29,TES5
        TEST L      Q16,Q30,QBS
QAS     QUEUE       16
        GATE LS     STA
        TEST L      Q18,K136
        ADVANCE     1
        DEPART      16
        QUEUE       13
        DEPART      13
        TRANSFER    .010,SBA,TAB
TAB     TERMINATE
TES5    TEST L      Q29,Q30,QBS
        QUEUE       29
        GATE LS     STA
        TEST L      Q31,K136
        ADVANCE     1
        DEPART      29
        QUEUE       13
        DEPART      13
        TRANSFER    ,SBA
QBS     QUEUE       30
        GATE LS     STA
        TEST L      Q55,K136
ZZZ2    ADVANCE     1
        DEPART      30
        QUEUE       13
        DEPART      13
```

```
 365              TRANSFER    ,SBA
         * STAFFORD S.B. TRAFFIC GENERATION
 366              GENERATE    8,1
 367              QUEUE       17
 368              GATE LP     STA
 369              TEST GE     Q18,K116,YZX1
 370              TEST L      Q31,K116
 371       YZX1   ADVANCE     1
 372              DEPART      17
 373              QUEUE       13
 374              DEPART      13
         * PEMBINA S.B. TRAFFIC APPRCACHING HARROW
 375       SBA    ADVANCE     9
 376              TRANSFER    .011,SBB,TAC
 377       TAC    TERMINATE
         * HARROW S.B. TRAFFIC GENERATICN
 378              GENERATE    17,9
 379              QUEUE       40
 380              TEST E      Q25,K0
 381              TEST L      Q18,K105
 382              ADVANCE     1
 383              DEPART      40
 384       SBB    QUEUE       25
 385              DEPART      25
         * PEMBINA S.B. TRAFFIC APPRCACHING JUBILEE EXIT
 386              ADVANCE     27
 387              TRANSFER    .237,SBX,TAD
 388       TAD    TERMINATE
         * JUBILEE S.B. TRAFFIC GENERATION
 389       SBX    ADVANCE     10
 390              TRANSFER    ,SBC
 391              GENERATE    9,4
 392       SBC    ADVANCE     33
         * PEMBINA S.B. TRAFFIC APPRCACHING PCINT ROAD-WINDEMERE
 393              TRANSFER    .026,TES6,QCS
 394       TES6   TRANSFER    .080,TES7,QDS
 395       QDS    QUEUE       32
 396              GATE LS     PRA
 397              TEST E      Q6,K0
 398              ADVANCE     1
 399              DEPART      32
 400              TERMINATE
 401       TES7   TEST L      Q59,K60,TBT2
 402              TEST L      Q59,Q31,TBT2
 403              TEST L      Q59,Q18,TBT3
 404              TEST L      Q59,Q55,QMS
 405              TRANSFER    ,TBT1
 406       TBT2   TEST L      Q31,Q18,TBT3
 407              TEST L      Q31,Q55,QMS
 408              TRANSFER    ,QES
 409       TBT3   TEST L      Q18,Q55,QMS
 410              TRANSFER    ,QCS
 411       TBT1   QUEUE       59
 412              GATE LS     PRA
 413              TEST L      Q60,K70
 414              ADVANCE     1
 415              DEPART      59
```

```
416              TRANSFER    ,SBE
417      QMS     QUEUE       55
418              GATE LS     PPA
419              TEST L      Q44,K70
420              ADVANCE     1
421              DEPART      55
422              TRANSFER    ,SBE
423      QES     QUEUE       31
424              GATE LS     PPA
425              TEST L      Q33,K70
426              TEST L      Q32,K7
427              ADVANCE     1
428              DEPART      31
429              QUEUE       61
430              DEPART      61
431              TRANSFER    ,SBE
432      QCS     QUEUE       18
433              GATE LS     PPA
434              TEST L      Q19,K70
435              ADVANCE     1
436              DEPART      18
437              TRANSFER    .948,TAF,NEX8
438      NEX8    QUEUE       61
439              DEPART      61
440              TRANSFER    ,SBE
441      TAF     TERMINATE
442      SBE     ADVANCE     51
       * PEMBINA S.B. TRAFFIC APPRCACHING MACGILLIVARY-OAKENWALD
443              TRANSFER    .010,TES8,QGS
444      TES8    TRANSFER    .252,TES9,QHS
445      TES9    TEST L      Q60,Q33,TCT2
446              TEST L      Q60,Q19,TCT3
447              TEST L      Q60,Q44,SSS3
448              TRANSFER    ,TCT1
449      TCT2    TEST L      Q33,Q19,TCT3
450              TEST L      Q33,Q44,SSS3
451              TRANSFER    ,QGS
452      TCT3    TEST L      Q19,Q44,SSS3
453              TRANSFER    ,QIS
454      TCT1    QUEUE       60
455              GATE LS     MAA
456              ADVANCE     1
457              DEPART      60
458              QUEUE       21
459              DEPART      21
460              TERMINATE
461      SSS3    QUEUE       44
462              GATE LS     MAA
463              ADVANCE     1
464              DEPART      44
465              QUEUE       21
466              DEPART      21
467              TERMINATE
468      QHS     TRANSFER    .504,QIS,TAI
469      QIS     QUEUE       19
470              GATE LS     MAA
471              ADVANCE     1
```

```
472           DEPART      19
473           QUEUE       21
474           DEPART      21
475     TAI   TERMINATE
476     QGS   QUEUE       33
477           GATE LS     MAA
478           TRANSFER    .020,QKS,QJS
479     QJS   DEPART      33
480           QUEUE       34
481           TEST E      Q2,K0
482           ADVANCE     1
483           DEPART      34
484           TERMINATE
485     QKS   TEST E      Q34,K0
486           ADVANCE     1
487           DEPART      33
488           QUEUE       21
489           DEPART      21
490           TERMINATE
              START       18
              RESET
              START       72
              END
```

BLOCK NUMBER	SYMBOL	REFERENCES BY CARD NUMBER					
21	GPR	32					
28	JUG	43					
24	LJU	45	47				
4	LMA	23	28				
14	LPR	37	39				
31	LST	55	58				
129	NBA	78	86	95	104	133	149
249	NBC	172	183	195	206	216	273
252	NBE	276					
302	NBF	294	305	315	329		
303	NBG						
305	NBH	334					
321	NBI	334					
73	NEX1	92					
95	NEX2	115					
105	NEX3	115					
108	NEX4	128					
113	NEX5	128					
110	NEX6	135					
170	NEX7	192					
438	NEX8	476					
215	NEX9	239					
227	NEY1	239					
230	NEY2	254					
234	NEY3	254					
240	NEY4	240					
216	NEY5	240					
193	NEY6	210					
187	NEY7	210					
194	NEY8	217					
203	NEY9	217					
76	QAN	68					
340	QAS	370					
85	QBN	62					
358	QBS	372	382				
67	QCN	61	65				
432	QCS	432	449				
173	QDN	159					
395	QDS	433					
161	QEN	153	156				
423	QES	447					
279	QFN	296					
314	QGN	336	337				
476	QGS	483	491				
329	QHN	353					
468	QHS	484					
469	QIS	493	508				
479	QJS	518					
485	QKS	518					
417	QMS	443	446	448			
8	RPM	21					
375	SBA	380	390	398			
384	SBB	411					

392	SBC	428						
442	SBF	226	258	264	455	461	470	479
389	SBX	424						
156	SSS1	176	177					
461	SSS3	487	490	492				
37	STG	51						
348	TAB	390						
377	TAC	411						
388	TAD	424						
441	TAF	476						
475	TAI	508						
135	TAT2	154						
138	TAT3	155	158					
139	TAT4	157	160					
145	TAT5	165	166					
179	TAT6	199	200					
167	TAT9	187	188					
411	TBT1	444						
406	TBT2	440	441					
409	TBT3	442	445					
454	TCT1	488						
449	TCT2	485						
452	TCT3	486	489					
92	TEA	92	192					
102	TEB							
128	TEC	149						
184	TEE							
251	TEI	276						
43	TES1	62						
42	TES2	61						
131	TES3	153						
338	TES4	370						
349	TES5	371						
394	TES6	432						
401	TES7	433						
444	TES8	483						
445	TES9	484						
47	TET2	63						
50	TET3	64	67					
51	TET4	66	69					
59	TTT2	70						
150	TTT4	161						
268	TTT5	280						
270	TTT6	281						
261	TTT7	284						
263	TTT8	287						
255	TTT9	295						
297	XYZ2	321	322	323				
123	XYZ3	141	142	143				
371	YZX1	403						
295	ZZZ1	320						
361	ZZZ2							

TABLE SYMBOLS AND CORRESPONDING NUMBERS

1	A
2	B
3	C
4	D
5	E
6	F
7	G
8	H
9	I
10	J
11	K
12	L
13	M
14	N

LOGIC SWITCH SYMBOLS AND CORRESPONDING NUMBERS

5	JUB
1	MAA
2	MAB
3	PRA
4	PRB
6	STA
7	STB

```
  1     QTABLE     1      1      10     10
  2     QTABLE     3      1      10     10
  3     QTABLE     4      1      10     10
  4     QTABLE     5      1      10     10
  5     QTABLE     7      1      10     10
  6     QTABLE     8      1      10     10
  7     QTABLE     9      1      10     10
  8     QTABLE     11     1      10     10
  9     QTABLE     12     1      10     10
  10    QTABLE     14     1      10     10
  11    QTABLE     16     1      10     10
  12    QTABLE     17     1      10     10
  13    QTABLE     18     1      10     10
  14    QTABLE     19     1      10     10
  1     GENERATE   100
  2     TERMINATE  1
* MACGILLIVARY SIGNALS
  3     GENERATE   1      0      0      1
  4     LOGICI     1
  5     GATE LS    1      8
  6     ADVANCE    63     2
  7     TRANSFER          4
  8     ADVANCE    13     2
  9     LOGICS     2
  10    ADVANCE    13     2
  11    LOGICR     2
  12    TRANSFER          4
* POINT ROAD SIGNALS
  13    GENERATE   1      0      0      1
  14    LOGICI     3
  15    GATE LS    3      21
  16    ADVANCE    12
  17    LOGICS     4
  18    ADVANCE    56     2
  19    LOGICR     4
  20    TRANSFER          14
  21    ADVANCE    27     2
  22    TRANSFER          14
* JUBILEE SIGNALS
  23    GENERATE   1      0      0      1
  24    LOGICI     5
  25    GATE LS    5      23
  26    ADVANCE    57     2
  27    TRANSFER          24
  28    ADVANCE    22     2
  29    TRANSFER          24
* STAFFORD SIGNALS
  30    GENERATE   1      0      0      1
  31    LOGICI     6
  32    GATE LS    6      37
  33    ADVANCE    16
  34    LOGICS     7
  35    ADVANCE    28
  36    TRANSFER          31
  37    ADVANCE    53     2
  38    LOGICR     7
  39    TRANSFER          31
* PEMBINA N.B. TRAFFIC GENERATION APPROACHING MACGILLIVARY-OAKENWALD
  40    GENERATE   4      2
  41    TRANSFER   .017   42     67
  42    TRANSFER   .094   43     85
  43    TEST L     Q1     Q20    47
  44    TEST G     Q41    Q1     50
  45    TEST L     Q57    Q1     67
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 47   TEST L      020   041   50
 48   TEST L      057   020   76
 49   TRANSFER          51
 50   TEST L      057   041   59
 51   QUEUE       57
 52   GATE LS     1
 53   TEST L      058   K70
 54   ADVANCE     1
 55   DEPART      57
 56   QUEUE       2
 57   DEPART      2
 58   TRANSFER          129
 59   QUEUE       41
 60   GATE LS     1
 61   TEST L      042   K70
 62   ADVANCE     1
 63   DEPART      41
 64   QUEUE       2
 65   DEPART      2
 66   TRANSFER          129
 67   QUEUE       1
 68   GATE LS     1
 69   TEST L      05    K70
 70   ADVANCE     1
 71   DEPART      1
 72   TRANSFER    .034  73    92
 73   QUEUE       2
 74   DEPART      2
 75   TRANSFER          129
 76   QUEUE       20
 77   GATE LS     1
 78   TEST L      023   K70
 79   TEST L      022   K7
 80   ADVANCE     1
 81   DEPART      20
 82   QUEUE       2
 83   DEPART      2
 84   TRANSFER          129
 85   QUEUE       22
 86   GATE LS     1
 87   TEST E      021   K0
 88   ADVANCE     1
 89   DEPART      22
 90   QUEUE       21
 91   DEPART      21
 92   TERMINATE
* OAKENWALD W.B. TRAFFIC GENERATION
 93   GENERATE    33    12
 94   TRANSFER    .277  95    105
 95   QUEUE       3
 96   GATE LR     1
 97   GATE LR     2
 98   ADVANCE     1
 99   DEPART      3
100   QUEUE       2
101   DEPART      2
102   QUEUE       21
103   DEPART      21
104   TERMINATE
105   QUEUE       35
106   TEST L      Q5    K70
107   TRANSFER    BOTH  108   113
108   GATE LR     1
109   GATE LR     2
110   ADVANCE     1
```

```
 112    TRANSFER            129
 113    TEST E      Q2      K0
 114    TRANSFER            110
* MACGILLIVARY E.B. TRAFFIC GENERATION
 115    GENERATE    19      12
 116    QUEUE       4
 117    GATE LR     1
 118    GATE LS     2
 119    TEST GE     Q5      K70     123
 120    TEST GE     Q23     K70     123
 121    TEST GE     Q42     K70     123
 122    TEST L      Q58     K70
 123    ADVANCE     1
 124    DEPART      4
 125    QUEUE       21
 126    DEPART      21
 127    TRANSFER    .601    128     129
 128    TERMINATE
* PEMBINA N.B. TRAFFIC APPROACHING POINT ROAD-WINDEMERE
 129    ADVANCE     59
 130    TRANSFER    .010    131     161
 131    TEST L      Q5      Q23     135
 132    TEST G      Q42     Q5      138
 133    TEST L      Q58     Q5      161
 134    TRANSFER            139
 135    TEST L      Q23     Q42     138
 136    TEST L      Q58     Q23     173
 137    TRANSFER            139
 138    TEST L      Q58     Q42     150
 139    QUEUE       59
 140    GATE LS     3
 141    GATE LS     4
 142    TEST GE     Q9      K84     145
 143    TEST GE     Q24     K84     145
 144    TEST L      Q43     K84
 145    ADVANCE     1
 146    DEPART      59
 147    QUEUE       6
 148    DEPART      6
 149    TRANSFER            249
 150    QUEUE       42
 151    GATE LS     3
 152    GATE LS     4
 153    TEST GE     Q9      K84     156
 154    TEST GE     Q24     K84     156
 155    TEST L      Q43     K58
 156    ADVANCE     1
 157    DEPART      42
 158    QUEUE       6
 159    DEPART      6
 160    TRANSFER            249
 161    QUEUE       5
 162    GATE LS     3
 163    GATE LS     4
 164    TEST GE     Q9      K84     167
 165    TEST GE     Q24     K94     167
 166    TEST L      Q43     K84
 167    ADVANCE     1
 168    DEPART      5
 169    TRANSFER    .990    92      170
 170    QUEUE       6
 171    DEPART      6
 172    TRANSFER            249
 173    QUEUE       23
 174    GATE LS     3
```

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 176   TEST GE    024   K84   179
 177   TEST GE    09    K84   179
 178   TEST L     043   K84
 179   ADVANCE    1
 180   DEPART     23
 181   QUEUE      6
 182   DEPART     6
 183   TRANSFER         249
 184   TERMINATE
* POINT ROAD W.B. TRAFFIC GENERATION
 185   GENERATE   22    20
 186   TRANSFER   .798  193   187
 187   QUEUE      38
 188   TEST L     09    K84
 189   TEST E     05    K0
 190   ADVANCE    1
 191   DEPART     38
 192   TRANSFER         249
 193   TRANSFER   .620  194   203
 194   QUEUE      39
 195   TEST L     033   K70
 196   GATE LR    3
 197   TEST E     061   K0
 198   ADVANCE    1
 199   DEPART     39
 200   QUEUE      61
 201   DEPART     61
 202   TRANSFER         442
 203   QUEUE      7
 204   GATE LR    3
 205   TEST E     039   K0
 206   ADVANCE    1
 207   DEPART     7
 208   QUEUE      6
 209   DEPART     6
 210   QUEUE      61
 211   DEPART     61
 212   TERMINATE
* WINDEMERE E.B. TRAFFIC GENERATION
 213   GENERATE   30    13
 214   TRANSFER   .097  215   227
 215   TRANSFER   .902  240   216
 216   QUEUE      8
 217   GATE LR    3
 218   TEST E     036   K0
 219   TEST E     037   K0
 220   ADVANCE    1
 221   DEPART     8
 222   QUEUE      61
 223   DEPART     61
 224   QUEUE      6
 225   DEPART     6
 226   TERMINATE
 227   QUEUE      36
 228   TEST L     019   K70
 229   TRANSFER   BOTH  230   234
 230   TEST E     061   K0
 231   ADVANCE    1
 232   DEPART     36
 233   TRANSFER         442
 234   GATE LR    3
 235   ADVANCE    1
 236   DEPART     36
 237   QUEUE      61
 238   DEPART     61
```

```
 240   QUEUE      37
 241   GATE LR    3
 242   TEST L     Q24   K84
 243   TEST E     Q6    K0
 244   ADVANCE    1
 245   DEPART     37
 246   QUEUE      61
 247   DEPART     61
 248   TRANSFER         240
* PEMBINA N.B. TRAFFIC APPROACHING JUBILEE EXIT
 249   ADVANCE    41
 250   TRANSFER   .794  251   252
 251   TERMINATE
* PEMBINA N.B. TRAFFIC APPROACHING JUBILEE ENTRANCE
 252   ADVANCE    10
 253   TEST L     Q9    Q24   268
 254   TEST L     Q43   Q9    270
 255   QUEUE      43
 256   GATE LS    5
 257   TEST L     Q27   K42   261
 258   TEST L     Q12   K53
 259   TEST L     Q26   K53
 260   TRANSFER         263
 261   TEST L     Q28   K53
 262   TEST L     Q14   K53
 263   ADVANCE    1
 264   DEPART     43
 265   QUEUE      10
 266   DEPART     10
 267   TRANSFER         302
 268   TEST L     Q24   Q43   255
 269   TRANSFER         279
 270   QUEUE      9
 271   GATE LS    5
 272   TEST L     Q28   K53
 273   TEST L     Q14   K53
 274   ADVANCE    1
 275   DEPART     9
 276   QUEUE      10
 277   DEPART     10
 278   TRANSFER         302
 279   QUEUE      24
 280   GATE LS    5
 281   TEST L     Q27   K42
 282   TEST L     Q12   K53
 283   TEST L     Q26   K53
 284   ADVANCE    1
 285   DEPART     24
 286   QUEUE      10
 287   DEPART     10
 288   TRANSFER         302
* JUBILEE N.B. TRAFFIC GENERATION
 289   GENERATE   7     2
 290   QUEUE      11
 291   GATE LR    5
 292   TEST L     Q27   K42   295
 293   TEST GE    Q12   K53   297
 294   TEST GE    Q26   K53   297
 295   TEST GE    Q28   K53   297
 296   TEST L     Q14   K53
 297   ADVANCE    1
 298   DEPART     11
 299   QUEUE      10
 300   DEPART     10
 301   TRANSFER         302
```

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 302   ADVANCE     26
* PEMBINA N.B. TRAFFIC DIRECTIONAL BREAKDOWN
 303   ADVANCE     7
 304   TRANSFER    .560   305   321
* PEMBINA N.B. TRAFFIC TURNING ONTO STAFFORD W.B.
