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A DISSERTATION

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DOCTOR OF PHILOSOPHY

BY

ROBERT THORNTON ALGUIRE

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COMPUTER MODEL FOR REGIONAL PLANNING

OF WATER AND SEWER SYSTEMS

Approved by

Geo. W. Reid

[signature]

[signature]

Wm R Southard

Dissertation Committee

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The objective of this study was to take an existing model that was capable of projecting both population and demand and evaluating a selection of network models in order to derive a practical planning technique for regional water and sewer systems. This research had as its goal the development of a usable tool that would give the average planning group a systematic approach for analyzing water and sewer networks -- a technique, which upon completion, would be functional without modification, for any type or size of region.

This was accomplished by the construction of six procedures which used three computer models: the inventory and data projection procedure which provides the input; the population model and procedure which generates the desirable alternatives in terms of people and their socio-economic characteristics; the land use procedure which allocates the output of the population model to an areal scheme; the demand model and procedure which produces the water demand and sewage output for the given areal scheme; the network model and procedure which optimizes on a least cost basis, while maximizing utilization of resources, the networks of water and sewerage that fulfill the alternatives available; and finally the plan procedures for the development of a continuing and comprehensive plan.

The steps between each procedure have built-in planner intervention points where the using group may "game" new alternatives based on the results and data acquired from the previous procedure. The procedures and models have relaxed the tedious process necessary to formulate a regional plan. The

techniques are spelled out on a step-by-step basis and all procedures and models are fully operational. The flexibility of the approach can only be realized when one applies it to an area and procedes to the gaming of each alternative against the desired future worlds.

This report is a portion of a major research grant from the office of Water Resources Research of the Department of Interior which is uniquely the author's. The total concept can be reviewed by reading the final report on "Systems Approach to Metropolitan and Regional Area Water and Sewer Planning." This report was co-authored by George W. Reid and Robert T. Alguire for OWRR in May, 1973.

COMPUTER MODEL FOR REGIONAL PLANNING

OF WATER AND SEWER SYSTEMS

CHAPTER I

INTRODUCTION

1.1 Objectives

The prime objective of this research has been to develop a systems approach which would provide a practical method of planning regional water and sewer systems. The proposed techniques will equip the urban planner with the methodology for the selection of an optimal "plan" and for the establishment of the conditional boundaries from the solutions of all foreseeable developments. Using this approach, the model then becomes an effective tool in planning, for it not only furnishes the necessary output on which the planner can develop the water and sewer plan, but it also gives him the capability of gaming all the alternatives for each of the possible worlds.

It is this approach that makes this research unique. The basic approach from the very start was to develop a model that did not produce a mathematically elegant solution from the basic input data. The model, with built in intervention and decision levels for the user, was designed to proceed in steps. At each step the user explores all possible solutions and decides the possible worlds to be evaluated in the next level. This not only gives the operator the flexibility of gaming other alternatives but forces intervention and evaluation of alternatives based on the previous levels prior to proceding to the next phase.

If one evaluates the past efforts of others in this area, the greater part of this work is polarized as mathematically elegant at one end and scenarios on the other. It was,therefore,decided that this work would be dedicated to the fulfillment of the need for a system that lies somewhere between these two poles, a system that would not generalize in broad overall solutions nor run through complicated algorithms using specialized and expensive data inputs to "the solution".

It is to this approach that this research is dedicated. It is a system that not only employs readily available data for each phase, but one that forces the user to evaluate the results and alternatives produced at each level prior to proceeding to the next phase. Thus it insures that the user understands the results and commitments made previously. It is an approach in which a planner can re-evaluate new alternatives as they are developed and, most of all, it is a system that does not provide a "solution", but the data on which meaningful planning decisions can be evaluated and made.

1.2 State of the Art

A review of literature can best be stated by using a computer information retrieval system known as GIPSY to search the Water Resources Scientific Information Center (WRSIC) file compiled by the Office of Water Resources Research. This file is maintained by WRSIC and contains all the pertinent literature in the field of water research. This research of the files led to a large number of related articles. A review of these abstracts revealed that only a limited number were applicable to large areas on a regional basis. Of these, only a few were directly related to this study. Most dealt with specific regions and were geared to data collection, definable problems, or the development of general and specific recommendations related only to that defined region.

The ones that did offer new concepts, applicable methodology and modeling techniques, or pertinent conclusions are reviewed in this section. The general trend being followed is best summarized by Robert Dorfman (1), who states: "New methods for designing water resources systems are being evaluated as part of a general social tendency toward expressing social problems in the formal modes that have been restricted to scientific and engineering problems." This evolution has been following two general types of models -- simulation and analytical. The simulation is the use of algorithms, usually on computers, to depict sequential time changes of events. This method produces estimations of situations at a projected time under control of specific decisions. The analytical models used explicit mathematical functions of design variables to predict efforts of time.

In the area of planning and resource management models, variations of linear and non-linear programing have been used extensively. Linear programing was used because of the unique min-max capability, and because if all functions can be reduced to a linear foremat, the solutions are usually simple. This is rarely the case, however, since most functions over time are non-linear, especially cost. When one forces linearity, the accuracy of his simulation is reduced. This has given rise to the use of non-linear programing. Since general non-linear solutions get extremely difficult, most work in this area has been with defined, such as concaved, non-linear functions. D. P. Loucks (2) used this method for the solutions of branching multi-stage river-reservoir problems.

John Dracup (3), using an algorithm of parametric linear programing, developed a model of the San Gabriel Valley in Southern California for surface and ground water. The study used five sources to meet three requirements over the period from 1960 to 1990. This method is described as an effective guide for long-range optimum decision-making for water-resources systems. S. C. Parikh (4) and R. C. Harboe (5) used dynamic programing in their respective models to solve problems on firm energy production. The Parikh model used two actual reservoirs in Northern California to validate the model and also to check the effect of non-covexity on the constraint set. Harboe used incremental dynamic programing techniques to solve an objective function for multiple purpose water systems expressed in physical terms. Both models optimize the use of interconnected water reservoir systems. In the area of resource allocation models, Reynolds and Conner (6) developed an economic allocation model, which is based on the assumption that the prevailing goal of society is strictly economic. Also, along this line of thinking, Guise and Flinn (7) used non-linear programing to maximize social payoffs for large scale water resource development. This model was then applied to the Nurumbidgee irrigation area of New Wales (8).

Supply and demand models, which are the major thrust of this research, were initiated at the University of Oklahoma by George W. Reid (9). The basic model uses demographic data and economic inputs to provide outputs for statistical areas. This research provides the basic input for the model that will be developed in the following chapters. Delucica and Rogers (10) used the North Atlantic Region (NAR) to develop a model that had a non-linear objective function and linear constraints. This model minimized efficiency costs and was based on a critical period analysis and selected risk levels.

The area of simulation has produced several applicable techniques of water system management. Beard and others (11) used simulation on a simplified version of a proposed Texas water system. The techniques, network analysis and sequential search, are compared over a 17 year period under variations of inputs and demands.

Dracup and others (12) developed a model to predict available water supply using long term precipitation data to generate the runoff in a regional water basin. Dracup (13) then worked on the conjunctive use of ground water systems by maximizing benefits and minimizing cost. This process used linear and dynamic programing to study the capabilities of the system and then compared their effectiveness.

1.3 General Methodology

The model, which is discussed in detail through all phases by Reid and Alguire (14), was an extension of previous work done by Reid (9). This concept starts with three sectors -- Demographic, Industrial, and Agricultural. Each of these sectors are measured and evaluated within the framework of the existing political system. This evaluation becomes an information system which is projected into the future within the time frame of the study. The past, present and future sectors of the information system are applied to the water and sewer system in order to develop the "plan", as shown in Figure 1-1.

The information system is developed out of each sector. The demographic sector, which relates to population in the urban and rural areas, is measured on a per capita basis. This includes all categories of operation from the domestic, commercial, and public life styles. The industrial sector, on the other hand, is measured in terms of manufacturing uses of water. It is segregated into the Standard Industrial Classification (SIC) codes and is measured on a per employee basis for each two digit code. Agricultural sector is measured on a per acre basis and is that quantity of water used for

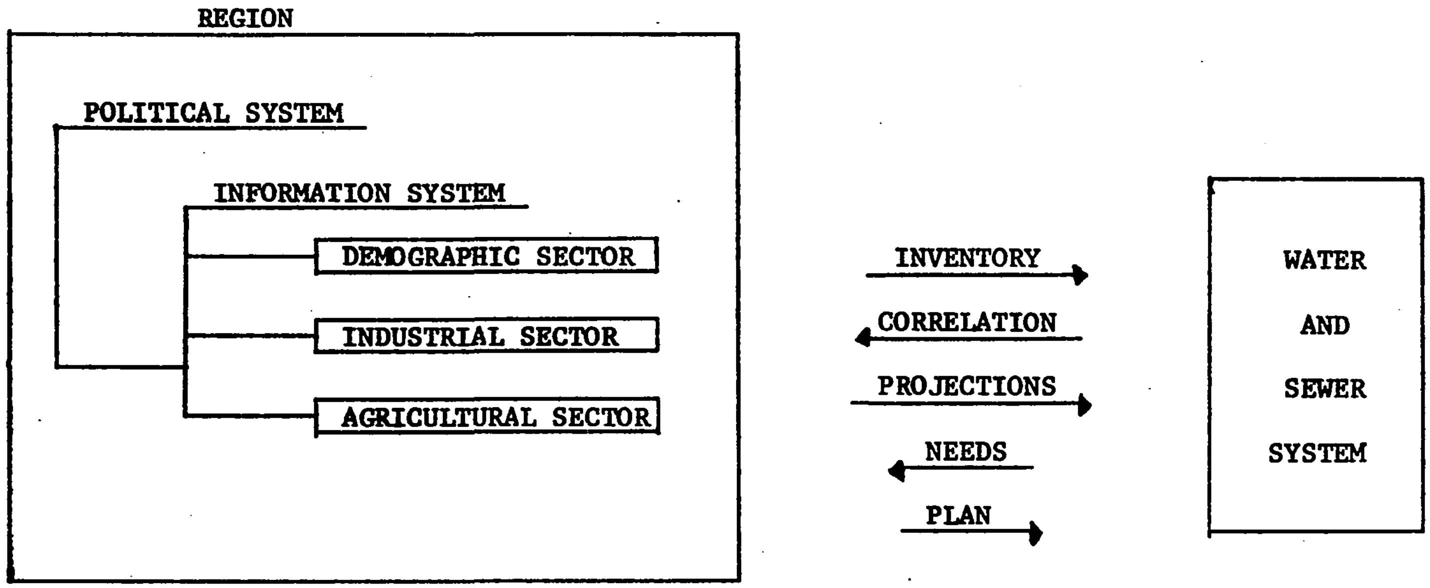


Figure 1-1. System Sector Relationship

irrigation of crops. This information system is derived from a procedure of data collection or inventories in each sector, and the water and sewer system. The procedure developed was designed to use data which is relatively easy to acquire and update. Data that has to be specifically developed for a study and for each new update is of questionable value. Data, if at all possible, should be acquired or derived from sources that are not only already available but which are also updated periodically by assignment. This creates a study which is not only comprehensive, but also has a built-in capability to be used continually at a minimum of cost.

After collection, the data is then projected through the time frame of the study, in this case twenty years (see Figure 1-2). This time frame can be any length of time that is divisible into five year increments from the base year. This five year increment was selected because it is the most realistic time frame in which projections can be made with a high degree of accuracy before updating the base data. This then requires the project to be self-continuing on a five year cycle. Therefore, it becomes the first built-in intervention step in the system.

This intervention is one of the primary goals that was established at the very outset of the study. It is the very heart of a practical system in planning. A system that is mathematically simulated through the time frame of the study and requires only the input data to produce "THE PLAN" out of the other end, has failed to be of practical use. Even if the answer produced is relatively accurate, the use of a plan that is not fully understood by its users and which locks them in on one solution cannot be fully justified. It is not realistic to plan that far in advance without approaching it on an incremental basis.

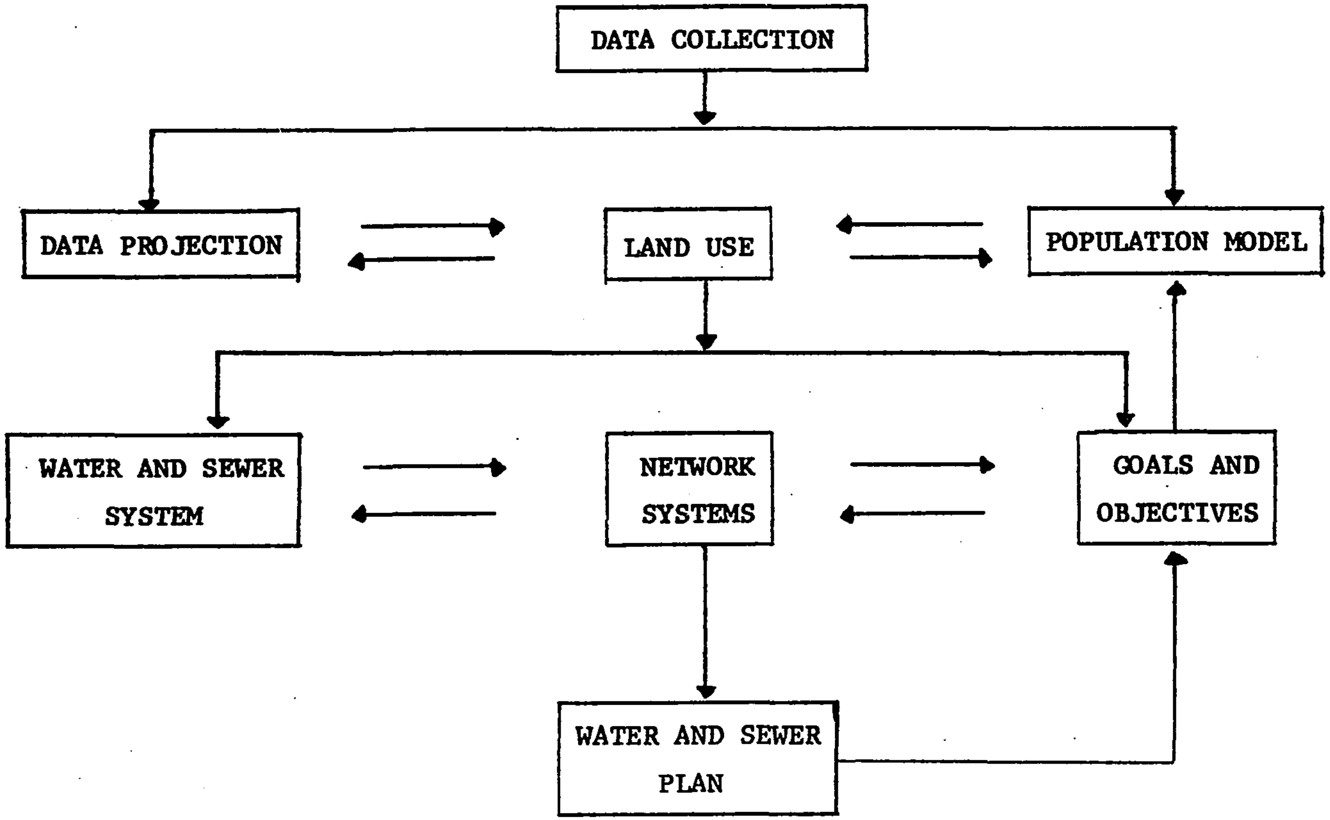


Figure 1-2. Operational Flow Chart

When one uses this incremental approach, he is forced to understand the system. Each step requires a review of how the previous alternatives changed the system and a decision as to which of these alternatives will be applied to the next time increment for evaluation. This then leads to the technique developed by Reid (9, 14) of projecting the data based on the use of goals. Reid set these goals as probable, practical and possible as shown in Figure 1-3 (14).

A possible world is one that a user would strive for. It might even be described as idealistic. These possible goals, although idealistic, must be tempered with judgment. The capability of a primary arterial street system to function, even during peak hours, in an uncongested state or adequate water even for peak summer loads on a continuous basis are the possible goals. It would take heavy dedication of resources that are also needed in other areas, but these goals are attainable.

The probable goals are those that are attainable if the system is allowed to "drift" into the next time increment using the non-systems approach -- an approach that is based on the political and socio-economical demands without strong requirements for realistic planning. This system usually lags behind growth and can be wasteful of resources.

The practical goals are the ones in which we are striving to identify with this process and they lie somewhere between the possible and the probable goals.