 305   TEST L      012    026   314
 306   TEST E      027    K0    314
 307   QUEUE       12
 308   GATE LR     6
 309   ADVANCE     1
 310   DEPART      12
 311   QUEUE       13
 312   DEPART      13
 313   TERMINATE
 314   QUEUE       26
 315   GATE LR     6
 316   ADVANCE     1
 317   DEPART      26
 318   QUEUE       13
 319   DEPART      13
 320   TERMINATE
* PEMBINA N.B. TRAFFIC REMAINING ON PEMBINA
 321   TEST LE     014    023   329
 322   QUEUE       14
 323   GATE LS     7
 324   ADVANCE     1
 325   DEPART      14
 326   QUEUE       15
 327   DEPART      15
 328   TERMINATE
 329   QUEUE       23
 330   GATE LS     7
 331   ADVANCE     1
 332   DEPART      23
 333   QUEUE       15
 334   DEPART      15
 335   TERMINATE
* PEMBINA S.B. TRAFFIC GENERATION
 336   GENERATE    4      1
 337   TRANSFER    .010   338   340
 338   TEST L      016    029   349
 339   TEST L      016    030   358
 340   QUEUE       16
 341   GATE LS     6
 342   TEST L      018    K136
 343   ADVANCE     1
 344   DEPART      16
 345   QUEUE       13
 346   DEPART      13
 347   TRANSFER    .010   375   348
 348   TERMINATE
 349   TEST L      029    030   358
 350   QUEUE       29
 351   GATE LS     6
 352   TEST L      031    K136
 353   ADVANCE     1
 354   DEPART      29
 355   QUEUE       13
 356   DEPART      13
 357   TRANSFER           375
 358   QUEUE       30
 359   GATE LS     6
 360   TEST L      055    K136
 361   ADVANCE     1
 362   DEPART      30
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 364    DEPART      13
 365    TRANSFER           375
* STAFFORD S.B. TRAFFIC GENERATION
 366    GENERATE    8      1
 367    QUEUE       17
 368    GATE LR     6
 369    TEST GE     Q18    K116   371
 370    TEST L      Q31    K116
 371    ADVANCE     1
 372    DEPART      17
 373    QUEUE       13
 374    DEPART      13
* PEMBINA S.B. TRAFFIC APPROACHING FARROW
 375    ADVANCE     8
 376    TRANSFER    .011   384    377
 377    TERMINATE
* FARROW S.B. TRAFFIC GENERATION
 378    GENERATE    17     9
 379    QUEUE       40
 380    TEST E      Q25    K0
 381    TEST L      Q18    K105
 382    ADVANCE     1
 383    DEPART      40
 384    QUEUE       25
 385    DEPART      25
* PEMBINA S.B. TRAFFIC APPROACHING JUBILEE EXIT
 386    ADVANCE     27
 387    TRANSFER    .237   389    388
 388    TERMINATE
* JUBILEE S.B. TRAFFIC GENERATION
 389    ADVANCE     10
 390    TRANSFER           392
 391    GENERATE    9      4
 392    ADVANCE     33
* PEMBINA S.B. TRAFFIC APPROACHING POINT ROAD-WINDEMERE
 393    TRANSFER    .026   394    432
 394    TRANSFER    .080   401    395
 395    QUEUE       32
 396    GATE LS     3
 397    TEST E      Q6     K0
 398    ADVANCE     1
 399    DEPART      32
 400    TERMINATE
 401    TEST L      Q59    K60    406
 402    TEST L      Q59    Q31    406
 403    TEST L      Q59    Q18    409
 404    TEST L      Q59    Q55    417
 405    TRANSFER           411
 406    TEST L      Q31    Q18    409
 407    TEST L      Q31    Q55    417
 408    TRANSFER           423
 409    TEST L      Q18    Q55    417
 410    TRANSFER           432
 411    QUEUE       59
 412    GATE LS     3
 413    TEST L      Q60    K70
 414    ADVANCE     1
 415    DEPART      59
 416    TRANSFER           442
 417    QUEUE       55
 418    GATE LS     3
 419    TEST L      Q44    K70
 420    ADVANCE     1
 421    DEPART      55
 422    TRANSFER           442
```

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 424   GATE LS     3
 425   TEST L      Q33   K70
 426   TEST L      Q32   K7
 427   ADVANCE     1
 428   DEPART      31
 429   QUEUE       61
 430   DEPART      61
 431   TRANSFER          442
 432   QUEUE       18
 433   GATE LS     3
 434   TEST L      Q19   K70
 435   ADVANCE     1
 436   DEPART      18
 437   TRANSFER    .948  441   438
 438   QUEUE       61
 439   DEPART      61
 440   TRANSFER          442
 441   TERMINATE
 442   ADVANCE     61
* PEMBINA S.B. TRAFFIC APPROACHING MACGILLIVARY-OAKENWALD
 443   TRANSFER    .010  444   476
 444   TRANSFER    .252  445   468
 445   TEST L      Q60   Q33   449
 446   TEST L      Q60   Q19   452
 447   TEST L      Q60   Q44   461
 448   TRANSFER          454
 449   TEST L      Q33   Q19   452
 450   TEST L      Q33   Q44   461
 451   TRANSFER          476
 452   TEST L      Q19   Q44   461
 453   TRANSFER          460
 454   QUEUE       60
 455   GATE LS     1
 456   ADVANCE     1
 457   DEPART      60
 458   QUEUE       21
 459   DEPART      21
 460   TERMINATE
 461   QUEUE       44
 462   GATE LS     1
 463   ADVANCE     1
 464   DEPART      44
 465   QUEUE       21
 466   DEPART      21
 467   TERMINATE
 468   TRANSFER    .504  469   475
 469   QUEUE       19
 470   GATE LS     1
 471   ADVANCE     1
 472   DEPART      19
 473   QUEUE       21
 474   DEPART      21
 475   TERMINATE
 476   QUEUE       33
 477   GATE LS     1
 478   TRANSFER    .020  485   479
 479   DEPART      33
 480   QUEUE       34