The identification and projection of these two latter goals established the boundaries of the envelope in which the practical solutions will lie. This establishes in the mind of the user the constraints of the system. As he looks at the alternatives open in that time increment, he can more

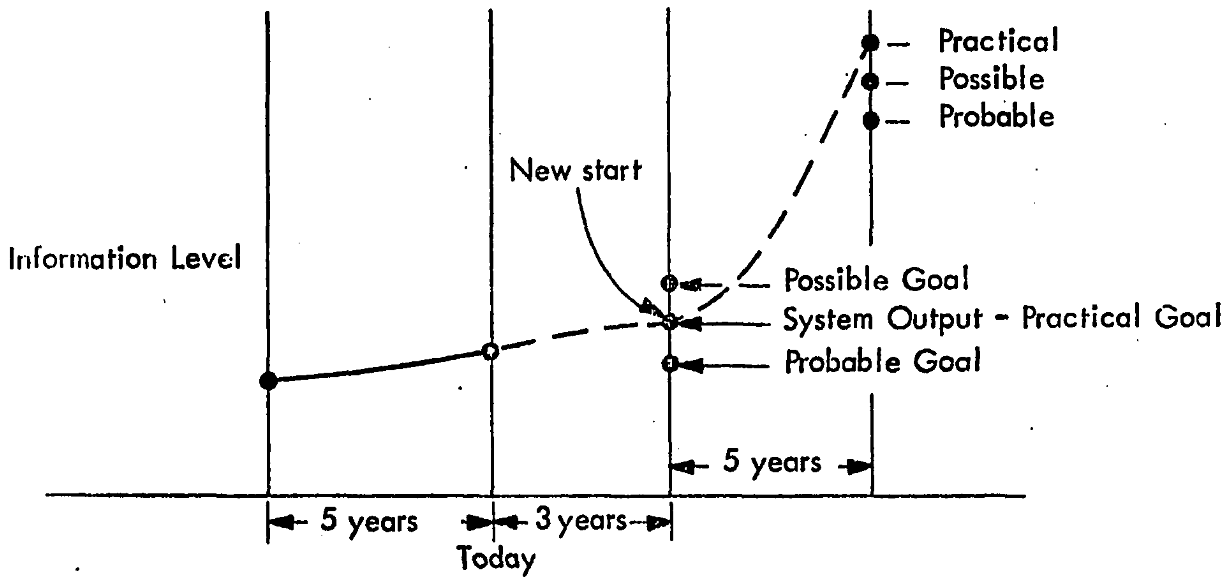


Figure 1-3. Planning Process.

realistically reach the practical goal for that time increment. This practical goal, or a selection of practical goals, becomes the data base for the next time increment.

After the information system has been identified and projected into the time frame of the study, the actual computerized system begins. A Cohort-Survival Population Model takes this data and "grows" the region into the future. The output of this program is extensive and gives most of the demographic information required for developing the system. It also has the greatest capability of gaming alternatives for future goals. One can look at the demographical consequences of what possible alternatives might bring. A decision to pursue heavy industry will bring jobs and economical rewards, but also heavy water and sewer requirements. Large amounts of people and socio-economical problems will also arise with this "boom" of prosperity. As one watches these decisions grow into the future, he becomes aware of the ramifications each alternative brings.

This is the beginning of intuitive planning -- a realization that practical goals are those that are not only obtainable, but ones that the total system can afford. Many possible goals can be acquired in a regional system, but if the user is not "growing" his comprehensive plan through the time frame, he may achieve a set of goals that cost the system more resources than it will ever have or be able to acquire -- a position that many of our larger metropolitan regions find themselves in today.

The demographic data is then allocated to an areal scheme for each increment. These schemes are based on the population projections of the alternatives that the user wanted to investigate. Again the user is asked to intervene and select alternatives for investigation. The selection of these schemes has vast ramifications on the water and sewer system of the region, to say nothing of the other systems, such as transportation and education, inherent to this region. The user may wish to "game" alternatives to verify which are practical and warrant further investigation and those which do not.

These selections are then used as input to the demand model. This program computes the amount of water that each statistical area unit (SAU) needs and their discharges. These demand functions were derived from the information system and depict the demands in any of several areal formats. One can investigate the requirements of political boundaries, and the loadings on particular sources and treatment facilities. For each areal scheme these demands can be projected and evaluated before the selection of the alternative to be processed into the next phase.

The final program is a network model which evaluates the capacities and cost funtions of the system. It will take each of these alternatives and determine the system's capability to be expanded in order to service the alternatives that the user has inputed into the region. This gives the user the answers to evaluate each alternative in the "selection" of a plan; not a plan that a system of models says is the solution.

As the user progresses through this methodology, he should become aware that this system is a practical approach to a most complicated process. There is no single solution, but a step by step process, where one is trying to achieve a practical goal that best benefits his region. It is a process that requires constant evaluation of where the system is and where it is going. Only then can one hope to produce a systematic approach to a problem that changes as fast as our modern society.

CHAPTER II

DATA PREPARATION AND THE POPULATION MODEL

2.1 Introduction

This chapter is a review of the data collection procedures and the population model. This information is covered in detail by Reid and Alguire (14) if a more comprehensive explanation is desired. Many of these procedures were originally formulated by Reid (9) and later modified for this particular study. The study by Reid was originally done for a defined area and therefore required a certain amount of alterations for general use.

The principles of the population model are basically unchanged from the work done by Reid, although several of the subroutines were modified. Most of the modifications were done in the area of input data requirements. Subroutines were added to compute the intermittent cycle data points internally. This was done in order to reduce the large quantities of input data that this model requires. The population model was also altered in the procedures for handling migration. This was modified so that the model could be "gamed" through alternatives with little change in the input data. These changes are covered in detail in the report to OWRR and will not be covered in this study.

2.2 Sewer and Water System

The most demanding of the data collection is that of the water and sewer system. A complete information file is required for this area of the study. The exact methodology required is again detailed in the OWRR Final Report and only the general requirements will be covered here.

A complete inventory of all resources, available and projected, is the first step. Each source is identified as to quantity, quality, and capability. This includes all projects existing and "in the mill", and gives the user an idea as to the region's capabilities, both immediate and in the near future. The next phase is the evaluation of the network that connects the sources with the treatment and distribution systems. Finally, the actual distribution system is inventoried.

The economic analysis of the water system is the next phase of the inventory and data collection. Each segment of this system, from source to distribution, is evaluated on a cost basis. The operating cost of all phases is determined and the debt structure is analyzed. This information includes the estimated life and expansion capabilities. The cost data is tabulated as fixed and variable. The variable data is computed on a million gallon per day basis. Upon completion, the user should have a complete understanding of the limitations and capabilities of the water system.

Basically, the same process is repeated for the sewer network. One of the main differences is an analysis of the capabilities of the receiving streams to handle the effluent. This can be a major control point and must be carefully evaluated. Again, the importance of the cost analysis cannot be overestimated, for on these cost figures all projection of practical goals rely. They determine the accuracy of the projected plan and its relationship to the real world. A plan that looks good but is economically unachievable is an exercise in futility.

The next phase that must be accomplished is the determination of the demand function for each sector. This was done from the past records of water use and discharge for each category (see Chapter IV for listing). After this data was accumulated and categorized, it was projected using regression analysis. A linear equation was developed for each category. The industrial sector produced a large number of linear equations with zero slope. This can be expected when production is directly related to the number of employees and the production techniques are fixed. If some industries, especially significant users, do not fit into their category because of some unique manufacturing process, they can be inputed as special users and are handled separately in the demand model.

2.3 General Data

This portion of the data collection is the thing that makes this region unique. It calls for a review of all local, regional, and state statutory regulations and controls; the political boundaries and agencies that make up the region; and a review of their past cooperative projects, which will also prove beneficial for future recommendations. This section more or less establishes the rules and regulations under which this region is operating. It will allow the user to select more realistic alternatives for "gaming" the computer runs and to avoid any that are not practical or legal.

2.4 Population Model

The data requirements for this model are mainly available from the U. S. Census Reports and are augmented and verified by local and state data sources.

All of the input and projections are easily attainable or derived from these sources. The method used by Reid and Alguire (14) is by no means absolute but is discussed and verified in that report.

The model has a multiplicity of capabilities designed into it. The output can be for any arrangement of three disaggregated regions, usually United States, State and Region. The model will handle any size area from a city to a nation, and project the data in five year cycles from the base year to any projected year desired. The rapidity with which our society changes precludes the running of the model much past twenty to thirty years except for general information.

The model output (see Figures 2-1 through 2-5) gives the population by age, sex, and race for each area and five year period. This population projection is then further divided into areas of specific interest. The first area, using the same format as the base population projection, is the migration that has occurred within that area during the last five years. If the data is positive, the migration has come into the area.

The rest of the output gives a good chronographic profile of the area. It contains the income levels and distribution that occur during that time. The distribution that occurs at each income level is further categorized by the number of households and total labor force. This data is then summarized at the bottom of the output sheet (see Figure 2-4).

Finally, the information is displayed as to the population that exists in each category of occupation and industry. This will give the user a good demographic profile of the population at each time cycle. This data is used to project land use (see Chapter III).

When the population model is run for the period of the study, the user can quickly visualize the demographic profile of the region as it grows through time under a selected alternative or set of goals. It is this capability that makes this model unique. It has been used successfully for all types of areas and its full capability as a planning tool has yet to be realized.

1990 POPULATION PROJECTION

UNITED STATES - U.S. CENSUS SERIES C
SCALE FACTOR =1000.

AGE	WHITE MALE	WHITE FEMALE	NON-W MALE	NON-W FEMALE	TOTAL WHITE	TOTAL NON-W	TOTAL MALE	TOTAL FEMALE	TOTAL POP.
0- 4	10712.	10257.	2627.	2342.	20969.	4969.	13339.	12599.	25937.
5- 9	9992.	9650.	2613.	2225.	19642.	4838.	12605.	11875.	24480.
10- 14	9023.	8754.	2444.	1999.	17778.	4443.	11467.	10753.	22220.
15- 19	8142.	7919.	2214.	1698.	16061.	3912.	10356.	9617.	19973.
20- 24	7105.	6880.	1727.	1337.	13985.	3064.	8832.	8217.	17049.
25- 29	8419.	8210.	2146.	1555.	16629.	3701.	10565.	9766.	20330.
30- 34	8721.	8598.	2277.	1595.	17319.	3872.	10998.	10192.	21191.
35- 39	7969.	8020.	1947.	1389.	15989.	3336.	9916.	9409.	19325.
40- 44	6670.	7246.	1294.	1121.	13915.	2415.	7964.	8367.	16331.
45- 49	5607.	5843.	910.	875.	11451.	1785.	6517.	6718.	13235.
50- 54	4663.	4887.	705.	749.	9550.	1454.	5368.	5635.	11004.
55- 59	4380.	4698.	598.	686.	9078.	1285.	4979.	5384.	10363.
60- 64	4476.	5013.	543.	642.	9490.	1186.	5020.	5656.	10676.
65- 69	4137.	4964.	452.	536.	9102.	988.	4589.	5501.	10090.
70- 74	3313.	4299.	325.	411.	7612.	736.	3638.	4710.	8348.
75- 79	2430.	3499.	223.	307.	5929.	530.	2653.	3806.	6459.
80- 84	1557.	2569.	140.	214.	4126.	353.	1697.	2782.	4480.
85 +	1279.	2444.	135.	240.	3723.	375.	1413.	2685.	4098.
TOTAL	108595.	113752.	23320.	19921.	222347.	43241.	131915.	133674.	265588.
PERCENT	40.9	42.8	8.8	7.5	83.7	16.3	49.7	50.3	100.0
MEDIAN AGE	30.5	33.0	25.1	26.2	31.8	25.5	29.4	32.0	30.7
SEX RATIO					955.	1171.			987.

Figure 2-1.

UNITED STATES - U.S. CENSUS SERIES C

1990

NET MIGRATION(X1000.)

AGE GROUP	WHITE FEMALE	NON-W FEMALE	WHITE MALE	NON-W MALE	TOTAL
0 - 4	135.	14.	186.	15.	350.
5 - 9	115.	13.	155.	18.	301.
10 - 14	77.	8.	116.	13.	214.
15 - 19	119.	9.	154.	11.	294.
20 - 24	191.	27.	181.	13.	412.
25 - 29	174.	27.	260.	21.	483.
30 - 34	118.	28.	221.	22.	390.
35 - 39	94.	18.	145.	15.	272.
40 - 44	46.	7.	48.	7.	109.
45 - 49	28.	4.	30.	4.	66.
50 - 54	24.	3.	13.	3.	43.
55 - 59	24.	3.	19.	3.	49.
60 - 64	17.	2.	14.	3.	37.
65 - 69	15.	1.	4.	3.	23.
70 - 74	8.	2.	3.	2.	14.
75 - 79	2.	0.	2.	0.	3.
80 - 84	2.	0.	0.	0.	2.
85 +	0.	0.	0.	0.	0.
TOTAL	1189.	168.	1552.	152.	3061.

Figure 2-2.

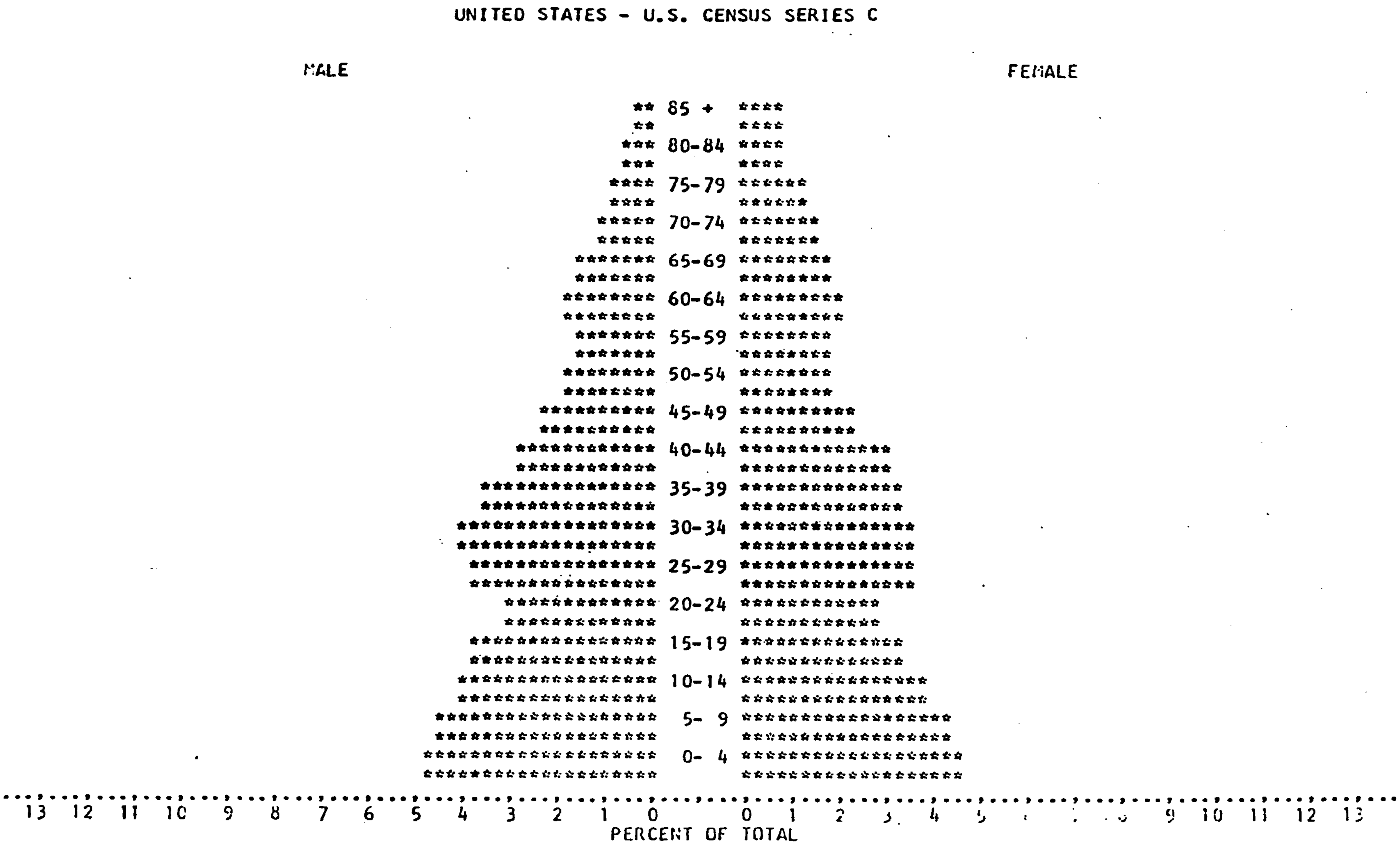

UNITED STATES - U.S. CENSUS SERIES C
MALE
FEMALE
85 +
80-84
75-79
70-74
65-69
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5- 9
0- 4
13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 2 3 4 9 10 11 12 13
PERCENT OF TOTAL

Figure 2-3.