 481   TEST E      Q2    K0
 482   ADVANCE     1
 483   DEPART      34
 484   TERMINATE
 485   TEST E      Q34   K0
 486   ADVANCE     1
 487   DEPART      33
```

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489    DEPART       21
490    TERMINATE
       START        18
```

RELATIVE CLOCK 1800 ABSOLUTE CLOCK 1800
BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	18	11	0	18	21	1	19	31	0	38	41	0	455
2	0	18	12	0	18	22	0	18	32	0	38	42	0	445
3	0	1	13	0	1	23	0	1	33	0	19	43	0	415
4	0	38	14	0	38	24	0	46	34	0	19	44	0	32
5	0	38	15	0	38	25	0	46	35	0	19	45	0	32
6	0	19	16	0	19	26	0	23	36	0	19	46	0	0
7	0	19	17	0	19	27	0	23	37	1	19	47	0	383
8	1	19	18	0	19	28	1	23	38	0	18	48	0	38
9	0	18	19	0	19	29	0	22	39	0	18	49	0	0
10	0	18	20	0	19	30	0	1	40	0	455	50	0	345

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	29	61	0	315	71	0	42	81	0	38	91	0	30
52	0	29	62	0	315	72	0	42	82	0	38	92	0	33
53	0	29	63	0	315	73	0	40	83	0	38	93	0	53
54	0	29	64	0	315	74	0	40	84	0	38	94	0	53
55	0	29	65	0	315	75	0	40	85	0	30	95	0	42
56	0	29	66	0	315	76	0	38	86	0	30	96	0	42
57	0	29	67	0	42	77	0	38	87	0	30	97	0	42
58	0	29	68	0	42	78	0	38	88	0	30	98	0	42
59	1	316	69	0	42	79	0	38	89	0	30	99	0	42
60	0	315	70	0	42	80	0	38	90	0	30	100	0	42

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
101	0	42	111	0	11	121	0	0	131	0	460	141	0	66
102	0	42	112	0	11	122	0	0	132	0	75	142	0	66
103	0	42	113	0	5	123	0	88	133	0	74	143	0	0
104	0	42	114	0	5	124	0	88	134	0	0	144	0	0
105	0	11	115	0	92	125	0	88	135	0	385	145	0	66
106	0	11	116	0	92	126	0	88	136	0	92	146	0	66
107	0	11	117	4	92	127	0	88	137	0	0	147	0	66
108	0	6	118	0	38	128	0	39	138	0	294	148	0	66
109	0	6	119	0	38	129	18	482	139	2	68	149	0	66
110	0	11	120	0	0	130	0	464	140	0	66	150	2	226

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
151	0	224	161	2	78	171	0	75	181	0	90	191	0	54
152	0	224	162	0	76	172	0	75	182	0	90	192	0	54
153	0	224	163	0	76	173	2	92	183	0	90	193	0	23
154	0	0	164	0	76	174	0	90	184	0	0	194	0	7
155	0	0	165	0	0	175	0	90	185	0	77	195	0	7
156	0	224	166	0	0	176	0	90	186	0	77	196	0	7
157	0	224	167	0	76	177	0	0	187	0	54	197	0	7
158	0	224	168	0	76	178	0	0	188	0	54	198	0	7
159	0	224	169	0	76	179	0	90	189	0	54	199	0	7
160	0	224	170	0	75	180	0	90	190	0	54	200	0	7

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
201	0	7	211	0	16	221	0	38	231	0	4	241	0	17
202	0	7	212	0	16	222	0	38	232	0	4	242	0	17
203	0	16	213	0	59	223	0	38	233	0	4	243	0	17
204	0	16	214	0	59	224	0	38	234	0	0	244	0	17
205	0	16	215	0	55	225	0	38	235	0	0	245	0	17
206	0	16	216	0	38	226	0	38	236	0	0	246	0	17
207	0	16	217	0	38	227	0	4	237	0	0	247	0	17
208	0	16	218	0	38	228	0	4	238	0	0	248	0	17
209	0	16	219	0	38	229	0	4	239	0	0	249	3	526
210	0	16	220	0	38	230	0	4	240	0	17	250	0	523

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL

253	0	417	263	0	223	273	0	83	283	0	110	293	0	253
254	0	83	264	0	223	274	0	83	284	0	110	294	0	0
255	1	224	265	0	223	275	0	83	285	0	110	295	0	0
256	0	223	266	0	223	276	0	83	286	0	110	296	0	0
257	0	223	267	0	223	277	0	83	287	0	110	297	0	253
258	0	223	268	0	334	278	0	83	288	0	110	298	0	253
259	0	223	269	0	110	279	0	110	289	0	253	299	0	253
260	0	223	270	0	83	280	0	110	290	0	253	300	0	253

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
301	0	253	311	0	112	321	0	359	331	0	128	341	0	82
302	14	669	312	0	112	322	0	231	332	0	128	342	0	82
303	12	655	313	0	112	323	0	231	333	0	128	343	0	82
304	0	643	314	0	172	324	0	231	334	0	128	344	0	82
305	0	284	315	0	172	325	0	231	335	0	128	345	0	82
306	0	112	316	0	172	326	0	231	336	0	453	346	0	82
307	0	112	317	0	172	327	0	231	337	0	453	347	0	82
308	0	112	318	0	172	328	0	231	338	0	449	348	0	1
309	0	112	319	0	172	329	0	128	339	0	78	349	0	371
310	0	112	320	0	172	330	0	128	340	0	82	350	1	86

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
351	0	85	361	0	284	371	0	223	381	0	106	391	0	197
352	0	85	362	0	284	372	0	223	382	0	106	392	22	797
353	0	85	363	0	284	373	0	223	383	0	106	393	0	775
354	0	85	364	0	284	374	0	223	384	0	765	394	0	755
355	0	85	365	0	234	375	7	673	385	0	765	395	1	66
356	0	85	366	0	223	376	0	666	386	7	765	396	0	65
357	0	85	367	0	223	377	0	7	387	0	758	397	0	65
358	1	285	368	0	223	378	0	106	388	0	156	398	0	65
359	0	284	369	0	223	379	0	106	389	2	602	399	0	65
360	0	284	370	0	0	380	0	106	390	0	600	400	0	65

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
401	0	689	411	2	81	421	0	357	431	0	94	441	0	6
402	0	689	412	0	79	422	0	357	432	3	171	442	14	703
403	0	83	413	0	79	423	3	97	433	0	168	443	0	689
404	0	81	414	0	79	424	0	94	434	0	168	444	0	681
405	0	81	415	0	79	425	0	94	435	0	168	445	0	507
406	0	606	416	0	79	426	0	94	436	0	168	446	0	96
407	0	115	417	3	360	427	0	94	437	0	168	447	0	94
408	0	97	418	0	357	428	0	94	438	0	162	448	0	94
409	0	493	419	0	357	429	0	94	439	0	162	449	0	411
410	0	151	420	0	357	430	0	94	440	0	162	450	0	150

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
451	0	106	461	2	216	471	0	172	481	0	2			
452	0	263	462	0	214	472	0	172	482	0	2			