UNITED STATES - U.S. CENSUS SERIES C
HOUSEHOLD AND INCOME CHARACTERISTICS

1990

INCOME	NUMBER OF HOUSEHOLDS	NUMBER IN LABOR FORCE
0 - 999	1086	2702
1000 - 1999	946	2354
2000 - 2999	963	2396
3000 - 3999	681	1694
4000 - 4999	800	1991
5000 - 5999	932	2319
6000 - 6999	1074	2673
7000 - 7999	1227	3053
8000 - 8999	1386	3449
9000 - 9999	1553	3865
10000 -10999	1723	4288
11000 -11999	1895	4716
12000 -12999	2067	5144
13000 -13999	2236	5565
14000 -14999	2400	5973
15000 -19999	14031	34921
20000 -24999	10529	26205
25000 -49999	28555	71069
50000 +	7434	18502

TOTAL HOUSEHOLDS	81519	PER CAPITA INCOME	6717
MEDIAN INCOME	22734	POP. IN GROUP QTRS.	7170
AVERAGE INCOME	21885	AVE. LABOR FORCE INCOME	8793
AVERAGE FAMILY SIZE	3.17	TOTAL PERSONAL INCOME	1784067.

Figure 2-4.

UNITED STATES - U.S. CENSUS SERIES C
POPULATION BY OCCUPATION
1990

OCCUPATION	POPULATION
PROFESSIONAL	31170.
MANAGERS	30049.
CLERICAL	34475.
SALES	8143.
FARMERS	5911.
FARMLABORER	3739.
SKILLED LBR	19122.
OPERATORS	26475.
HSEHOLD WKRS	719.
SERVICE WKRS	20906.
LABORERS	6977.
UNEMPLOYED	8554.
NOT EMPLABLE	62700.
ARMED FORCES	6649.
TOTAL	265588.
% UNEMPLOYED	4.36

TOTAL LABOR FORCE BY INDUSTRY
1990

INDUSTRY	LABOR FORCE
AGRICULTURE	0.
MINING	13811.
CONSTRUCTION	21946.
MANUFACTURNG	47810.
TRANSPORTION	10172.
TRADE	14670.
FINANCE	3211.
SERVICES	38124.
GOVERNMENT	46498.
TOTAL	196240.

Figure 2-5.

CHAPTER III

LAND USE

3.1 Introduction

The development of a truly usable comprehensive land use model has eluded society, even with its modern technology and equipment. A model that could be used by most urban areas and one that would give realistic projections of future land use is obviously a very desirable goal, but this model constantly escapes the practical because of the complexities that exist in each new increment of time and the existence of complicated social, economical, and political ramifications that occur with each new change.

Most professionals in this area can give an extensive report on the problems of developing a land use plan for the future and then achieving that goal. Many planning agencies use the plan only as a "guide" that is subject to change at each commission or committee meeting, subject as it were to an unpredictable array of pressure groups. With each change a myriad of new requests and side-effects results that dominate the plan until it becomes worthless.

There have been many models that have been developed for a particular metropolitan area, but these models soon become so specialized and complex that they become "computer school exercise type games" or an exercise in sophisticated programing techniques. It then takes, even with highly qualified personnel, longer to set up, de-bug, run, and interpret the data than it does for the land use to change .

As noted by Fredrick Bair, "The planner who produces a working comprehensive plan for now and the short-range future has done a highly commendable job. Of course, it will fade off at the edges five or six years ahead -- and it should." (15) It is this type of thinking coupled with the fact that the urban system is already operating on networks that are outdated, inadequate, and/or already capacitated, that proves the fallacy of detailed long range land planning and models.

As discussed in a special study of "Downtown Idea Exchange"(16), the future roles of downtown, and hence the urban area in total, cannot be agreed upon. What part will each portion of the city play 20 years from now? Will the Central Business District (CBD) be the "heart" and be revitalized with tremendous capital investment, or will the urban region "disperse" into self-sustaining new towns, or will the CBD be left to die and change like a living "Donut"? These, and many similar, are very complicated questions, and "which one is right?", if any one really is, becomes a whole new problem.

Add to this already entangled problem the current financial problems, environmental pollution, and the ensuing energy crisis, then one can quickly realize not only the difficulty, but the requirement for long range planning. It is almost like saying that the problem cannot be solved on one hand, while saying that is has to be solved on the other.

"The art of planning" needs to take a more realistic look at the future. The future plan should be developed to fit the "established goals" and, within the range of known or foreseeable trends, made to achieve this "desirable" world. It should not be allowed to "drift" to what could be construed to be a "probable" world.

The plan is developed knowing that the area will end up as what was described in Chapter 1, as the "practical" world. The planning agency must also realize that the "practical" world is not a fixed point in the future, but an identity that will not be known until it has been past, and the agency has had enough time to look back. To this end the author will identify these needs and the methods used to attain a portion of them.

3.2 Inventory Procedures

The current land use procedures are dependent on the specific metropolitan area under study. Most areas have a metropolitan planning agency and an individual planning department. These agencies and departments should have current land use descriptions for their respective areas.

The problem then becomes just a matter of coding this data into the structure of these models. This, of course, depends on how detailed their information is and how current. The information is placed into the SAU's as discussed in Chapter IV. The SAU's in the validation portion of this model were square miles or multiples of square miles for the rural country (1 to 6). This method fitted our coding system and allowed for easy adjustment for project land use changes. This was also the format used by ACOG, who furnished this data.

Assignment of population, institutional (general), and commercial, was accomplished using in this instance, ACOG's information and census data. It is important to check that the population assignment to all SAU's sums to the actual population of the area. The special land use data, such as hospitals, educational institutions and military installations, were acquired from the sources described in Appendix A (14).

A major portion of this effort should be spent allocating the employees by SIC codes to each SAU. This information is also usually available at the planning agencies. It is obvious that this procedure is straightforward and can be accomplished by following the procedures outlined in Chapter II and Appendix A (14).

3.3 Land Use Projections

The projection of land use is a key input to any study. There are reasonable methods for projecting population, commercialization, industrialization, and life styles, but if it cannot be placed with any degree of accuracy, then the whole process has lost most of its value. One could depict the total needs of the area, but optimizing sources, networks, or facilities would be impossible. Therefore, one must expend his best efforts towards the accomplishment of this goal.

There appear to be several good and reasonable techniques used for the accomplishment of this goal. The methods we found most practical in our research are presented below. It must be remembered that the purpose of this step is to take the desired goals and life styles and project this area into the best "desired" world that can be visualized by the concerned agencies. This can and is being accomplished in many ways. Some agencies have even been accused of "playing God" or to the other extreme of building to enhance "vested interest". The best approach is, as always, to achieve the most good for the most people, while minimizing the inconvenience and maximizing the values.

3.3.1 Professional Planner Method

The projected land use and population distribution used in the validation of this model were acquired by the following method. The professional agency was the Association of Central Oklahoma Governments (ACOG) Planning Department.

The method basically is to provide the incremental population increases for the various life styles and allow the professional staff of the agency to allocate this population and its corresponding new and changed land uses to the study area. There are many advantages to this method, the greatest one being that the staff has "grown" with the area and is familiar with its trends and political nature. They also are well acquainted with the socio-economic patterns and their ramifications.

This method should give a more realistic view of the future to the study area, since the areas that are more likely to develop are given the higher priorities. The desires of developers and political interest groups are clearer and can be better evaluated by this agency. The planners are also familiar with other networks and systems of the region (transportation, air pollution, housing, etc.) and have a "feel" for the effect that certain modifications of existing and developing land use patterns will have on them. These systems and networks also can, and usually do, provide real and uncontrollable constraints to the growth patterns.

The disadvantages of this method are also quite distinct and can, in many instances, exceed the advantages. The most obvious one is created by the very nature under which these planning agencies are usually organized. Many of the planning agencies, such as ACOG, were organized to fulfill federal requirements under the Office of Management and Budget Circular A-95, using the enabling statutes of the Public Authority Act and the Intergovernmental Cooperation Act. The enabling statutes allow the organization of the COG's (Coalition of Governments), but the Circular requires that federal aid applications for over one hundred federal assistance programs, and most federal development projects, must be submitted through the designated metropolitan clearinghouses, ACOG in this case. Although it was the intent of this legislation to encourage intergovernmental cooperation for full utilization of local resources, the political results are not always idealistic in nature. Each political identity is forced to join in order to receive federal aid upon which it has become dependent. Each with its own "goals" and "desires", which are not always compatible, is required to form and support yet another political organization that will develop new goals and a "desired world" which is usally, to some degree anyway, in conflict with the individual member's views. The largest conflict is generally between the COG and the largest political jurisdiction of that group, who has the greatest needs and population.

It is this built-in political strife that leads a metropolitan planning agency to define its "desirable world" against those of member political jurisdictions which are incompatible. This is also true, only in reverse, if a large political jurisdiction and its own planning agency are developing a plan of their own.

When the COG's or the planning area and all of its members start pulling together, by gaming the alternatives, and start striving for a common "desired world," then, and only then, will this disadvantage be resolved.

There are other disadvantages, mainly from an analysis standpoint. In other words, without complete analysis, the future land use developed by the planners may not give optimum solutions to all of the other networks and systems of the area under study. This leads to yet other approaches for land use forecasting.

3.3.2 Analytical Methods

The approach used here is one in which an analyst looks at the logical approach without any knowledge of the area. The methods used vary greatly from one analyst to another but are basically optimization in nature. The analyst may want to minimize transportation costs and/or adverse environmental effects. He may also have as a goal to maximize socio-economic mixing of minority groups with the study area.

The analyst will take an optimization technique to achieve the plan within the constraints of the given goals. The more comprehensive the goals are, the more complicated this approach becomes. When a water and sewer plan is the desired result of his work, the analyst may be working only with the maximium utilization of the resources and existing facilities and minimizing costs to provide the future requirements.

Even when using the best intentions and current knowledge about land use planning, the analyst rarely achieves a plan that is acceptable to the entire area. He has no way of knowing the full ramifications of "his plan". An analyst can fall into the trap of "playing God" for the fulfillment of the optimal goal of dollars and cents. This happened with the transportation systems when freeways were allowed to divide, displace, and otherwise create severe hardships on people for the rapid movement of automobiles.

The socio-economic and long-term effects of this technique were slow in being realized. However, it has become increasingly clear that this technique does not produce a comprehensive plan without "local knowledge" being one of the inputs. The analyst who usually comes into the area for this job only does not have to produce a plan that he is then required to defend daily or to "live with".

It also becomes difficult for the existing local agencies to update or alter this plan. The techniques used are usually highly technical and complicated. The staffs of these local agencies do not always have the qualified personnel to carry these techniques forward in time.

3.3.3 Analyst - Planner Approach

It has become obvious that of the first two approaches presented, a combination of the two will produce better results than either one individually. Ideally, the planning agency would have as an integral part of its staff an analyst and the tools that he would need to do his job. Then the optimization can be achieved where the "knowledge of the area" can be used as one of the constraints.

This method is basically a "gaming technique". The analyst will establish jointly with the planner the goals and constraints to be used and then develop a plan toward their fulfillment. The planner and analyst will then look at this plan and its resultant effects on the study area, and then to the best of their ability derive a solution by gaming several alternatives for the achievement of a solution that will serve the area and its desired goals.

The advantage of this approach is the emphasis of both the "inside" and "outside" inputs to the plan, which, ideally, should produce a more comprehensive achievement of the "desired world".

3.3.4 "Hard-Core" Mathematical Modeling

Land use forecasting by this technique is being used in many of the metropolitan areas. The models are usually developed by the agencies themselves. This is a major decision when the planning agency starts to develop its own land use model, since the personnel and computer hardware required are significant budget items.

There are many different models in use at the present time. Most, such as the one developed for the San Francisco area, are very sophisticated in scope (17). They not only account for every parcel of land in the study area, but have wide and varied assortments of algorithms for evaluating each piece of land and its future use. The actual runs are both time consuming and expensive. Models of this nature, although they do have a specific purpose, are not good general planning models.

They create tremendous requirements in data accumulations and management, since the data must be kept updated and edited. If a metropolitan area decides on a particular model, then it dictates what data are to be accumulated, which in turn limits the modeling capabilities.

There are other disadvantages to using detailed land use models. One is that these models are so expensive to run and intepret that budget allowances may restrict the number of runs that can be made by the agency. It could then become "stuck" with one or two alternatives and be forced to use one of them without being able to investigate any of the other future worlds it would like to.

Another disadvantage of this technique is that very few of the people that make the decisions can comprehend the inter-workings of these models and are required to wait for interpretations by highly skilled personnel. If they have a specific question about a land use change, they sometimes need to wait days for an answer.

What is really needed is a general mathematical model that has very short turn around (15 minutes or less), limited data requirements, and can easily be interpreted. A model that the user agencies could use to "game" alternatives and quickly evaluate the results would be an asset to them.

A model of this type is currently under investigation at the University of Oklahoma. This model uses the neighborhood as the basic land parcel. It divides the city into existing neighborhoods of different classifications. It then takes these neighborhoods and forecasts them into the future by five year increments. These neighborhoods, with their land uses, have been altered by the algorithms developed for each classification.

The population model has been programmed to file in a matrix the delta increases in population for each increment. These delta increases are partially allocated to the changes in the old neighborhoods. The remainder are divided by their socio-economical characteristics into new neighborhood requirements which have to be developed. The planner then can place these neighborhoods in several alternative arrangements. He can then determine by "gaming techniques" the "desired world".

The data that all these different modeling techniques develop can be used in this particular model. Since this portion of the model is so critical, the assorted techniques and their inherent qualities are explained below.

3.4 Land Use Validation

This area of forecasting cannot be validated except by time. The true purpose of land use forecasting is to take the goals and desired life styles and place them into a land use scheme that will produce this "desired world". It is the establishment of the world we would like to achieve. It must be obtainable under optimum conditions. The "realistic world", the one which will actually be reached by compromise, is the one that will be achieved. By minimizing the difference, we validate the plan.

The validation of a process is in a sense possible, or at least implied, by virtue of a scheme, such as the one we have presented. Several approaches, as in Section 3.3, are used, and by starting with different assumptions, we can arrive at common or "practical obtainable goals".

3.5 Data Level Theory

The land use assignments outlined in Chapter III can be summarized in terms of four levels.

I Available analysts and data which can be acquired through available literature.

II The analyst, working with professional literature, attempting to get better or more realistic values.

III Shifting the data control to that of the planner from that of the analyst.

IV Finally, using econometric models to develop data.

In this project, interstitial modeling, or gaming brings these four levels into an interactional operation.

CHAPTER IV

DEMAND MODEL

4.1 Introduction

This chapter deals with the development of the Demand Sub-Model. Taking the current and projected data that were accumulated (Chapters II and III), this model calculates the actual water demands and sewage output for the study region by selected areas and topics.

The model uses selected technical coefficients that were developed (Chapter II) or acquired from other studies (see References 18, 19, 20). These coefficients are then applied to the data files to acquire the water and sewer outputs. The model is one of the final steps toward the development of the water and sewer plan for the region. It gives not only the future requirements of the study area, but also the incremental increases these areas have. This allows the user to see the actual increase that the existing system can handle or the amount at which the system will be over capacitated if it is already at or near capacity. Applying this model, the user can gain an adequate perspective of the water and sewer network.

4.2 Model Description

The demand sub-model portion of this study is the most demanding of all the programs. Although the program is not extremely complicated, the data requirements are rather tedious. The greatest portion of the inventory and analysis chapter (Chapter II) was directed to acquiring the data and projected data for running this particular program.

This program, as in the previous sub-models, has a great deal of flexibility built into the routines. The development of programs that give the user this degree of flexibility is time consuming but extremely rewarding. The fact that a planning agency can easily explore all facets of the possible world without going through great data changes or even reprograming, and still have a comprehensive model is advantageous.

The model will not only give the water and sewage requirements for any particular study year, but, by using the sub-model DELTA, a new data file can be created that will give an incremental change in the requirements from one study period to another. This, coupled with good editing sub-routines, gives the agency the capability of looking at any size or particular area by study years and/or incremental changes.

4.2.1 Model Concept

The demand sub-model is an application of technical coefficients to derive the water and sewage requirements and the accounting of these requirements to the different study areas for output. This is an over simplification, of course, but it is the basic concept behind the model.

The data is supplied to the model for each statistical analysis unit (SAU). These SAU's were selected as one square mile areas. This is made possible by the methods of surveying used in this state, but the model does not require that these areas be one square mile. Any system can be used that will require six numerical digits and account for all the areas in the study region. The SAU's need to be kept in the size that approximates a square mile, but not more than two or three square miles. The SAU's can be as small as needed for the type of detail wanted.