453	0	91	463	0	214	473	0	172	483	0	2			
454	1	94	464	0	214	474	0	172	484	0	2			
455	0	93	465	0	214	475	0	262	485	0	110			
456	0	93	466	0	214	476	2	114	486	0	110			
457	0	93	467	0	214	477	0	112	487	0	110			
458	0	93	468	0	174	478	0	112	488	0	110			
459	0	93	469	3	175	479	0	2	489	0	110			
460	0	93	470	0	172	480	0	2	490	0	110			

LOGIC SWITCH - SET (ON) STATUS

SWITCH	NR STB	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
1	3	.233	42		.0	12.380	12.380	1	
2	1	.000	464	464	100.0	.000	.000		
3	3	.586	42		.0	25.142	25.142	2	
4	5	1.494	92		.0	29.239	29.239	3	4
5	4	.650	78		.0	15.012	15.012	4	2
6	1	.000	509	509	100.0	.000	.000		
7	2	.218	16		.0	24.562	24.562	5	
8	3	.571	38		.0	27.078	27.078	6	
9	5	.217	83		.0	4.722	4.722	7	
10	1	.000	669	669	100.0	.000	.000		
11	9	3.196	253		.0	22.743	22.743	8	
12	8	.672	112		.0	10.803	10.803	9	
13	1	.000	958	958	100.0	.000	.000		
14	6	.298	231		.0	2.324	2.324	10	
15	1	.000	359	359	100.0	.000	.000		
16	5	1.091	32		.0	23.951	23.951	11	
17	6	1.389	223		.0	11.215	11.215	12	
18	5	.456	171		.0	4.807	4.807	13	3
19	4	.609	175		.0	6.274	6.274	14	3
20	3	.353	38		.0	16.736	16.736		
21	1	.000	749	749	100.0	.000	.000		
22	3	.122	30		.0	7.366	7.366		
23	5	.736	92		.0	14.413	14.413		2
24	5	.263	110		.0	4.390	4.390		
25	1	.000	765	765	100.0	.000	.000		
26	8	.390	172		.0	9.319	9.319		
28	5	.176	128		.0	2.476	2.476		
29	5	1.265	86		.0	26.488	26.488		1
30	5	1.564	235		.0	9.880	9.880		1
31	5	.344	97		.0	6.391	6.391		3
32	4	.169	66		.0	4.621	4.621		1
33	4	.412	114	2	1.7	6.517	6.633		2
34	1	.001	2		.0	1.000	1.000		
35	1	.013	11		.0	2.181	2.181		
36	1	.002	4		.0	1.000	1.000		
37	2	.178	17		.0	18.941	18.941		
38	1	.029	54		.0	1.000	1.000		
39	1	.084	7		.0	21.714	21.714		
40	1	.058	106		.0	1.000	1.000		
41	3	.603	316		.0	3.436	3.436		1
42	5	.914	226		.0	7.283	7.283		2
43	6	.416	224		.0	3.343	3.343		1
44	5	.612	216		.0	5.106	5.106		2
55	5	.614	360		.0	3.074	3.074		3
57	2	.207	29		.0	12.862	12.862		
58	4	.569	68		.0	15.088	15.088		2
59	4	.255	81		.0	5.679	5.679		2
60	4	.347	94		.0	6.659	6.659		1
61	1	.000	334	334	100.0	.000	.000		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

TABLE A

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
42	12.380	10.355	520.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	9	21.42	21.4	78.5	.080	-1.099
11	12	28.57	49.9	50.0	.888	-.133
21	10	23.80	73.8	26.1	1.696	.832
31	10	23.80	97.6	2.3	2.503	1.797
41	1	2.38	100.0	.0	3.311	2.763

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 8

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
42	25.142	19.625	1056.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	6	14.28	14.2	85.7	.039	-1.230
11	6	14.28	28.5	71.4	.437	-.720
21	10	23.30	52.3	47.6	.835	-.211
31	3	7.14	59.5	40.4	1.232	.298
41	8	19.04	78.5	21.4	1.630	.808
51	2	4.76	83.3	16.6	2.028	1.317
61	6	14.28	97.6	2.3	2.426	1.827
71	1	2.38	100.0	.0	2.823	2.336

REMAINING FREQUENCIES ARE ALL ZERO

TABLE C

ENTRIES IN TABLE 88 | MEAN ARGUMENT 28.534 | STANDARD DEVIATION 24.687 | SUM OF ARGUMENTS 2511.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	24	27.27	27.2	72.7	.035	-1.115
11	8	9.09	36.3	63.6	.385	-.710
21	8	9.09	45.4	54.5	.735	-.305
31	11	12.50	57.9	42.0	1.086	.099
41	6	6.81	64.7	35.2	1.436	.504
51	10	11.36	76.1	23.8	1.787	.910
61	9	10.22	86.3	13.6	2.137	1.315
71	8	9.09	95.4	4.5	2.488	1.720
81	4	4.54	100.0	.0	2.838	2.125

REMAINING FREQUENCIES ARE ALL ZERO

TABLE D

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
76	15.223	12.878	1157.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	25	32.89	32.8	67.1	.065	-1.104
11	11	14.47	47.3	52.6	.722	-.327
21	10	13.15	60.5	39.4	1.379	.448
31	22	28.94	89.4	10.5	2.036	1.224
41	8	10.52	100.0	.0	2.693	2.001

REMAINING FREQUENCIES ARE ALL ZERO

TABLE F

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
16	24.562	20.312	393.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	3	18.75	18.7	81.2	.040	-1.159
11	3	18.75	37.5	62.5	.447	-.667
21	1	6.25	43.7	56.2	.854	-.175
31	2	12.50	56.2	43.7	1.262	.316
41	4	25.00	81.2	18.7	1.669	.809
51	1	6.25	87.5	12.5	2.076	1.301
61	2	12.50	100.0	.0	2.483	1.793

REMAINING FREQUENCIES ARE ALL ZERO

TABLE F

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
38	27.078	21.312	1029.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	8	21.05	21.0	78.9	.036	-1.223
11	4	10.52	31.5	68.4	.406	-.754
21	4	10.52	42.1	57.8	.775	-.285
31	5	13.15	55.2	44.7	1.144	.183
41	8	21.05	76.3	23.6	1.514	.653
51	3	7.89	84.2	15.7	1.883	1.122
61	3	7.89	92.1	7.8	2.252	1.591
71	3	7.89	100.0	.0	2.621	2.060

REMAINING FREQUENCIES ARE ALL ZERO

TABLE G

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
83	4.722	6.515	392.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	53	63.85	63.8	36.1	.211	-.571
11	16	19.27	83.1	16.8	2.329	.963
21	11	13.25	96.3	3.6	4.446	2.498
31	3	3.61	100.0	.0	6.563	4.032

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 11

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
253	22.743	19.187	5754.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	67	26.48	26.4	73.5	.043	-1.133
11	28	11.06	37.5	62.4	.483	-.612
21	36	14.22	51.7	48.2	.923	-.090
31	33	13.04	64.8	35.1	1.363	.430
41	33	13.04	77.8	22.1	1.802	.951
51	31	12.25	90.1	9.8	2.242	1.472
61	25	9.88	100.0	.0	2.682	1.993

REMAINING FREQUENCIES ARE ALL ZERO

TABLE I

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
112	10.803	14.257	1210.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	62	55.35	55.3	44.6	.092	-.687
11	13	11.60	66.9	33.0	1.018	.013
21	9	8.03	74.9	25.0	1.943	.715
31	9	8.03	83.0	16.9	2.869	1.416
41	14	12.50	95.5	4.4	3.795	2.117
51	5	4.46	100.0	.0	4.720	2.819

REMAINING FREQUENCIES ARE ALL ZERO

TABLE J

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
231	2.324	3.769	537.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	200	86.58	86.5	13.4	.430	-.351
11	13	5.62	92.2	7.7	4.731	2.301
21	18	7.79	100.0	.0	9.033	4.954

REMAINING FREQUENCIES ARE ALL ZERO

TABLE K

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
82	23.951	15.175	1964.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	7	8.53	8.5	91.4	.041	-1.512
11	18	21.95	30.4	69.5	.459	-.853
21	14	17.07	47.5	52.4	.876	-.194
31	10	12.19	59.7	40.2	1.294	.464
41	17	20.73	80.4	19.5	1.711	1.123
51	16	19.51	100.0	.0	2.129	1.782

REMAINING FREQUENCIES ARE ALL ZERO

TABLE L

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
223	11.215	13.980	2501.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	119	53.36	53.3	46.6	.089	-.730
11	25	11.21	64.5	35.4	.980	-.015
21	23	10.31	74.8	25.1	1.872	.699
31	26	11.65	86.5	13.4	2.764	1.415
41	24	10.76	97.3	2.6	3.655	2.130
51	6	2.69	100.0	.0	4.547	2.845

REMAINING FREQUENCIES ARE ALL ZERO

TABLE M

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
168	4.535	6.984	762.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	121	72.02	72.0	27.9	.220	-.506
11	21	12.50	84.5	15.4	2.425	.925
21	14	8.33	92.8	7.1	4.629	2.357
31	12	7.14	100.0	.0	6.834	3.789

REMAINING FREQUENCIES ARE ALL ZERO

RESET
START 72

RELATIVE CLOCK 7200 ABSOLUTE CLOCK 9000
BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	72	11	0	77	21	1	76	31	0	148	41	0	1805
2	0	72	12	0	77	22	0	76	32	0	148	42	0	1772
3	0	0	13	0	0	23	0	0	33	0	74	43	0	1583
4	0	153	14	0	152	24	0	183	34	0	74	44	0	128
5	0	153	15	0	152	25	0	183	35	0	74	45	0	128
6	1	77	16	0	76	26	1	92	36	0	74	46	0	0
7	0	76	17	0	76	27	0	91	37	1	74	47	0	1455
8	0	76	18	0	76	28	0	91	38	0	74	48	0	149
9	0	77	19	0	76	29	0	92	39	0	74	49	0	0
10	0	77	20	0	76	30	0	0	40	0	1805	50	0	1306

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	112	61	0	1195	71	0	161	81	0	149	91	0	189
52	0	112	62	0	1195	72	0	161	82	0	149	92	0	198
53	0	112	63	0	1195	73	0	154	83	0	149	93	0	219
54	0	112	64	0	1195	74	0	154	84	0	149	94	0	219
55	0	112	65	0	1195	75	0	154	85	0	189	95	0	164
56	0	112	66	0	1195	76	0	149	86	0	189	96	0	164
57	0	112	67	0	161	77	0	149	87	0	189	97	0	164
58	0	112	68	0	161	78	0	149	88	0	189	98	0	164
59	0	1194	69	0	161	79	0	149	89	0	189	99	0	164
60	0	1195	70	0	161	80	0	149	90	0	189	100	0	164

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
101	0	164	111	0	55	121	0	0	131	0	1877	141	0	250
102	0	164	112	0	55	122	0	0	132	0	292	142	0	250
103	0	164	113	0	44	123	0	383	133	0	291	143	0	0
104	0	164	114	0	44	124	0	383	134	0	0	144	0	0
105	0	55	115	0	380	125	0	383	135	0	1585	145	0	250
106	0	55	116	1	380	126	0	383	136	0	380	146	0	250
107	0	55	117	0	379	127	0	383	137	0	0	147	0	250
108	0	11	118	0	383	128	0	154	138	0	1206	148	0	250
109	0	11	119	0	383	129	17	1894	139	0	248	149	0	250
110	0	55	120	0	0	130	0	1895	140	0	250	150	0	958

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
151	0	960	161	0	309	171	0	309	181	0	382	191	0	250
152	0	960	162	0	311	172	0	309	182	0	382	192	0	250
153	0	960	163	0	311	173	0	380	183	0	382	193	0	58
154	0	0	164	0	311	174	0	382	184	0	0	194	0	27
155	0	0	165	0	0	175	0	382	185	0	308	195	0	27
156	0	960	166	0	0	176	0	382	186	0	308	196	0	27
157	0	960	167	0	311	177	0	0	187	0	250	197	0	27
158	0	960	168	0	311	178	0	0	188	0	250	198	0	27
159	0	960	169	0	311	179	0	382	189	0	250	199	0	27
160	0	960	170	0	309	180	0	382	190	0	250	200	0	27

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
201	0	27	211	0	31	221	0	168	231	0	23	241	0	44
202	0	27	212	0	31	222	0	168	232	0	23	242	0	44
203	0	31	213	0	235	223	0	168	233	0	23	243	0	44
204	0	31	214	0	235	224	0	168	234	0	0	244	0	44
205	0	31	215	0	212	225	0	168	235	0	0	245	0	44
206	0	31	216	0	168	226	0	168	236	0	0	246	0	44
207	0	31	217	0	168	227	0	23	237	0	0	247	0	44
208	0	31	218	0	168	228	0	23	238	0	0	248	0	44
209	0	31	219	0	168	229	0	23	239	0	0	249	12	2195
210	0	31	220	0	168	230	0	23	240	0	44	250	0	2186

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
251	[illegible]	[illegible]	261	[illegible]	[illegible]	271	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

253	0	1715	263	0	909	273	0	343	283	0	464	293	0	1024
254	0	343	264	0	909	274	0	343	284	0	464	294	0	0
255	0	903	265	0	909	275	0	343	285	0	464	295	0	0