The rural areas can be larger, but if development is a possibility within the time frame of the study, they should be reduced to the size that they will be after development. The time spent by a planning agency coding the SAU's in their study area will be worthwhile, if it is compatible with all other boundary areas used in this program (i.e. political jurisdiction, watershed, etc.). It is suggested that a map be used that has the other boundaries on it (including census tracts, although they have a bad habit of not being conducive to any other study but their own) and SAU's be made using these boundaries as much as possible. This will allow better analysis of the output results.

The coding of the other areas is accomplished much in the same fashion. The other areas are as follows:

1. Political jurisdistion
2. Watershed
3. Water treatment plant
4. Storage system
5. Waste treatment plant
6. Receiving stream
7. Water source

It is suggested that all areas except watershed and receiving stream be coded numerically in sequence. In other words, start with one and numerically allocate each succeeding number of each area till they are all accounted for. Each new plant or jurisdiction will be assigned the next number in its area. These numbers of the area members are needed to set the "Do Loops" within the model. This will also prevent the program from handling large matrices that have many zeros in their structure.

The coding of the streams and watersheds can best be accomplished by using the following scheme:

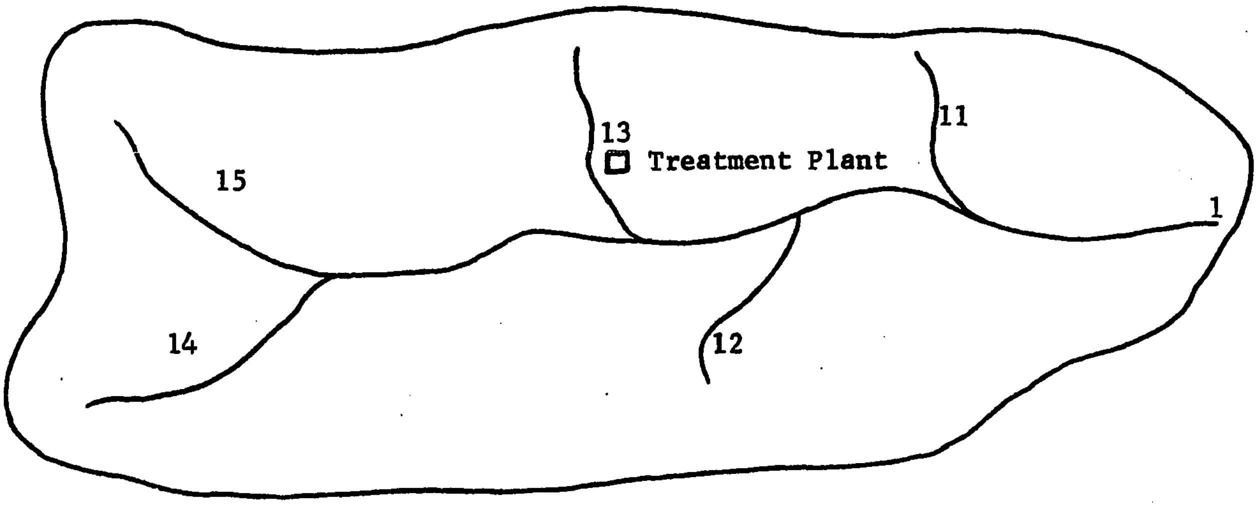


Figure 4-1. The Coding of Streams and Watersheds

This would be watershed 1 and the plant is on receiving stream 13.

The demand sub-model also has the capability of looking at several special areas made up of selected SAU's independently or with the general study. This allows the user to game several alternatives at one time to see which special area is more suited for certain goals or objectives.

The sub-model also has the capability of handling special users of water. These are the users that fit in one of the 29 assignment areas (such as SIC 24), but does not have water usage that fits the linear equation for computing it. These areas can be handled individually and this will relieve the model of complicated functions for water usage or sewage return flow.

These are the basic sub-model concepts and their general application. The use of this model will greatly reduce the process of computing water and sewage demands for large metropolitan areas. It also allows the user a large degree of freedom for exploring the alternatives for the future worlds.

4.2.2 Model Methodology

The demand sub-model is run for each time increment wanted by the study. For each run a data file of all the information described in Section 4.5 is needed. These data files are duplicated as far as the area codings are concerned. The base year (1970 for this study) contains the inventory data collected in Chapter II.

The data files for the future years are developed from the projected data. These files have to be built using the same areas that existed in the previous files, but can have new SAU's in addition to the old ones.

The model with all of its subroutines is shown in Tables 4-1 through 4-5. The model can easily be followed by using these diagrams and the program listings in Section 4.5.2. The outputs are by the following categories:

A. Water requirements by:
   1. Political jurisdiction
   2. Source of supply
   3. Water treatment plant
   4. Water storage system
   5. Special area

B. Sewage loads by:
   1. Political jurisdiction
   2. Watershed
   3. Sewage treatment plant
   4. Receiving stream
   5. Special area

With each category broken down by:

1. Domestic
2. Institutional (including hospitals, schools and military bases)
3. Commercial
4. Industrial by SIC code and special user irrigation

The outputs from the above categories can be selected by using Card 6 of the input data.

Table 4-1 MAIN (DEMAND)

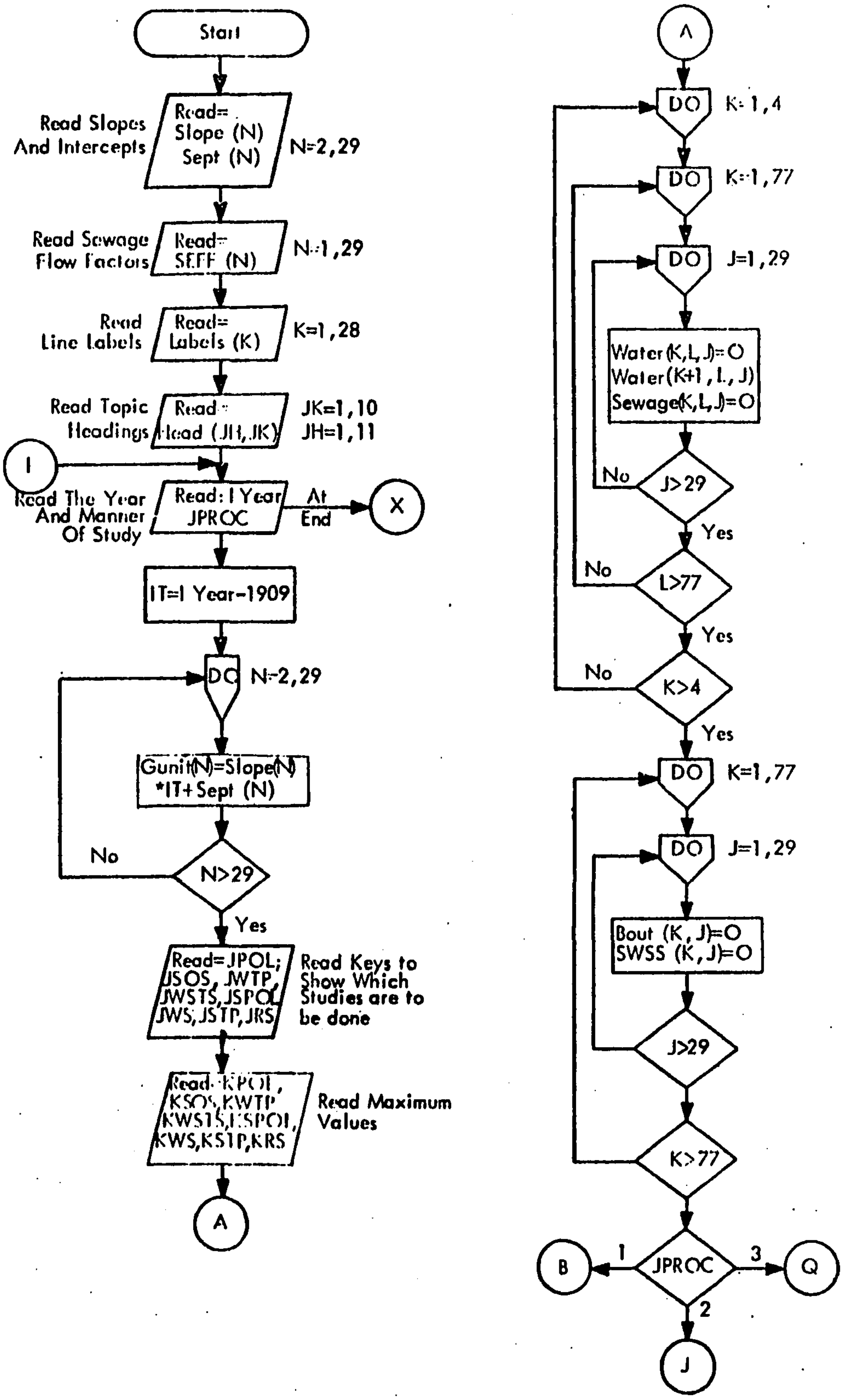


TABLE 4-1 MAIN (DEMAND) Cont.