256	0	909	266	0	909	276	0	343	286	0	464	296	0	0
257	0	909	267	0	909	277	0	343	287	0	464	297	0	1024
258	0	909	268	0	1372	278	0	343	288	0	464	298	0	1024
259	0	909	269	0	464	279	0	464	289	0	1025	299	0	1024
260	0	909	270	0	343	280	0	464	290	1	1025	300	0	1024

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
301	0	1024	311	0	432	321	0	1528	331	0	534	341	0	321
302	17	2740	312	0	432	322	0	994	332	0	534	342	0	321
303	0	2737	313	0	432	323	0	994	333	0	534	343	0	321
304	0	2749	314	0	739	324	1	994	334	0	534	344	0	321
305	0	1221	315	0	739	325	0	993	335	0	534	345	0	321
306	0	482	316	0	739	326	0	993	336	0	1801	346	0	321
307	0	482	317	0	739	327	0	993	337	0	1801	347	0	321
308	0	482	318	0	739	328	0	993	338	0	1785	348	0	4
309	0	482	319	0	739	329	0	534	339	0	306	349	0	1479
310	0	482	320	0	739	330	0	534	340	1	322	350	2	349

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
351	0	348	361	0	1129	371	0	896	381	0	425	391	0	803
352	0	348	362	0	1129	372	0	896	382	0	425	392	20	3140
353	0	348	363	0	1129	373	0	896	383	0	425	393	0	3142
354	0	348	364	0	1129	374	0	896	384	0	3094	394	0	3083
355	0	348	365	0	1129	375	1	2690	385	0	3094	395	0	245
356	0	348	366	0	896	376	0	2696	386	10	3094	396	0	246
357	0	348	367	0	896	377	0	27	387	0	3091	397	0	246
358	2	1130	368	0	896	378	0	425	388	0	752	398	0	246
359	0	1129	369	0	896	379	0	425	389	4	2339	399	0	246
360	0	1129	370	0	0	380	0	425	390	0	2337	400	0	246

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
401	0	2838	411	0	346	421	0	1452	431	0	403	441	0	31
402	0	2838	412	0	348	422	0	1452	432	1	701	442	17	2925
403	0	348	413	0	348	423	0	400	433	0	703	443	0	2922
404	0	343	414	0	348	424	0	403	434	0	703	444	0	2891
405	0	346	415	0	348	425	0	403	435	0	703	445	0	2208
406	0	2490	416	0	348	426	0	403	436	0	703	446	0	387
407	0	449	417	1	1450	427	0	403	437	0	703	447	0	372
408	0	400	418	0	1452	428	0	403	438	0	672	448	0	369
409	0	2041	419	0	1452	429	0	403	439	0	672	449	0	1821
410	0	642	420	0	1452	430	0	403	440	0	672	450	0	588

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
451	0	414	461	0	1046	471	0	730	481	0	5			
452	0	1248	462	0	1048	472	0	730	482	0	5			
453	0	379	463	0	1048	473	0	730	483	0	5			
454	0	369	464	0	1048	474	0	730	484	0	5			
455	0	370	465	0	1048	475	0	1065	485	0	442			
456	0	370	466	0	1048	476	0	445	486	0	442			
457	0	370	467	0	1048	477	0	447	487	0	442			
458	0	370	468	0	683	478	0	447	488	0	442			
459	0	370	469	0	727	479	0	5	489	0	442			
460	0	370	470	0	730	480	0	5	490	0	442			

LOGIC SWITCH - SET (ON) STATUS

SWITCH	NR MAA	NR JUB	NR STB	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
1	3	.280	161		.0	12.552	12.552	1	
2	1	.000	1774	1774	100.0	.000	.000		
3	3	.530	164		.0	23.274	23.274	2	
4	6	1.626	384		.0	30.502	30.502	3	1
5	5	.523	311		.0	12.125	12.125	4	
6	1	.000	2100	2100	100.0	.000	.000		
7	2	.140	31		.0	32.580	32.580	5	
8	4	.623	168		.0	26.708	26.708	6	
9	6	.237	343		.0	4.976	4.976	7	
10	1	.000	2740	2740	100.0	.000	.000		
11	11	3.074	1025		.0	21.599	21.599	8	1
12	9	.875	482		.0	13.074	13.074	9	
13	1	.000	3915	3915	100.0	.000	.000		
14	6	.294	994		.0	2.135	2.135	10	1
15	1	.000	1527	1527	100.0	.000	.000		
16	5	1.119	322		.0	25.043	25.043	11	1
17	7	1.383	896		.0	11.113	11.113	12	
18	6	.596	704		.0	6.105	6.105	13	1
19	9	.742	730		.0	7.323	7.323	14	
20	3	.351	149		.0	17.006	17.006		
21	1	.000	3326	3326	100.0	.000	.000		
22	4	.183	189		.0	6.984	6.984		
23	5	.630	382		.0	11.884	11.884		
24	6	.317	464		.0	4.922	4.922		
25	1	.000	3094	3094	100.0	.000	.000		
26	9	1.194	739		.0	10.759	10.759		
28	5	.182	534		.0	2.455	2.455		
29	5	1.294	350		.0	26.637	26.637		2
30	6	1.599	1131		.0	10.181	10.181		2
31	5	.462	403		.0	8.265	8.265		
32	3	.173	246		.0	5.081	5.081		
33	8	.557	447	3	.6	8.979	9.040		
34	1	.000	5		.0	1.000	1.000		
35	1	.019	55		.0	2.490	2.490		
36	1	.003	23		.0	1.000	1.000		
37	2	.177	44		.0	29.068	29.068		
38	1	.034	250		.0	1.000	1.000		
39	2	.112	27		.0	29.925	29.925		
40	1	.059	425		.0	1.000	1.000		
41	3	.591	1195		.0	3.566	3.566		
42	5	.814	960		.0	6.112	6.112		
43	7	.455	909		.0	3.605	3.605		
44	8	.750	1048		.0	5.154	5.154		
55	5	.753	1453		.0	3.735	3.735		1
57	2	.190	112		.0	12.276	12.276		
58	5	.428	250		.0	12.351	12.351		
59	5	.398	348		.0	8.241	8.241		
60	7	.484	370		.0	9.429	9.429		
61	1	.000	1345	1345	100.0	.000	.000		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

TABLE A

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
161	12.552	9.316	2021.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	31	19.25	19.2	80.7	.079	-1.240
11	48	29.81	49.0	50.9	.876	-.166
21	46	28.57	77.6	22.3	1.672	.906
31	35	21.73	99.3	.6	2.469	1.980
41	1	.62	100.0	.0	3.266	3.053

REMAINING FREQUENCIES ARE ALL ZERO

TABLE B

ENTRIES IN TABLE 164 | MEAN ARGUMENT 23.274 | STANDARD DEVIATION 21.187 | SUM OF ARGUMENTS 3817.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	35	21.34	21.3	78.6	.042	-1.051
11	33	20.12	41.4	58.5	.472	-.579
21	26	15.85	57.3	42.6	.902	-.107
31	14	8.53	65.8	34.1	1.331	.364
41	14	8.53	74.3	25.6	1.761	.836
51	15	9.14	83.5	16.4	2.191	1.308
61	23	14.02	97.5	2.4	2.620	1.780
71	4	2.43	100.0	.0	3.050	2.252

REMAINING FREQUENCIES ARE ALL ZERO

TABLE C

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
383	31.031	25.187	11885.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	82	21.40	21.4	78.5	.032	-1.192
11	40	10.44	31.8	68.1	.354	-.795
21	43	11.22	43.0	56.9	.676	-.398
31	44	11.48	54.5	45.4	.998	-.001
41	34	8.87	63.4	36.5	1.321	.395
51	37	9.66	73.1	26.8	1.643	.792
61	43	11.22	84.3	15.6	1.965	1.189
71	35	9.13	93.4	6.5	2.288	1.586
81	25	6.52	100.0	.0	2.610	1.983

REMAINING FREQUENCIES ARE ALL ZERO

TABLE [illegible]

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
311	12.170	12.792	3785.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	145	46.62	46.6	53.3	.082	-.873
11	27	8.68	55.3	44.6	.903	-.091
21	49	15.75	71.0	28.9	1.725	.690
31	64	20.57	91.6	8.3	2.547	1.471
41	26	8.36	100.0	.0	3.368	2.253

REMAINING FREQUENCIES ARE ALL ZERO

TABLE E

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
31	32.580	22.875	1010.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	5	16.12	16.1	83.8	.030	-1.380
11	3	9.67	25.8	74.1	.337	-.943
21	2	6.45	32.2	67.7	.644	-.506
31	5	16.12	48.3	51.6	.951	-.069
41	3	9.67	58.0	41.9	1.258	.368
51	7	22.58	80.6	19.3	1.565	.805
61	2	6.45	87.0	12.9	1.872	1.242
71	4	12.90	100.0	.0	2.179	1.679

REMAINING FREQUENCIES ARE ALL ZERO

TABLE F

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
168	26.708	23.500	4487.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	48	28.57	28.5	71.4	.037	-1.093
11	17	10.11	38.6	61.3	.411	-.668
21	14	8.33	47.0	52.9	.786	-.242
31	21	12.50	59.5	40.4	1.160	.182
41	14	8.33	67.8	32.1	1.535	.608
51	17	10.11	77.9	22.0	1.909	1.033
61	19	11.30	89.2	10.7	2.283	1.459
71	18	10.71	100.0	.0	2.658	1.884

REMAINING FREQUENCIES ARE ALL ZERO

TABLE G

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
343	4.976	6.257	1707.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	208	60.64	60.6	39.3	.200	-.635
11	78	22.74	83.3	16.6	2.210	.962
21	49	14.28	97.6	2.3	4.219	2.560
31	8	2.33	100.0	.0	6.229	4.158

REMAINING FREQUENCIES ARE ALL ZERO

TABLE H

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1024	21.619	18.937	22138.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	293	28.61	28.6	71.3	.046	-1.088
11	128	12.50	41.1	58.8	.508	-.560
21	130	12.69	53.8	46.1	.971	-.032
31	132	12.39	66.6	33.3	1.433	.495
41	130	12.69	79.3	20.6	1.896	1.023
51	125	12.20	91.6	8.3	2.359	1.551
61	86	8.39	100.0	.0	2.821	2.079

REMAINING FREQUENCIES ARE ALL ZERO

TABLE I

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
432	13.074	13.785	6302.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	197	40.87	40.8	59.1	.076	-.875
11	76	15.76	56.6	43.3	.841	-.150
21	76	15.76	72.4	27.5	1.606	.574
31	59	12.24	84.6	15.3	2.370	1.300
41	59	12.24	96.8	3.1	3.135	2.025
51	15	3.11	100.0	.0	3.900	2.751

REMAINING FREQUENCIES ARE ALL ZERO

TABLE J

ENTRIES IN TABLE 993 | MEAN ARGUMENT 2.136 | STANDARD DEVIATION 3.402 | SUM OF ARGUMENTS 2122.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	864	87.00	87.0	12.9	.467	-.334
11	74	7.45	94.4	5.5	5.147	2.604
21	55	5.53	100.0	.0	9.827	5.544

REMAINING FREQUENCIES ARE ALL ZERO

TABLE K

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
321	25.087	14.824	8053.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	16	4.98	4.9	95.0	.039	-1.624
11	67	20.87	25.8	74.1	.438	-.950
21	58	18.06	43.9	56.0	.837	-.275
31	52	16.19	60.1	39.8	1.235	.398
41	56	17.44	77.5	22.4	1.634	1.073
51	72	22.42	100.0	.0	2.032	1.748

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 1
ENTRIES IN TABLE 896 | MEAN ARGUMENT 11.113 | STANDARD DEVIATION 14.046 | SUM OF ARGUMENTS 9958.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	489	54.57	54.5	45.4	.089	-.720
11	93	10.37	64.9	35.0	.989	-.008
21	96	10.71	75.6	24.3	1.889	.703
31	93	10.37	86.0	13.9	2.789	1.415
41	91	10.15	96.2	3.7	3.689	2.127
51	34	3.79	100.0	.0	4.588	2.839

REMAINING FREQUENCIES ARE ALL ZERO

TABLE M

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
703	6.197	8.621	4357.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	468	66.57	66.5	33.4	.161	-.602
11	74	10.52	77.0	22.9	1.774	.557
21	75	10.66	87.7	12.2	3.388	1.716
31	86	12.23	100.0	.0	5.001	2.876

REMAINING FREQUENCIES ARE ALL ZERO

TABLE N

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
172	6.331	9.535	1089.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	122	70.93	70.9	29.0	.157	-.559
11	12	6.97	77.9	22.0	1.737	.489
21	15	8.72	86.6	13.3	3.316	1.538
31	20	11.62	98.2	1.7	4.896	2.587
41	3	1.74	100.0	.0	6.475	3.635

REMAINING FREQUENCIES ARE ALL ZERO

TABLE N

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
730	7.335	9.882	5355.000	NON-WEIGHTED

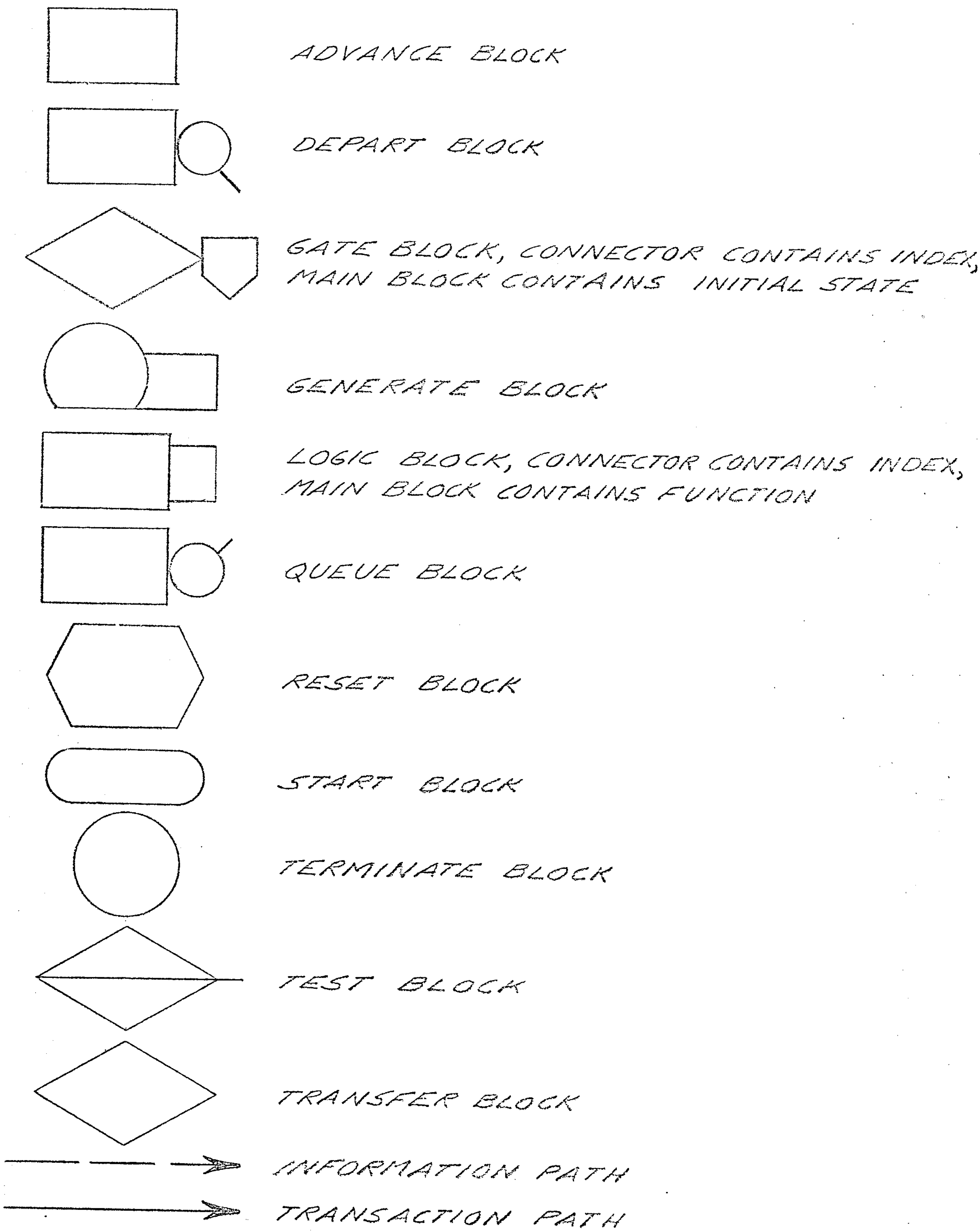
UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	428	58.63	58.6	41.3	.136	-.641
11	127	17.39	76.0	23.9	1.499	.370
21	62	8.49	84.5	15.4	2.862	1.382
31	95	13.01	97.5	2.4	4.225	2.394
41	18	2.46	100.0	.0	5.589	3.406

REMAINING FREQUENCIES ARE ALL ZERO

APPENDIX D

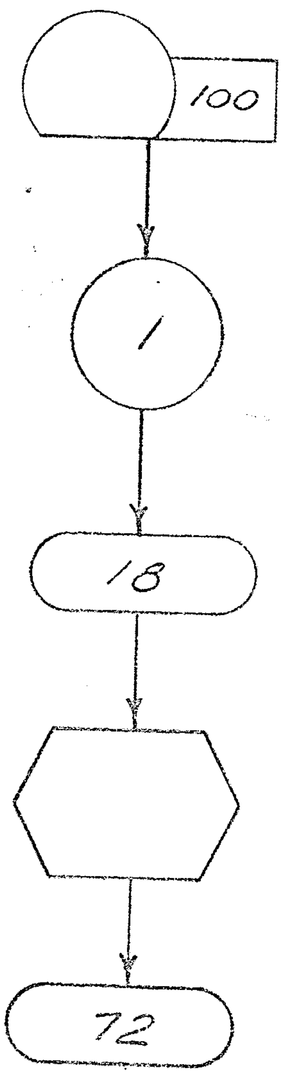
FLOWCHART OF GPSS PROGRAM FOR MORNING RUSH HOUR CONDITIONS ON SELECTED PORTION OF PEMBINA HIGHWAY WITH PROPOSED LANE EXPANSION

LEGEND OF BLOCK SYMBOLS
(USED IN THE GPSS FLOWCHART)

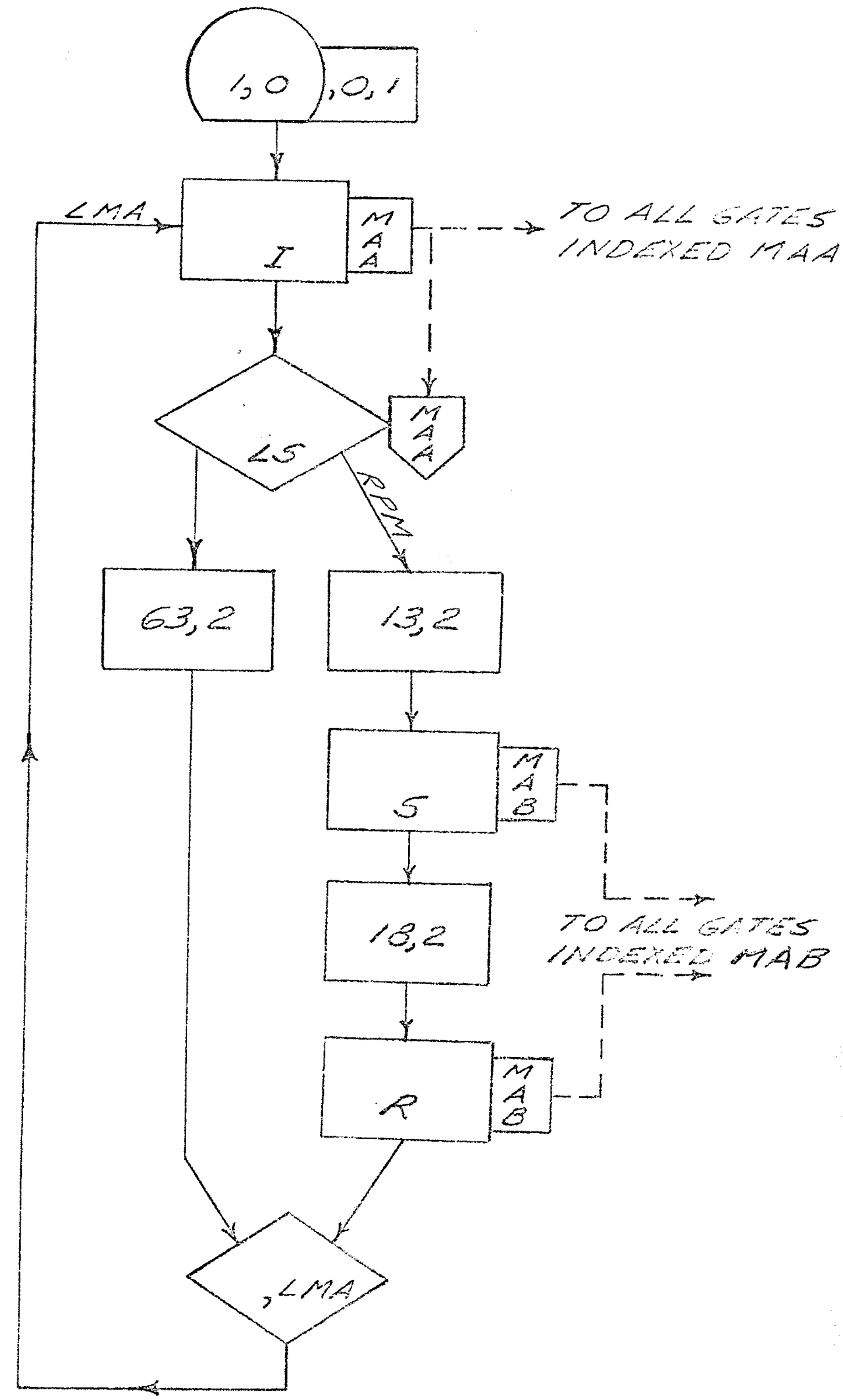


GPSS FLOWCHART

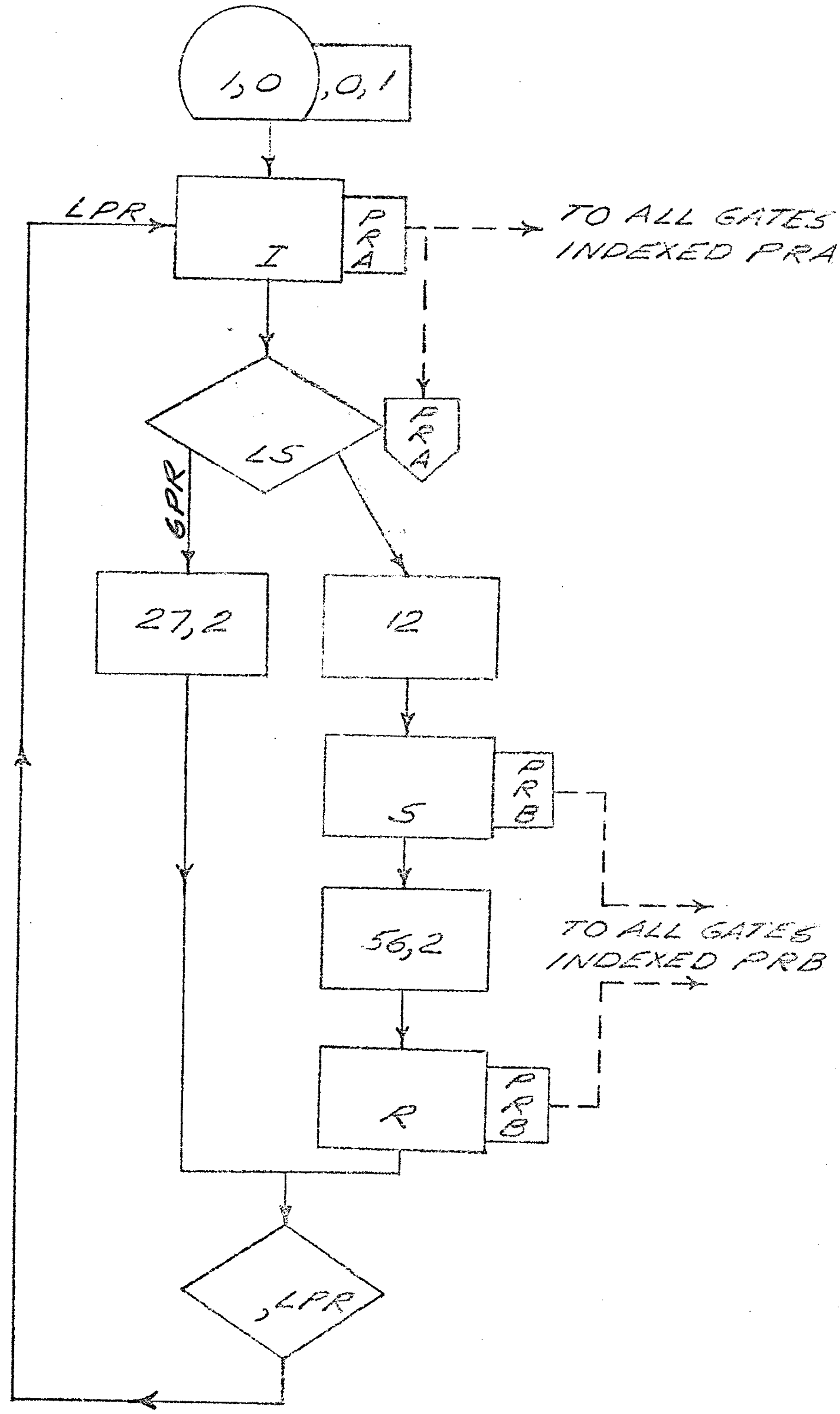
SIMULATION TIMER



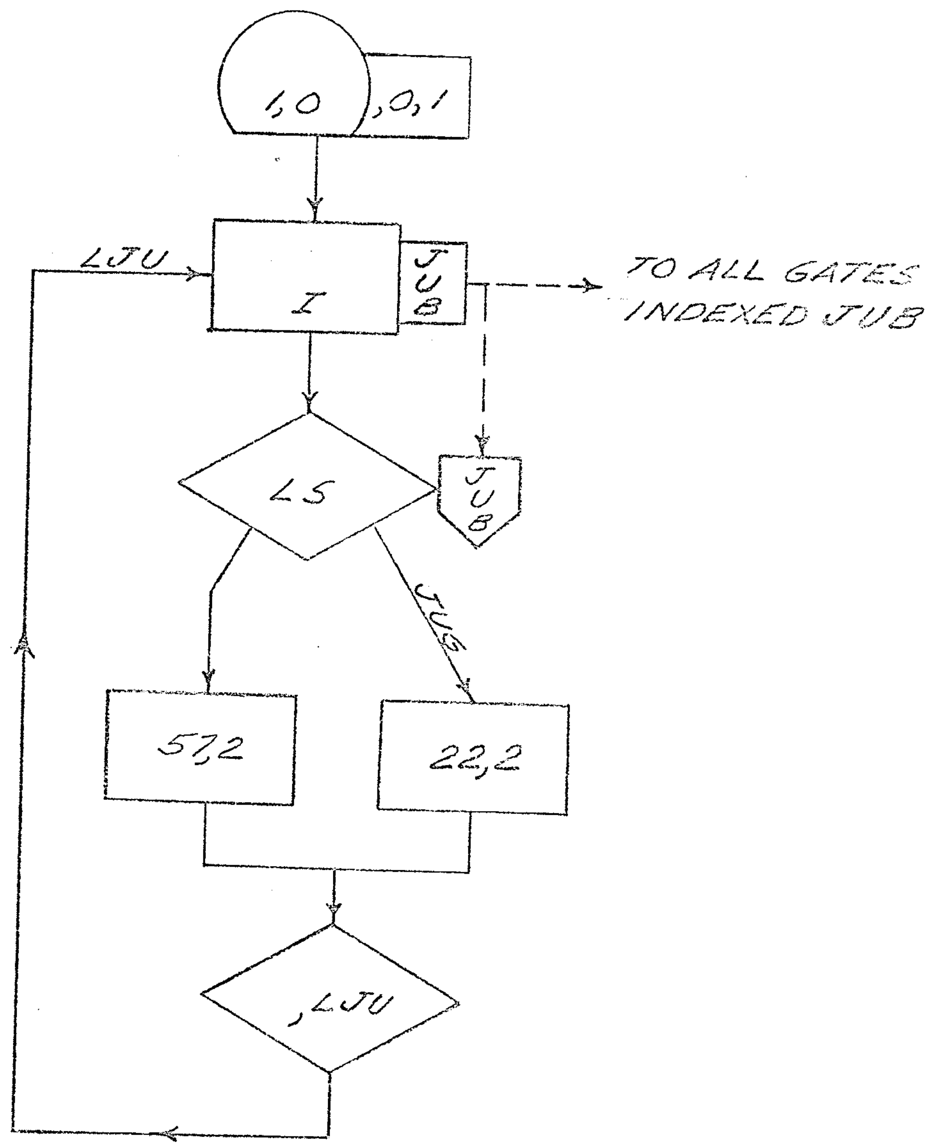
MacGILLIVARY SIGNALS



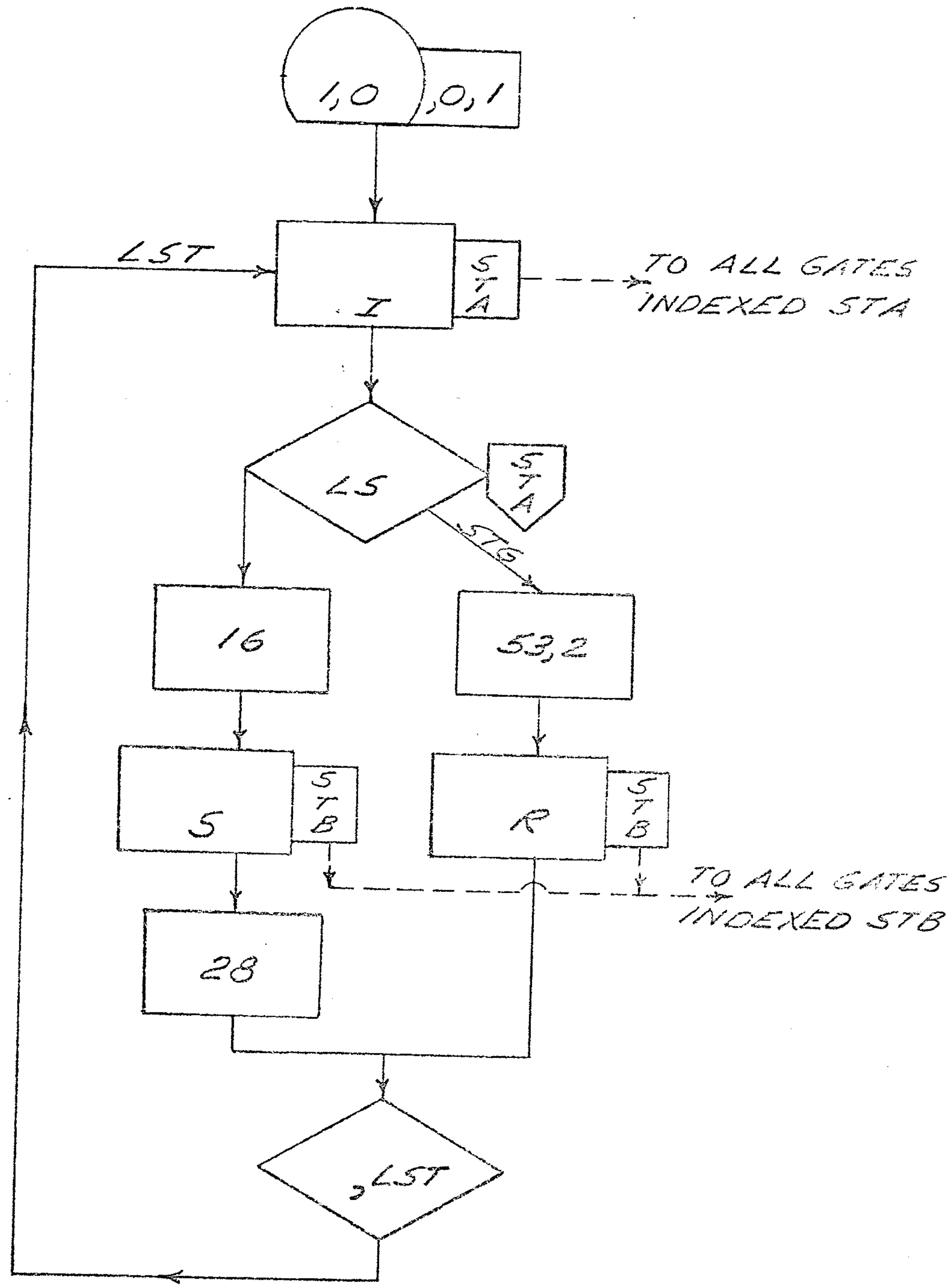
POINT ROAD SIGNALS



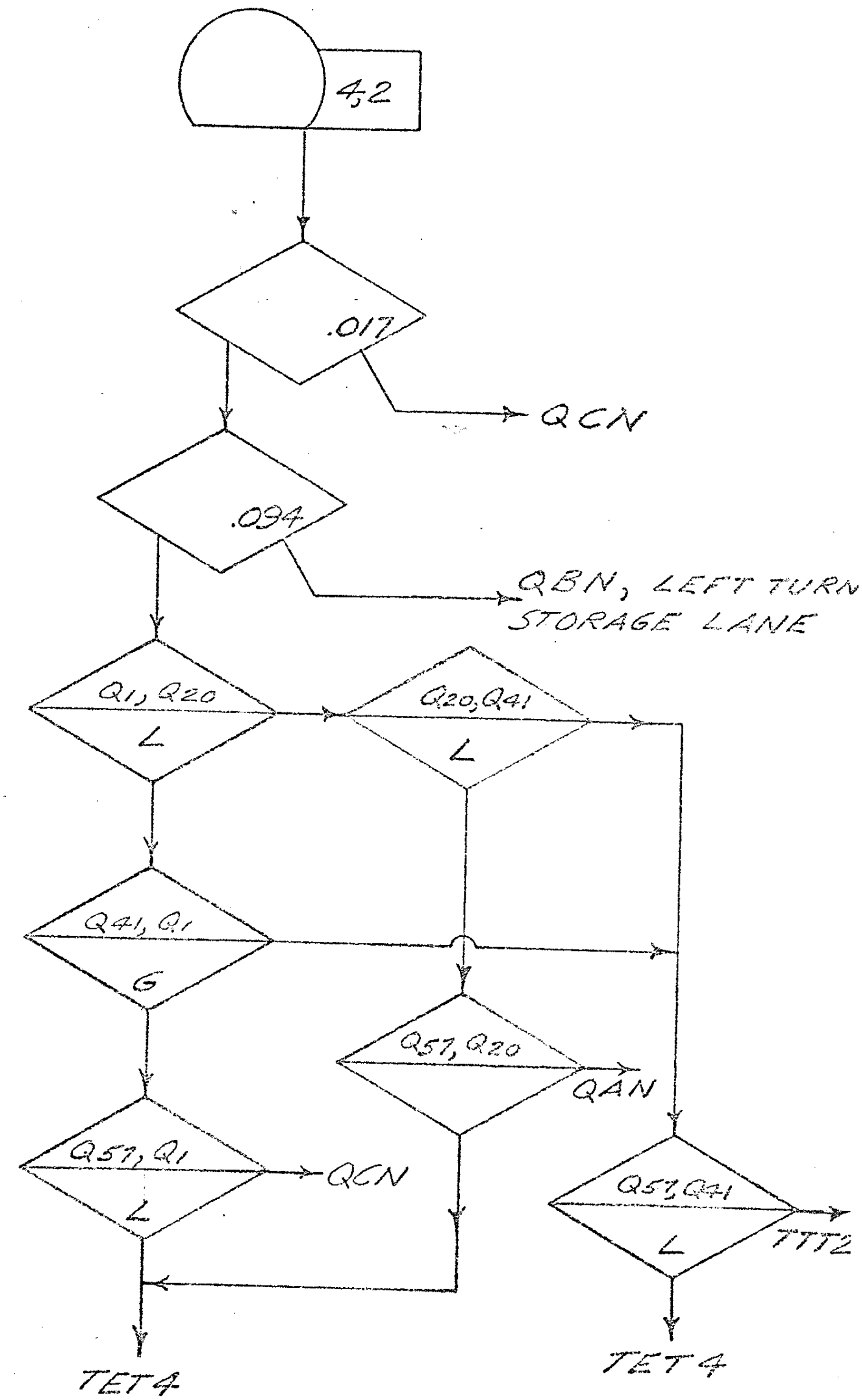
JUBILEE SIGNALS



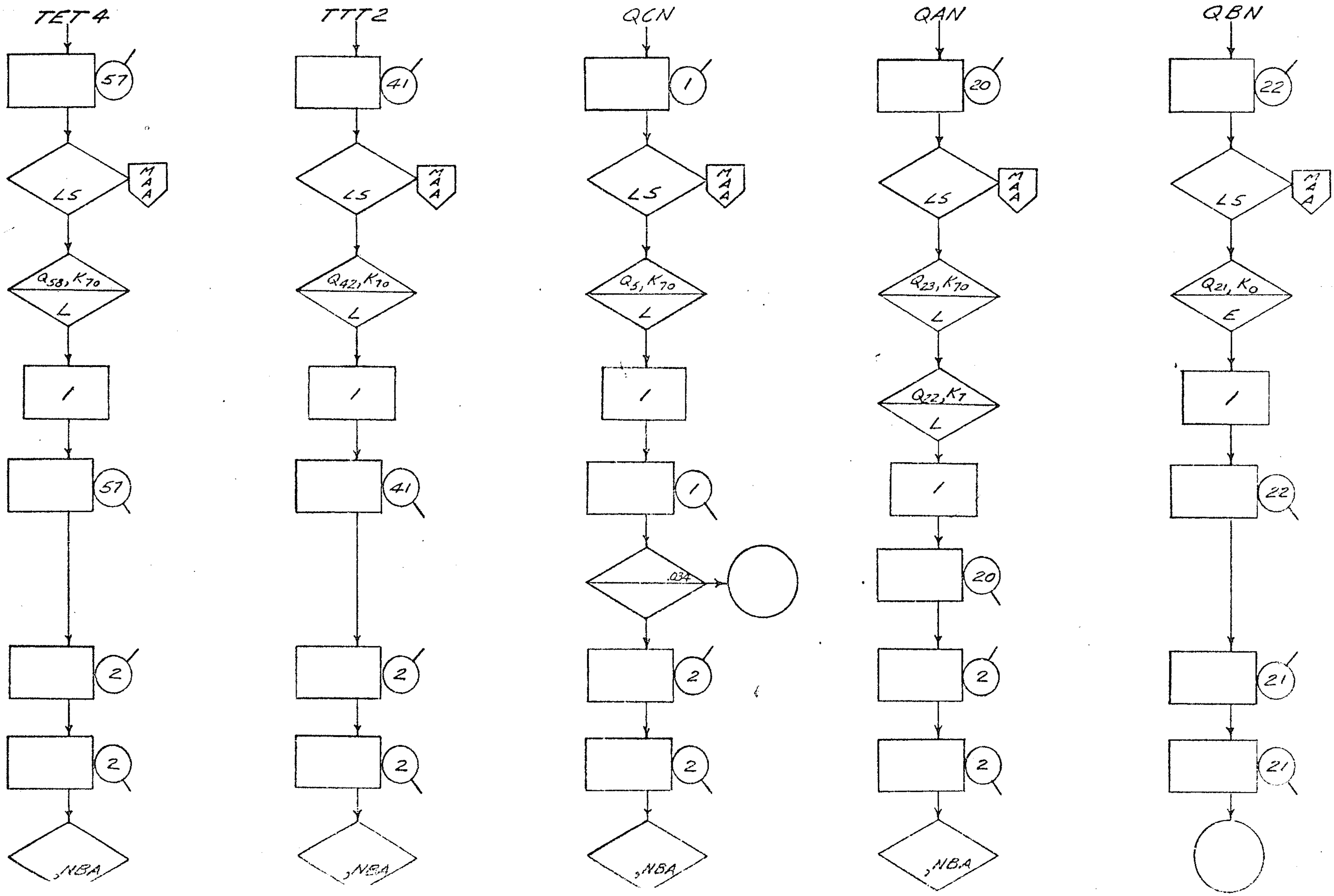
STAFFORD SIGNALS



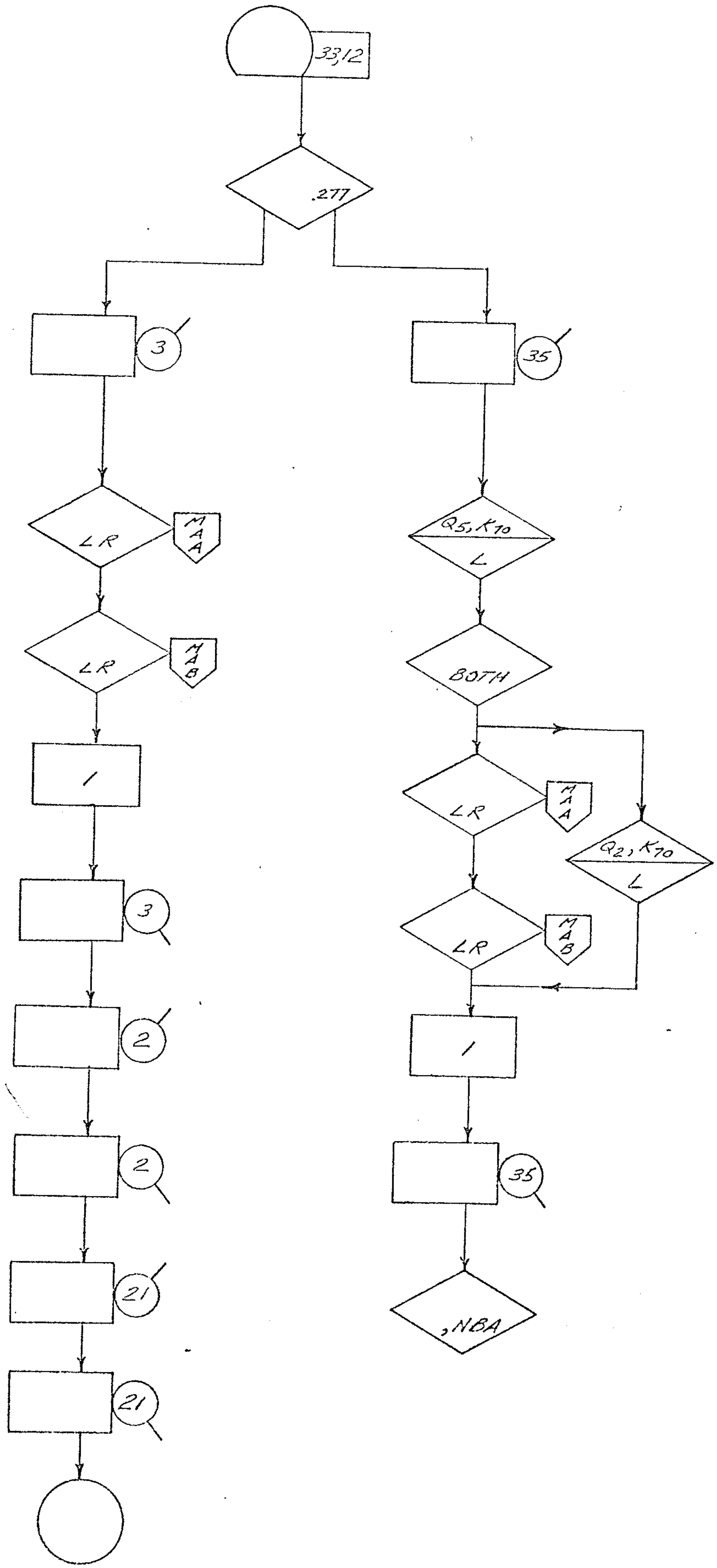
PEMBINA NORTH-BOUND TRAFFIC
- APPROACHING MACGILLIVARY OAKENWALD



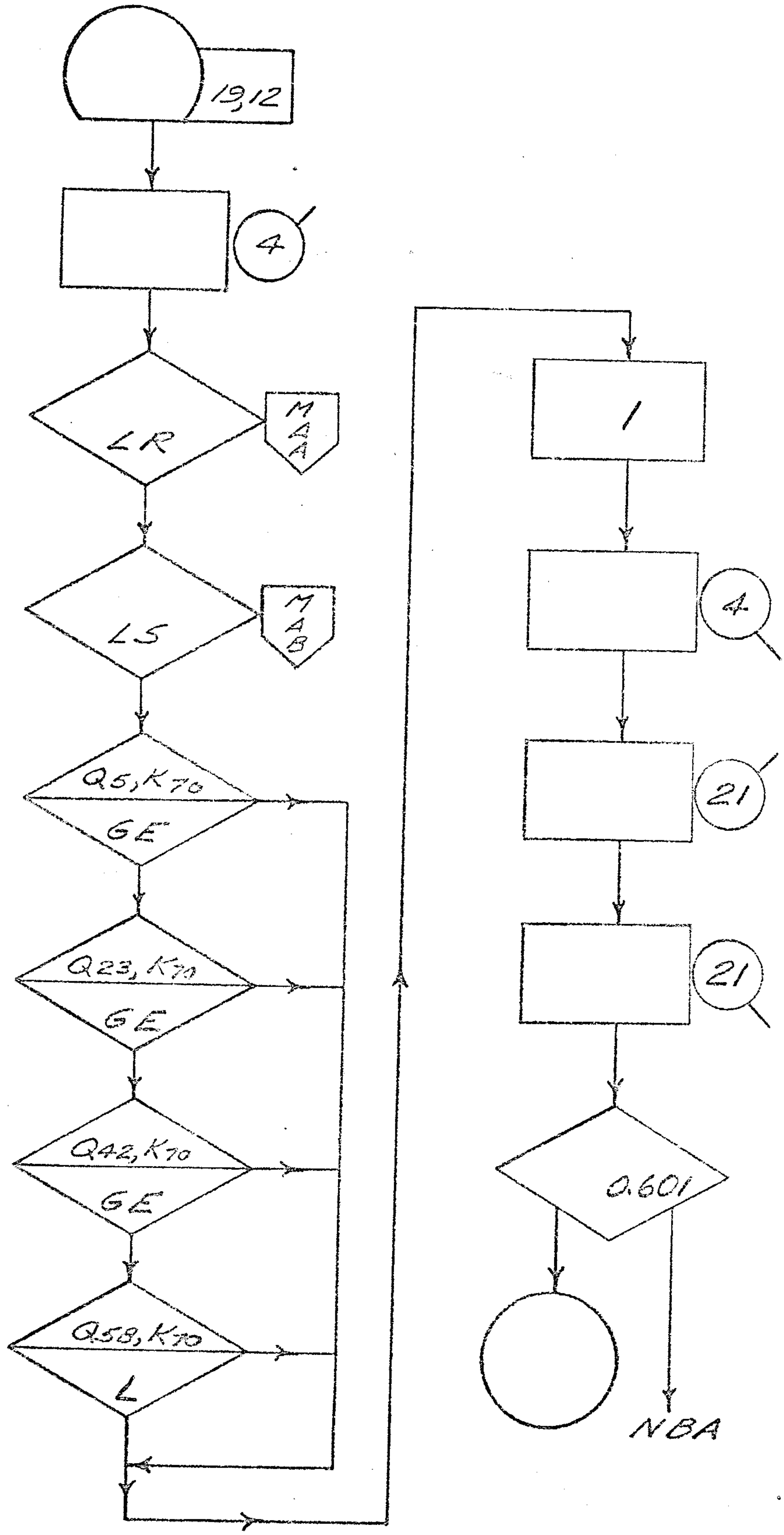
Pembina North Bound Traffic Queues At MacGillivary-Oakenwald



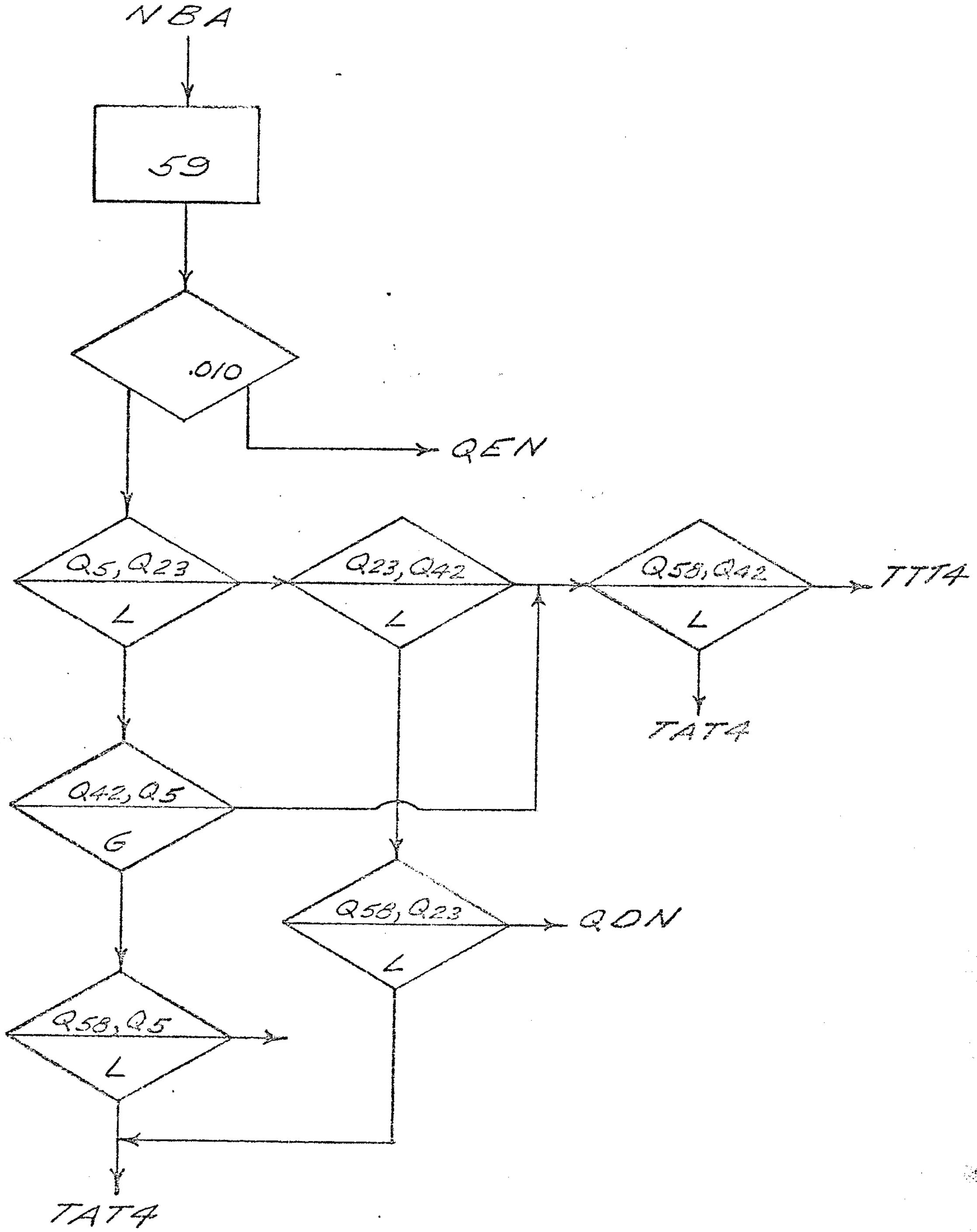
OAKENWALD WEST BOUND TRAFFIC



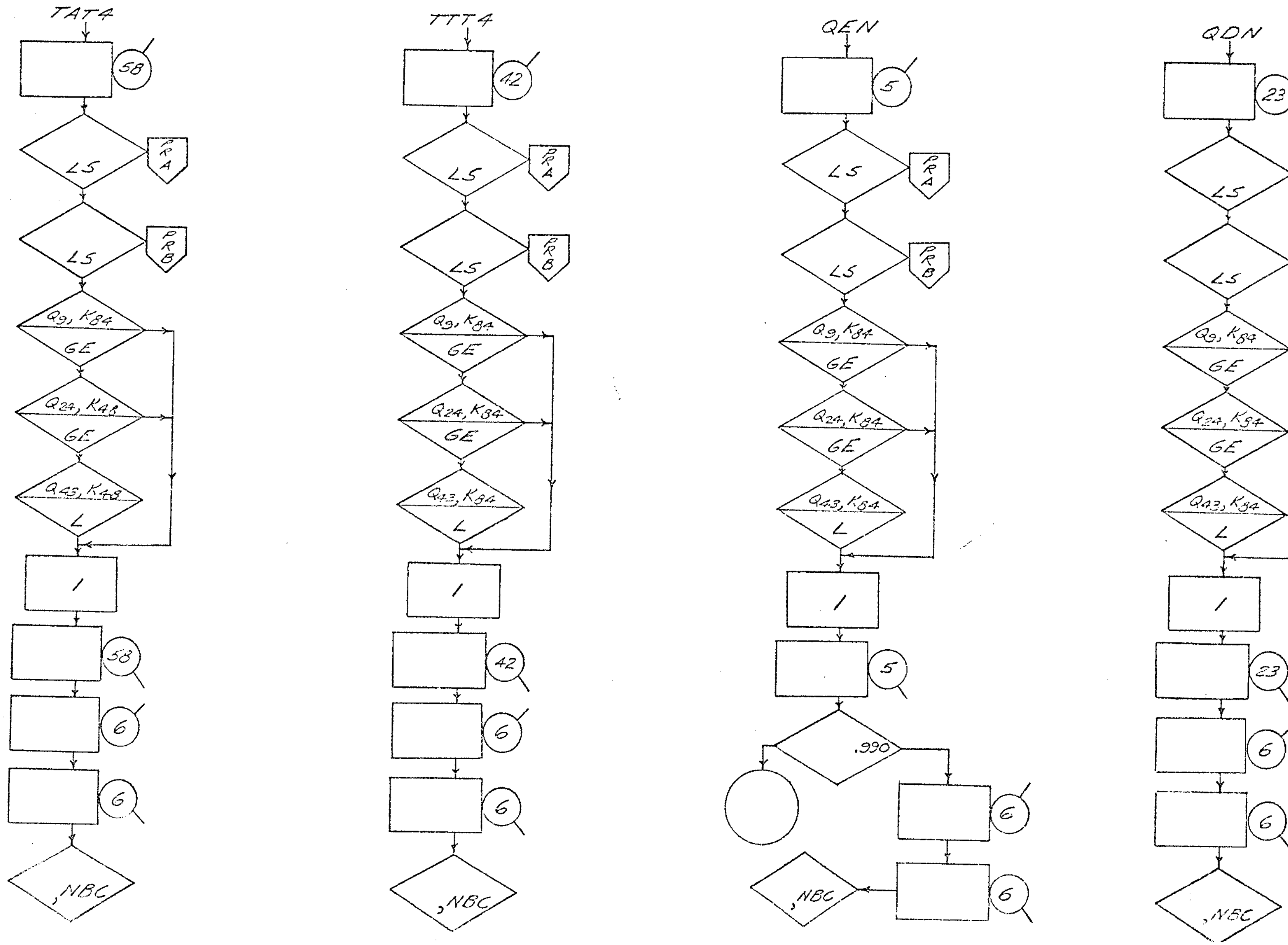
MacGillivary East Bound Traffic



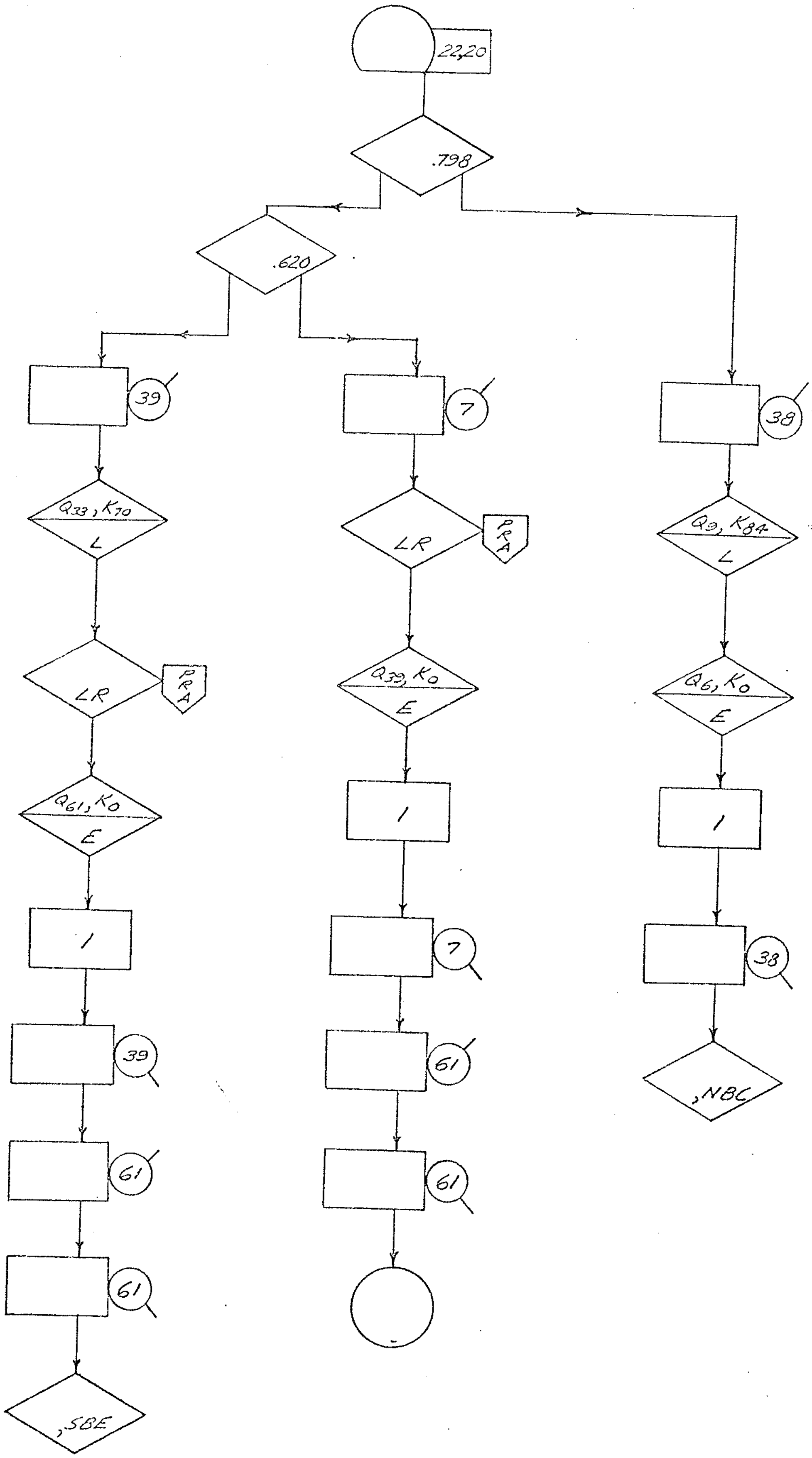
PEMBINA NORTH BOUND TRAFFIC APPROACHING POINT ROAD - WINDEMERE



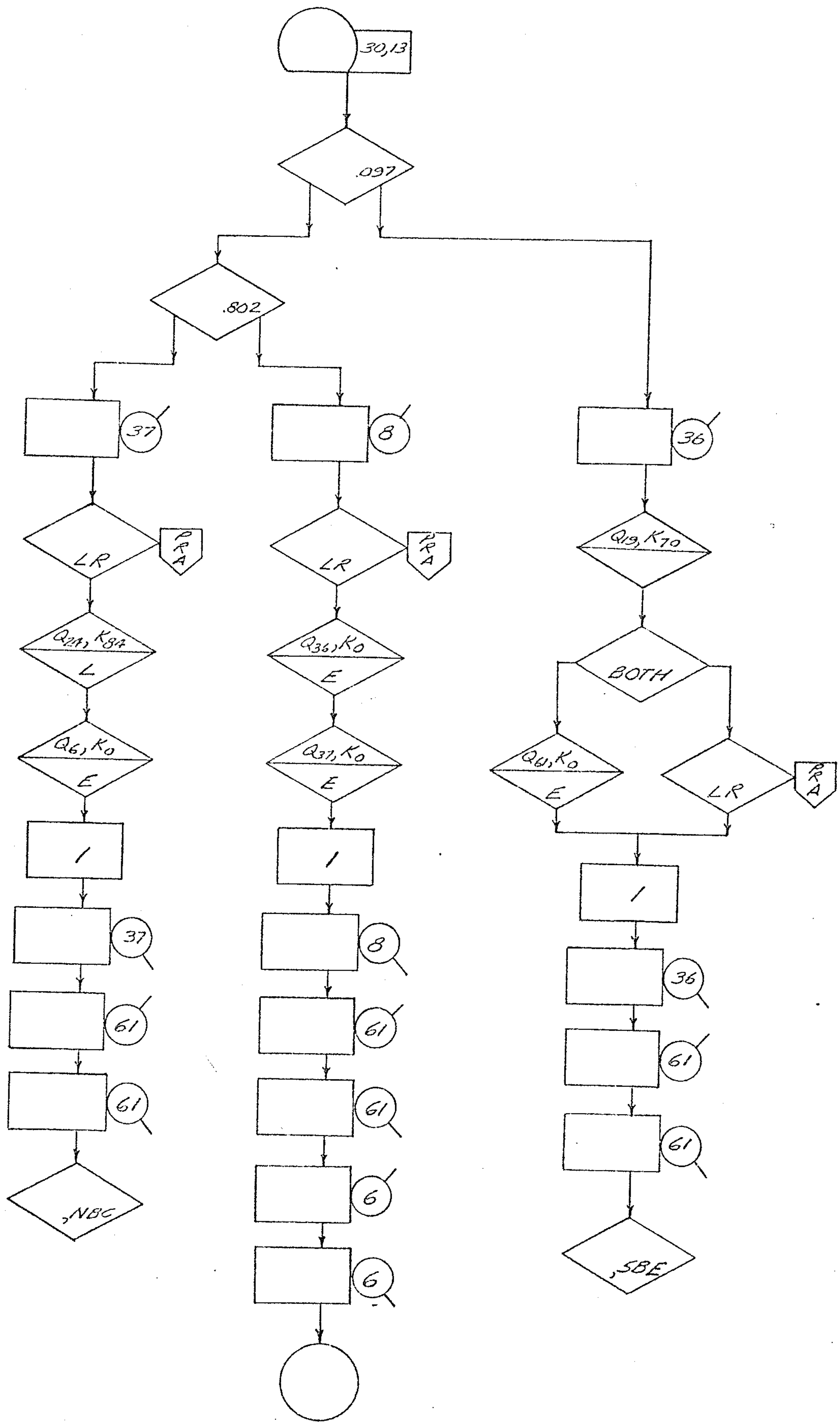
PEMBINA NORTH BOUND TRAFFIC
QUEUES AT POINT ROAD - WINDEMERE



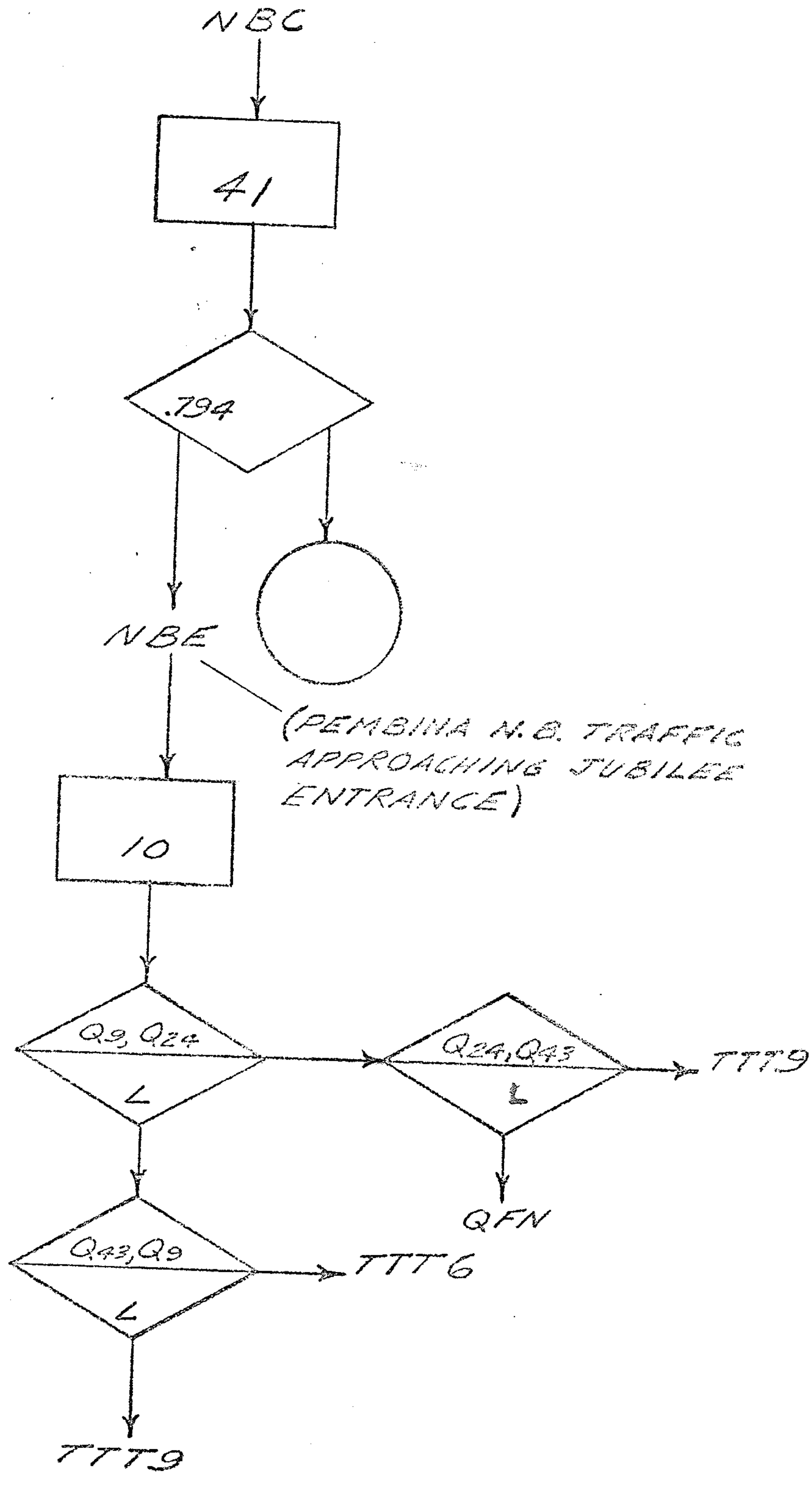
Point Road West Bound Traffic



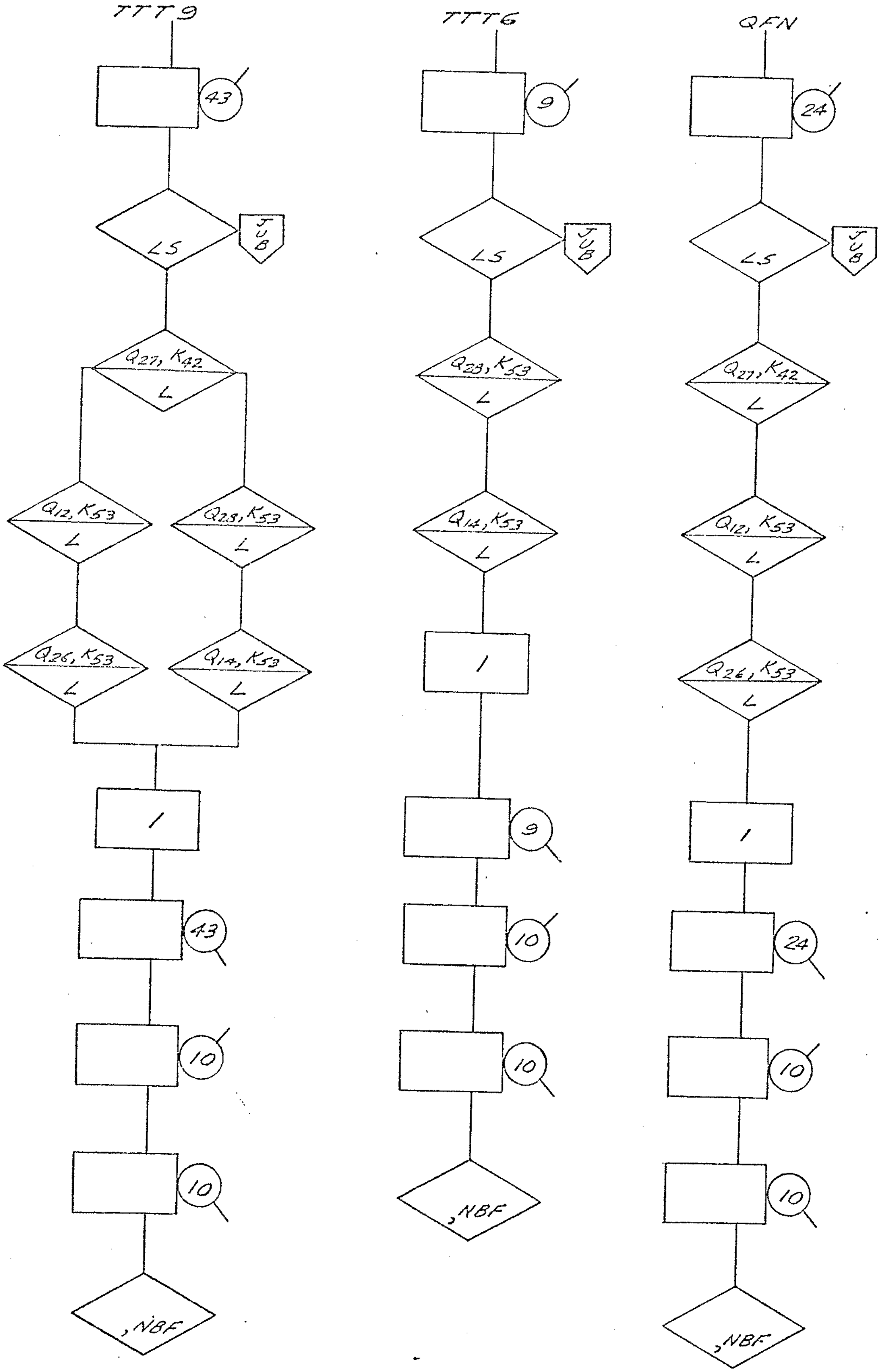
WINDEMERE EAST BOUND TRAFFIC



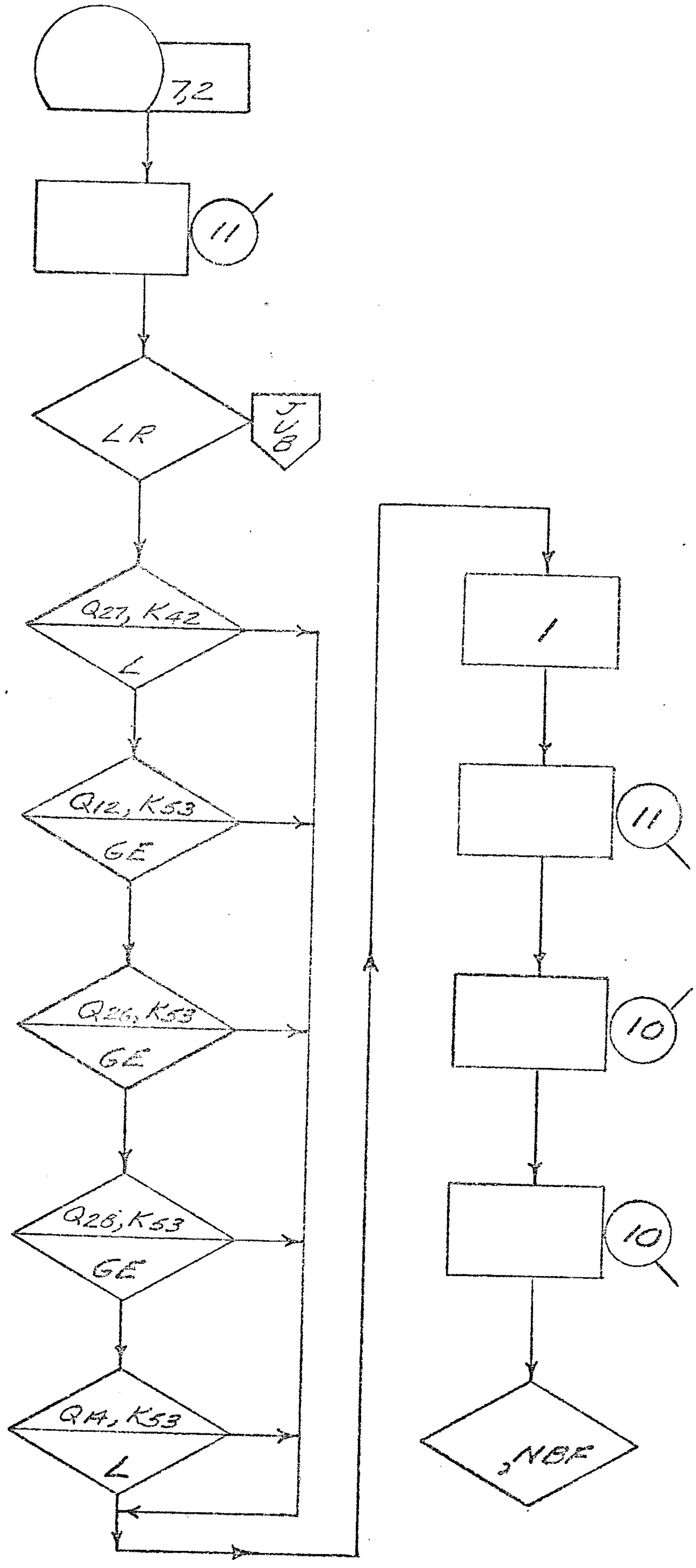
PEMBINA NORTH BOUND TRAFFIC APPROACHING JUBILEE EXIT



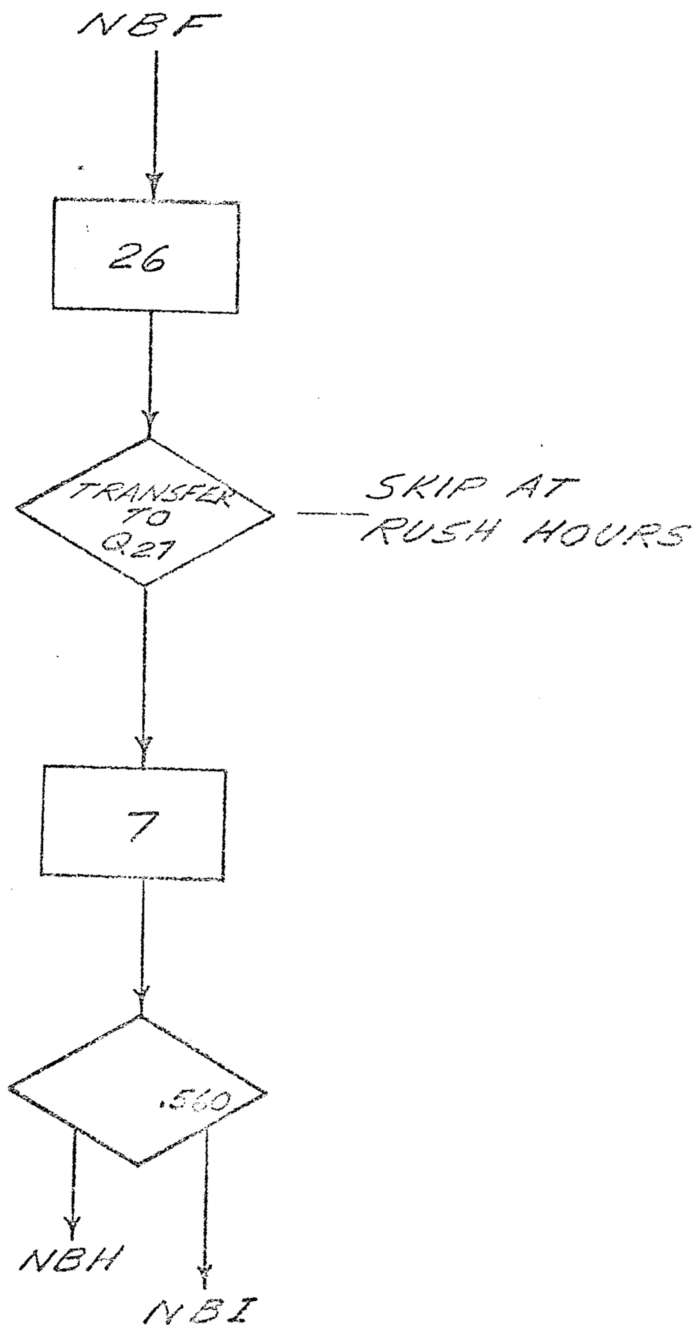
Pemeina North Bound Traffic At Jubilee



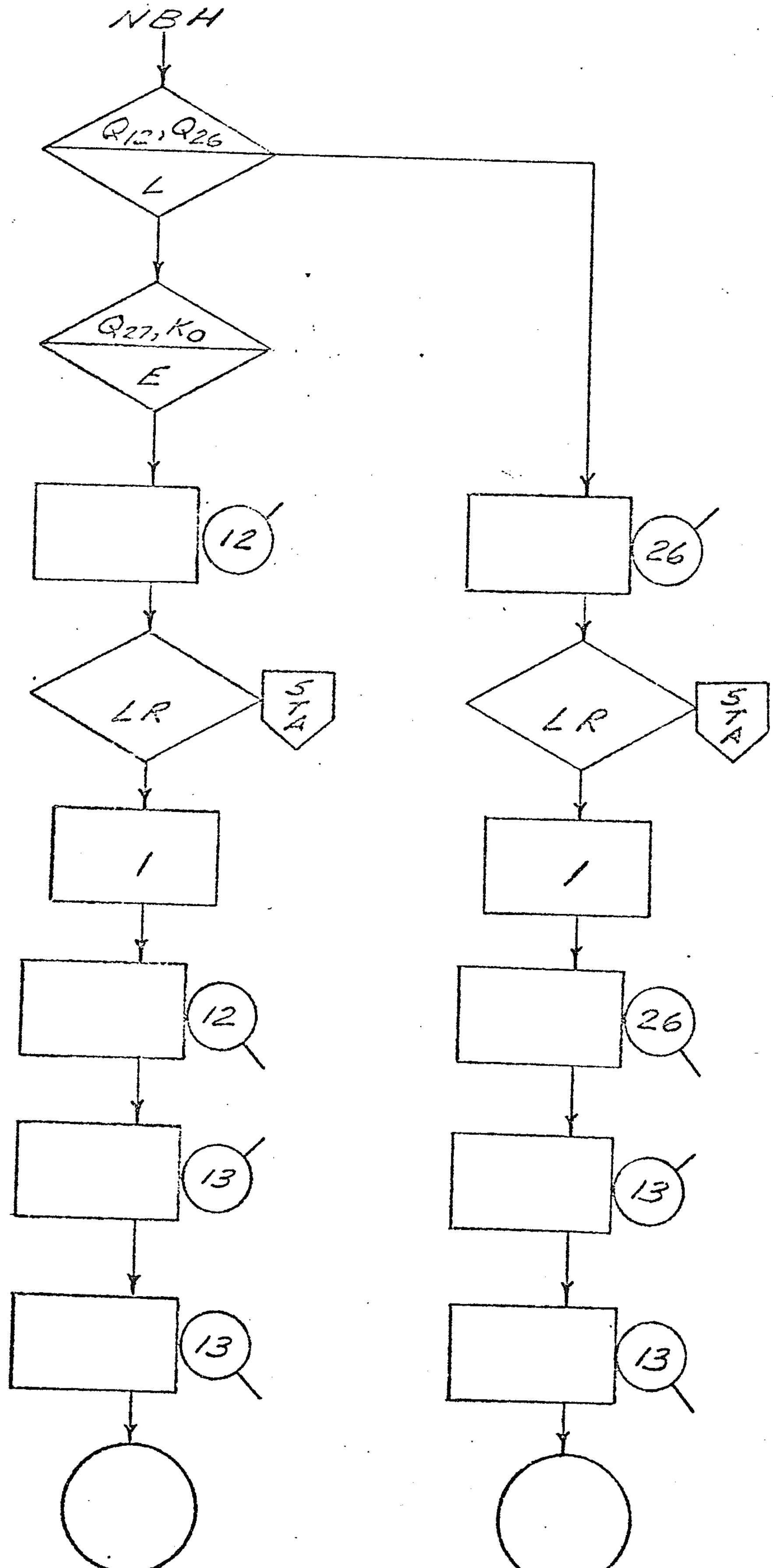
JUBILEE NORTH BOUND TRAFFIC



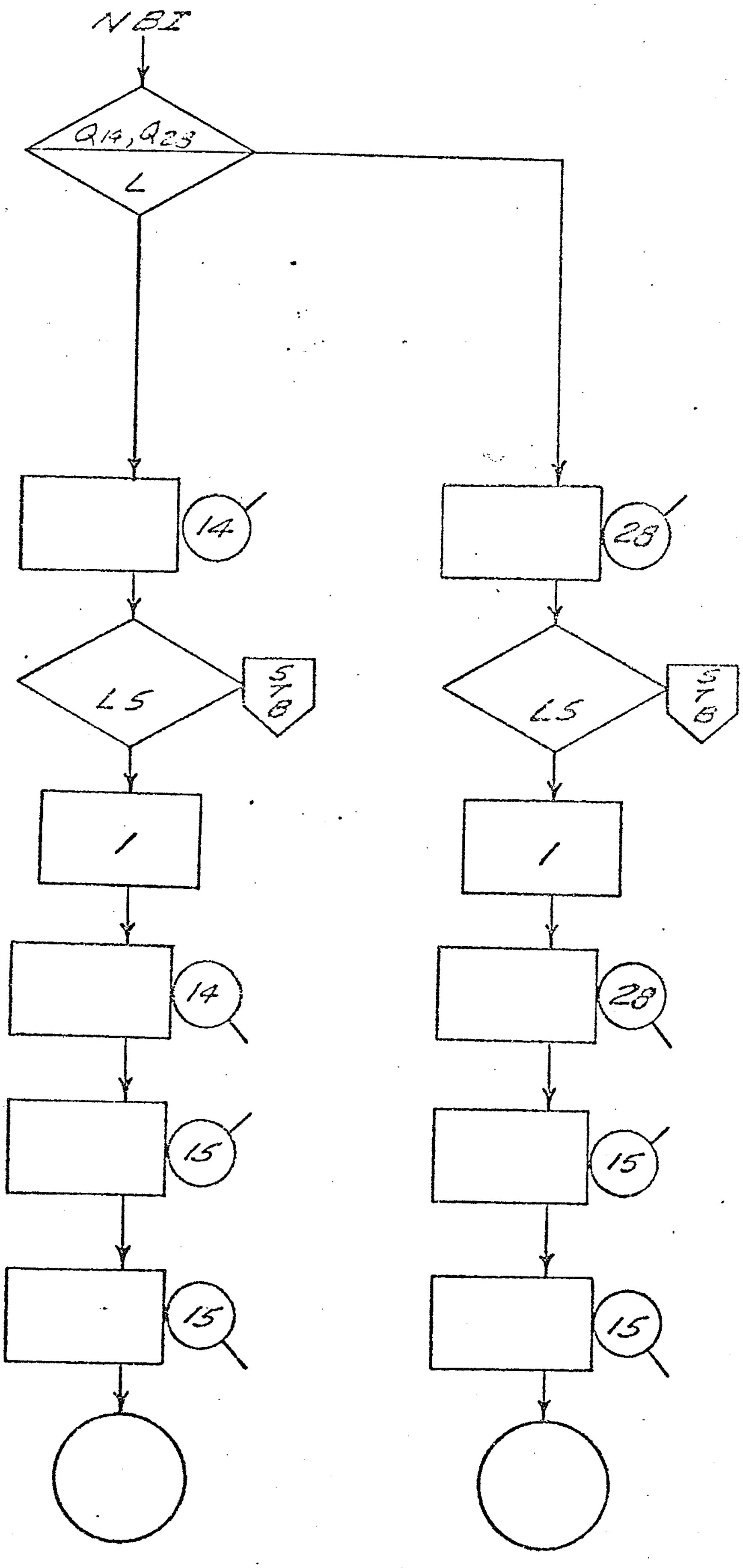
PEMBINA NORTH BOUND TRAFFIC APPROACHING HARROW



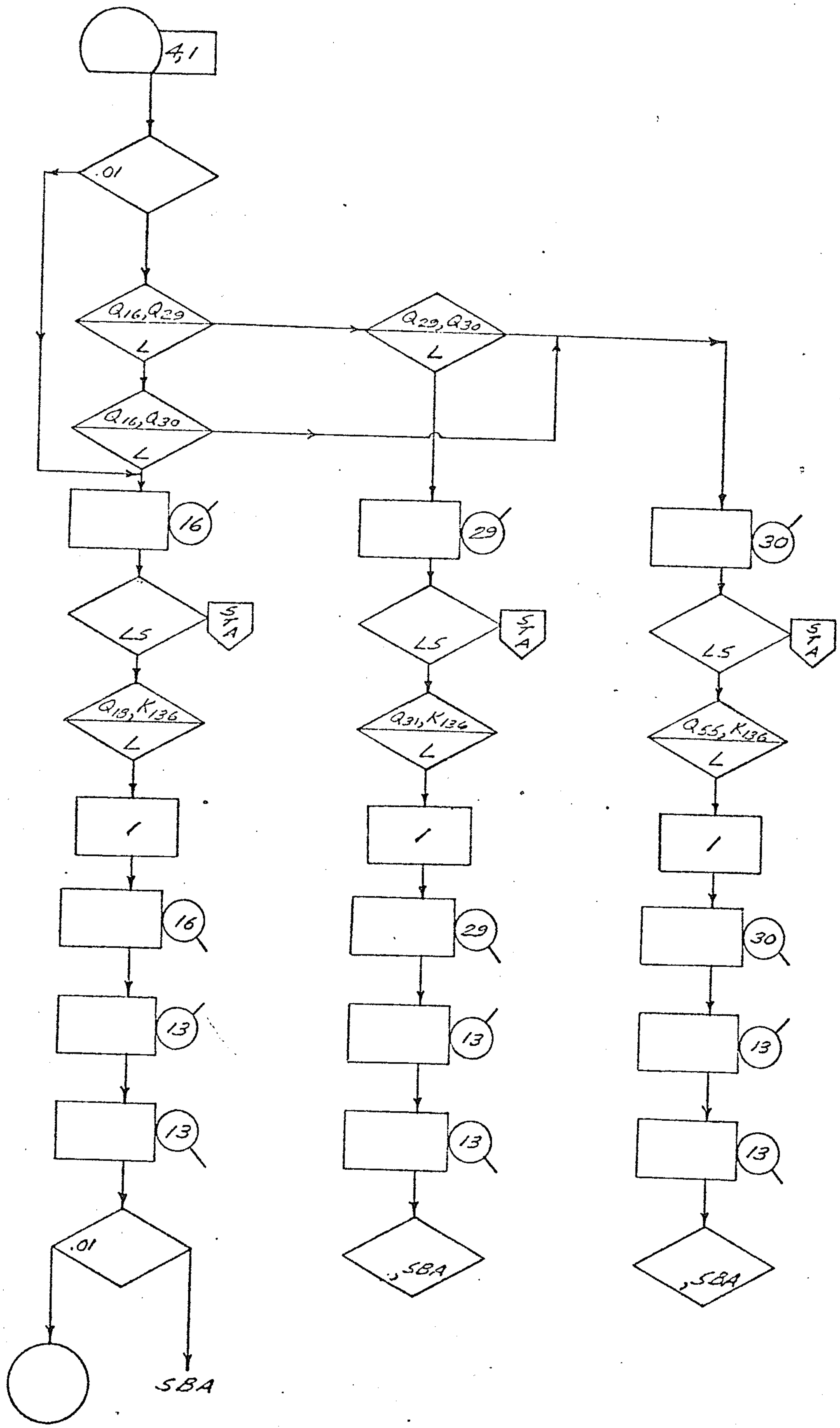
PEMBINA NORTH BOUND TRAFFIC TURNING ONTO STAFFORD



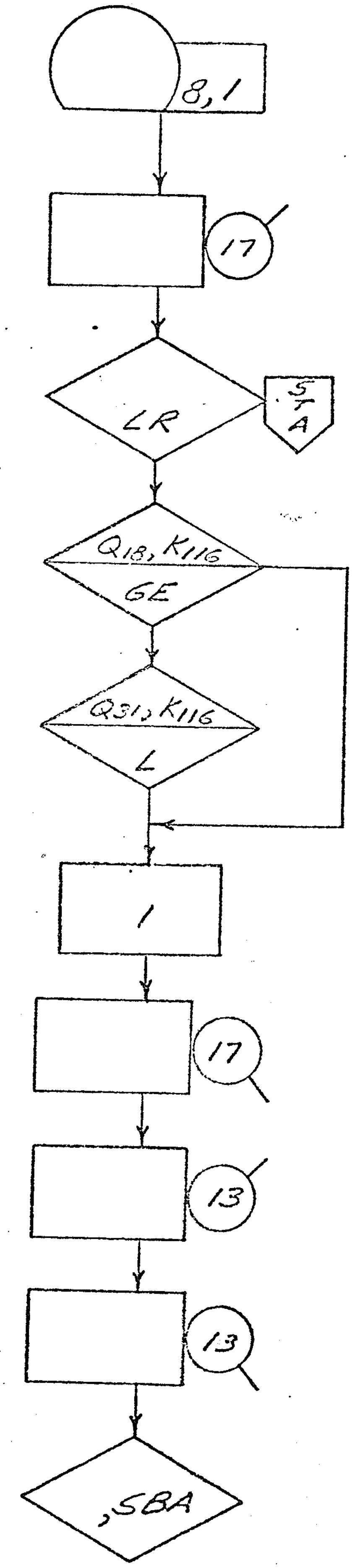
PEMBINA NORTH BOUND TRAFFIC
REMAINING ON PEMBINA



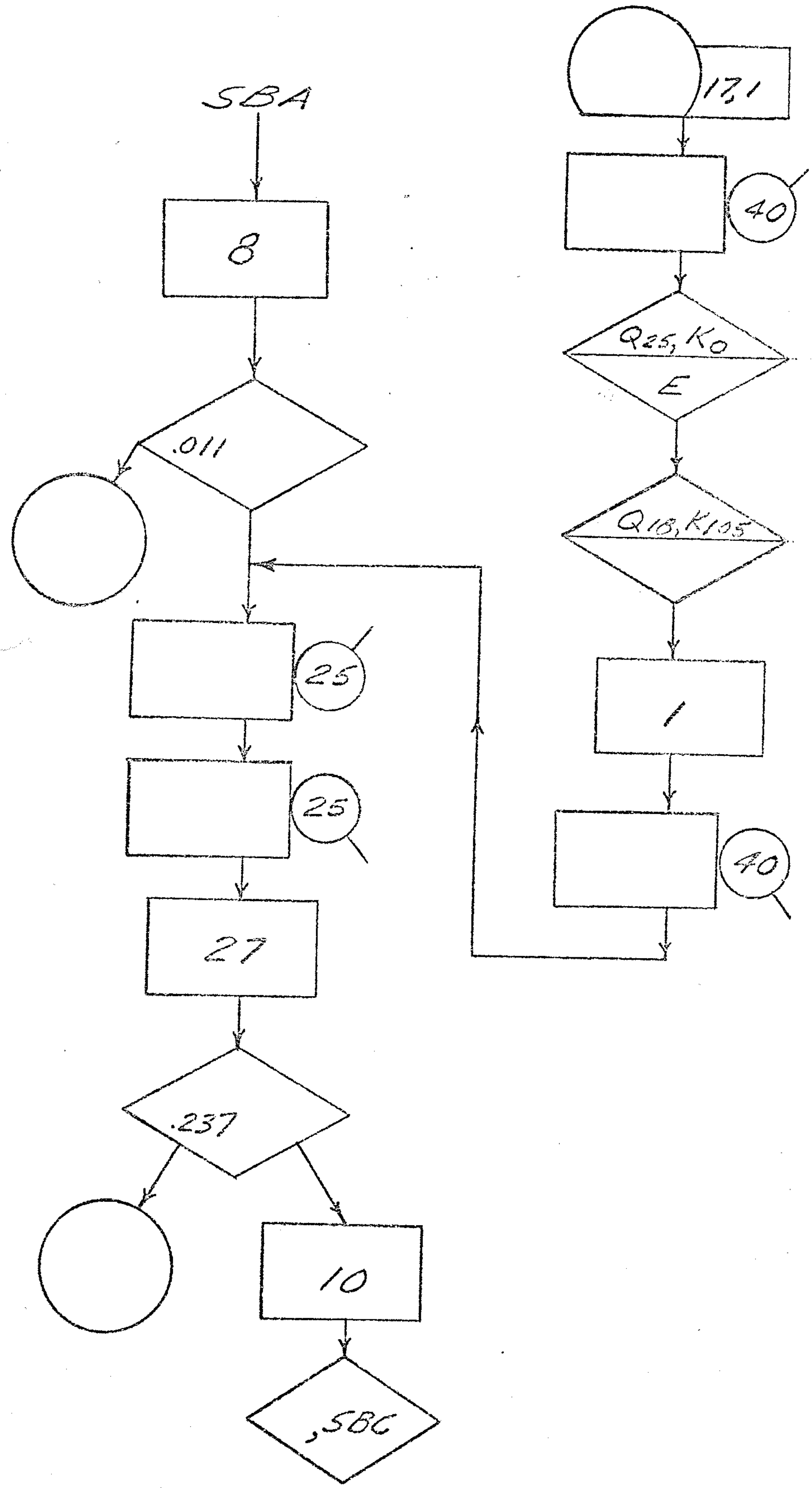
PEMBINA SOUTH BOUND TRAFFIC
APPROACHING STAFFORD



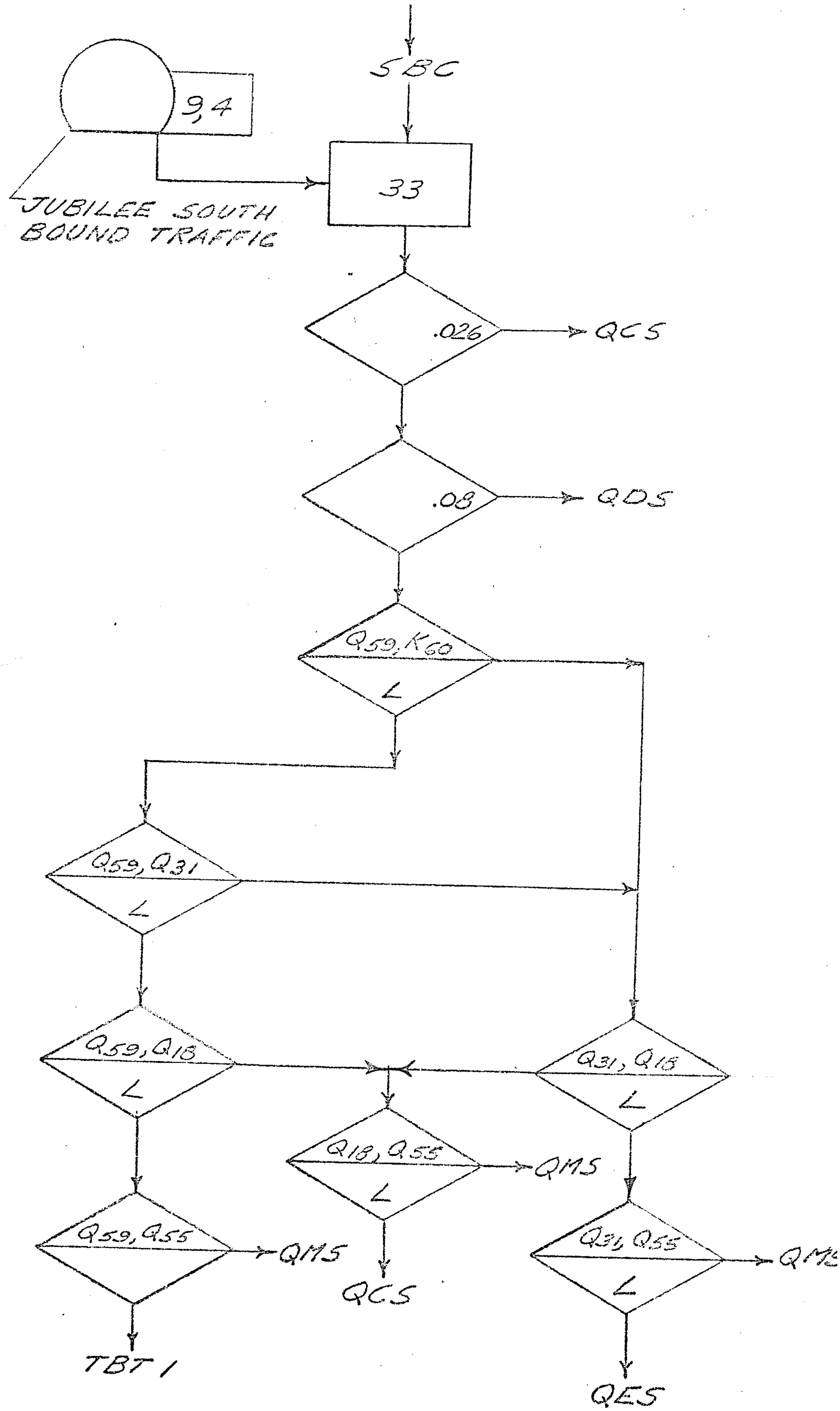
STAFFORD SOUTH BOUND TRAFFIC



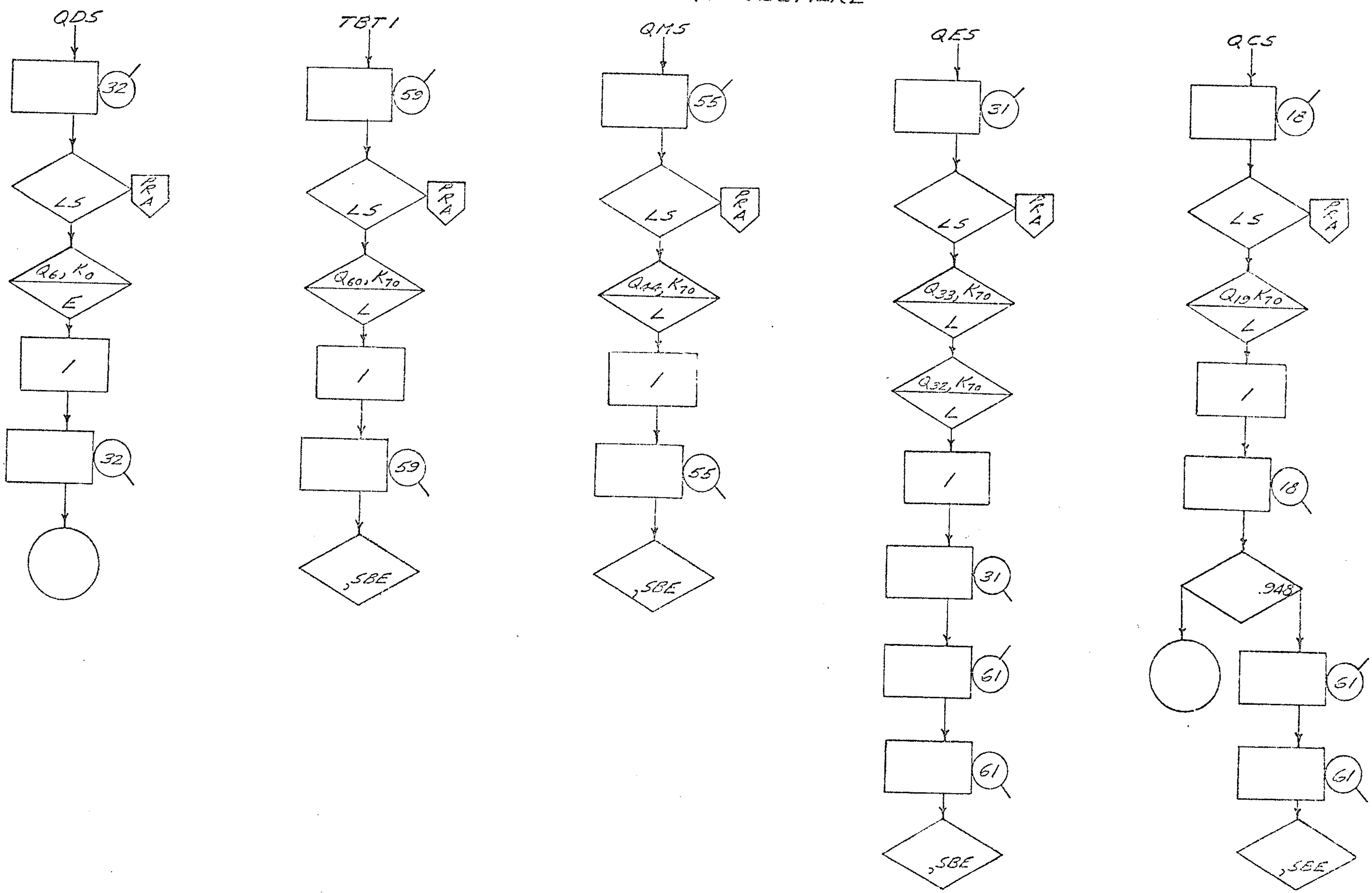
PEMBINA SOUTH BOUND TRAFFIC
APPROACHING HARROW; INCLUDING
HARROW SOUTH BOUND TRAFFIC



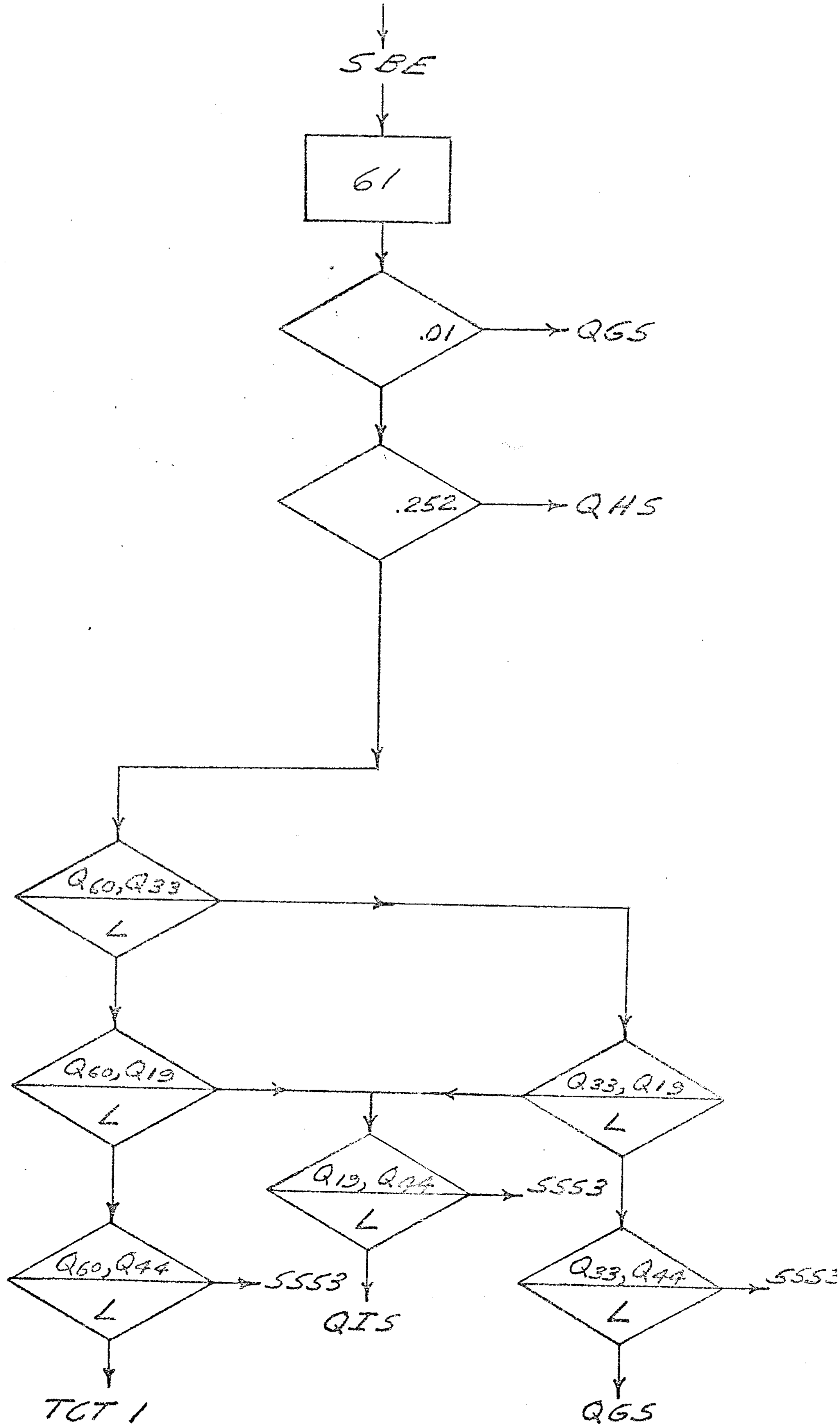
PEMBINA SOUTH BOUND TRAFFIC APPROACHING POINT ROAD-WINDEMERE



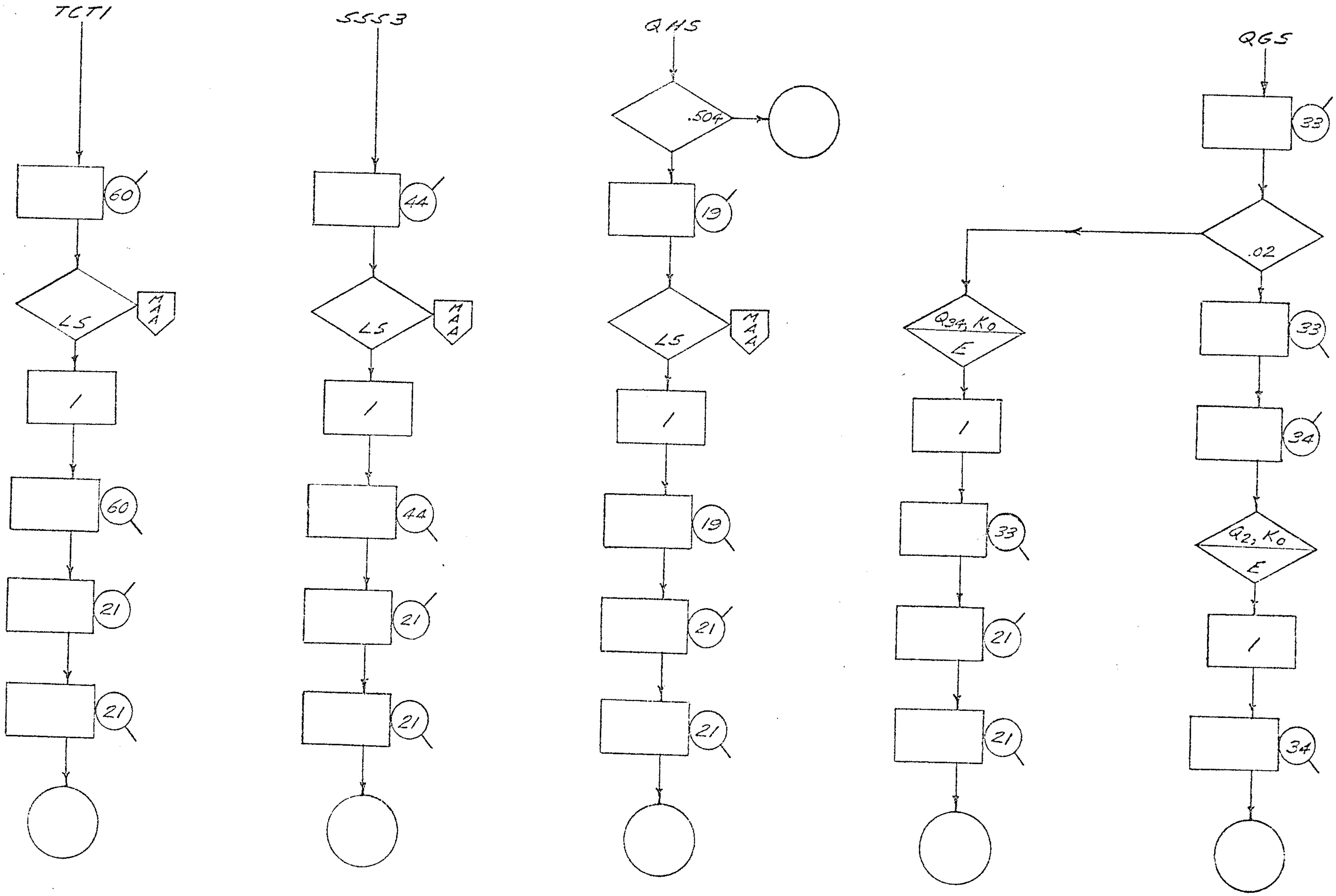
PEMBINA SOUTH BOUND TRAFFIC
AT POINT ROAD WINDEMERE



PEMBINA SOUTH BOUND TRAFFIC
APPROACHING MACGILLIVARY-OAKENWALD



PEMBINA SOUTH BOUND TRAFFIC
AT MACGILLIVARY



APPENDEX E

CONTENTS

QTABLE INDEX

QTABLE	QUEUE	QUEUE REPRESENTS TRAFFIC IN ONE OF LANES
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B	3	Oakenwald Westbound Traffic
C	4	MacGillivray Eastbound Traffic
D	5	Northbound on Pembina at Point Road-Windemere
E	7	Point Road Westbound
F	8	Windemere Eastbound
G	9	Northbound on Pembina at Jubilee
H	11	Jubilee Northbound
I	12	Northbound Pembina Turning Onto Stafford
J	14	Northbound Pembina Remaining on Pembina
K	16	Southbound on Pembina at Stafford
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<u>QUEUE INDEX</u>

QUEUE	REPRESENTS
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3	Oakenwald Westbound Traffic
4	MacGillivray Eastbound Traffic
5	N.B. Pembina at Point Road-Windemere
6	East Intersection Pembina-Point Road
7	Point Road Westbound Traffic
8	Windemere Eastbound Traffic
9	N.B. at Jubilee
10	Intersection Pembina-Jubilee
11	Jubilee Northbound Traffic
12	N.B. Pembina Turning Onto Stafford
13	West Intersection Pembina-Stafford
14	N.B. Pembina Passing Stafford
15	East Intersection Pembina Stafford
16	S.B. Pembina at Stafford
17	Stafford Southbound Traffic
18	S.B. Pembina at Point Road-Windemere
19	S.B. Pembina at MacGillivray-Oakenwald
20	N.B. Pembina at MacGillivray-Oakenwald
21	West Intersection Pembina-MacGillivray
22	Left Turn Storage Lane PEMbina at MacGillivray
23	N.B. Pembina at Point Road Windemere
24	N.B. Pembina at Jubilee

25	West Intersection Pembina-Harrow
26	N.B. Pembina Turning Onto Stafford
27	N.B. Pembina Turning Onto Stafford
28	N.B. Pembina Passing Stafford
29	S.B. Pembina at Stafford
30	S.B. Pembina at Stafford
31	S.B. Pembina at Point Road-Windemere
32	Left Turn Storage Lane Pembina S.B. at Windemere
33	S.B. Pembina at MacGillivray-Oakenwald
34	Left Turning S.B. Pembina at MacGillivray
35	Oakenwald Right Turn Lane at Pembina
36	Windemere Traffic Turning Right
37	Windemere Traffic Turning Right
38	Right Turn Yield Point Road at Pembina
39	Point Road Left Turning Traffic
40	Harrow Southbound Traffic
41	N.B. Pembina at MacGillivray-Oakenwald
42	N.B. Pembina at Point Road-Windemere
43	N.B. Pembina at Jubilee
44	S.B. Pembina at MacGillivray-Oakenwald
55	S.B. Pembina at Point Road-Windemere
57	N.B. Pembina at MacGillivray-Oakenwald
58	N.B. Pembina at Point Road-Windemere
59	S.B. Pembina at Point Road-Windemere
60	S.B. Pembina at MacGillivray-Oakenwald
61	West Intersection Pembina-Windemere