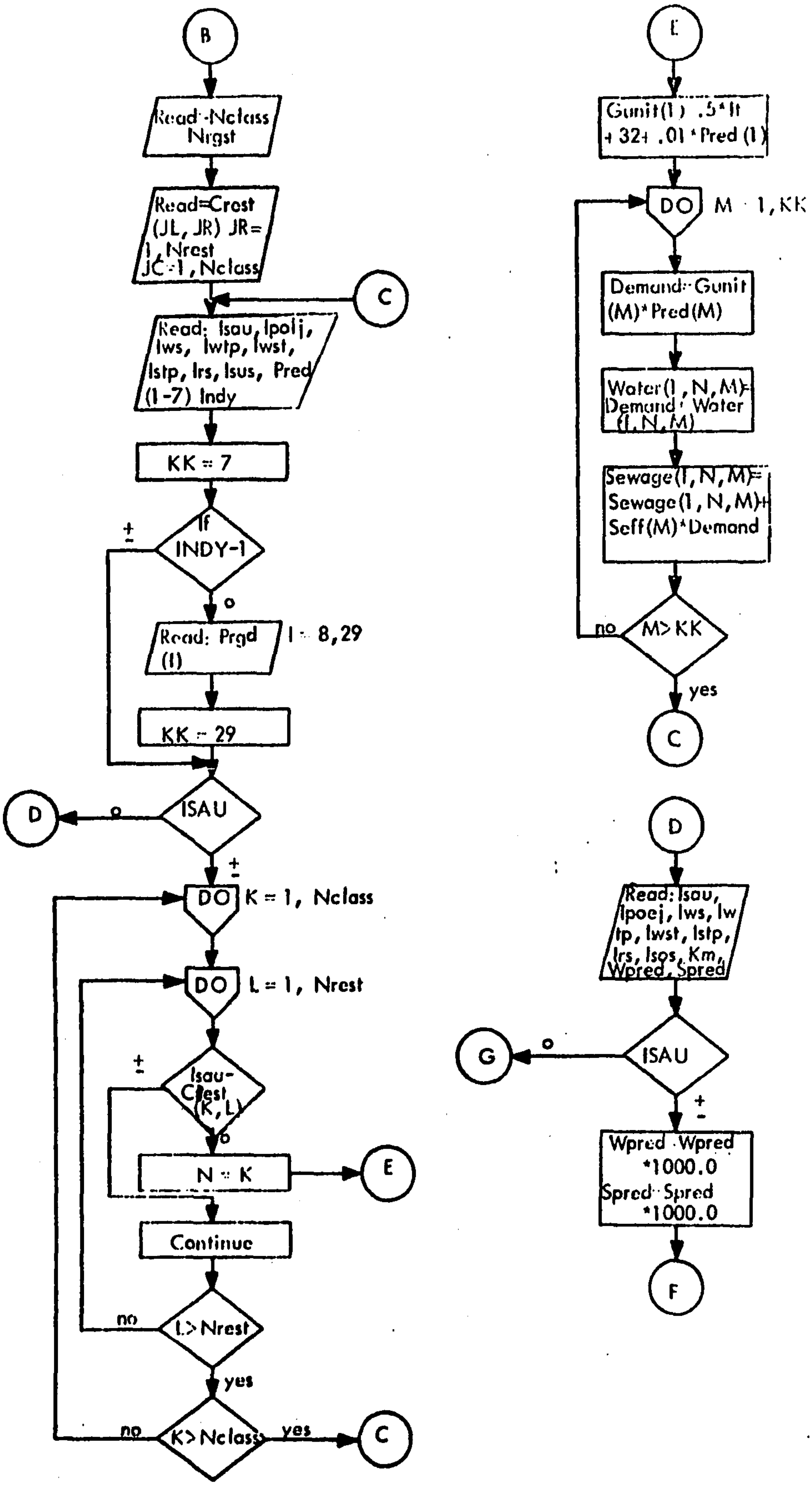


TABLE 4-1 MAIN (DEMAND) Cont.

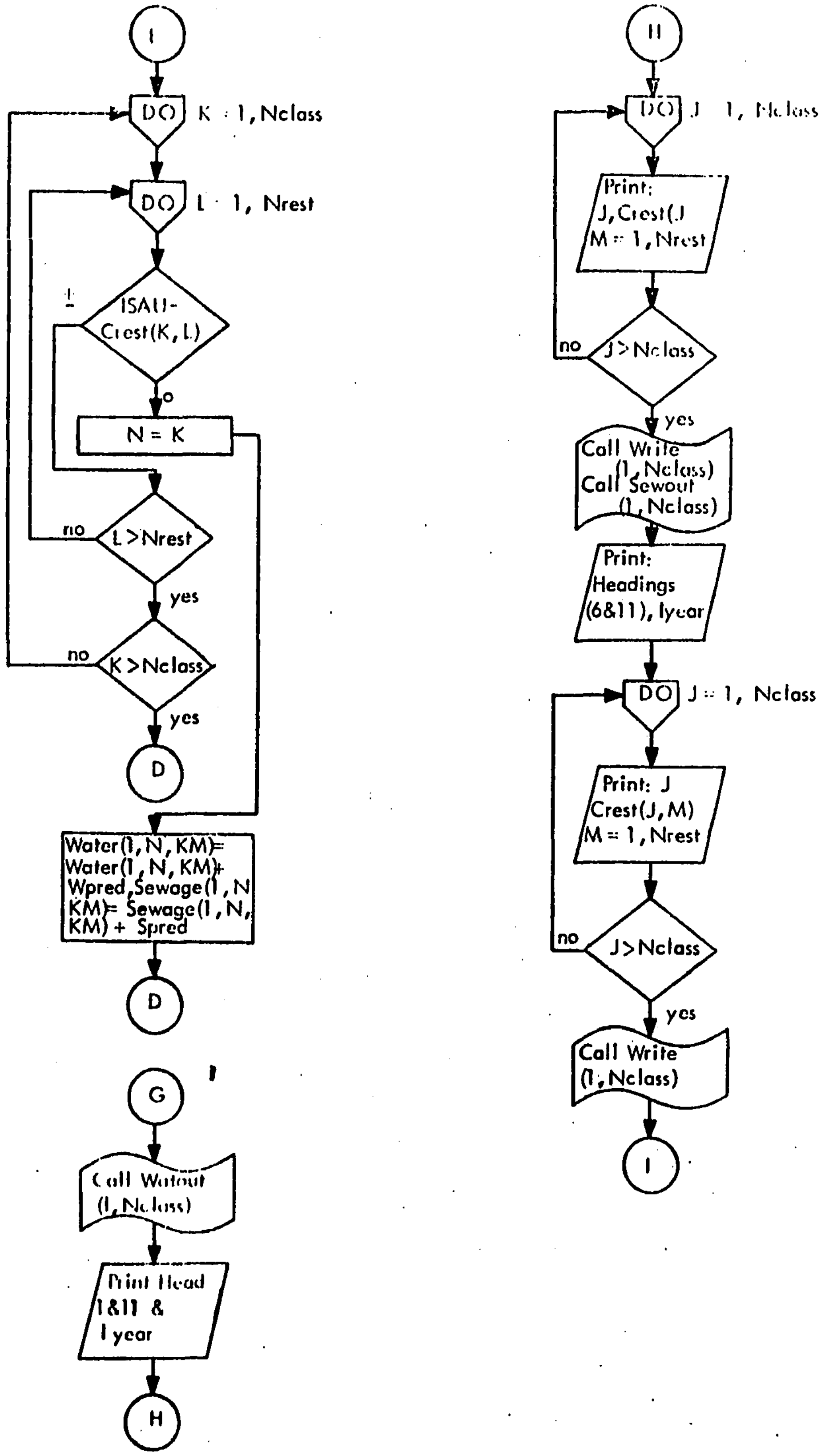


TABLE 4-1 MAIN (DEMAND) Cont.

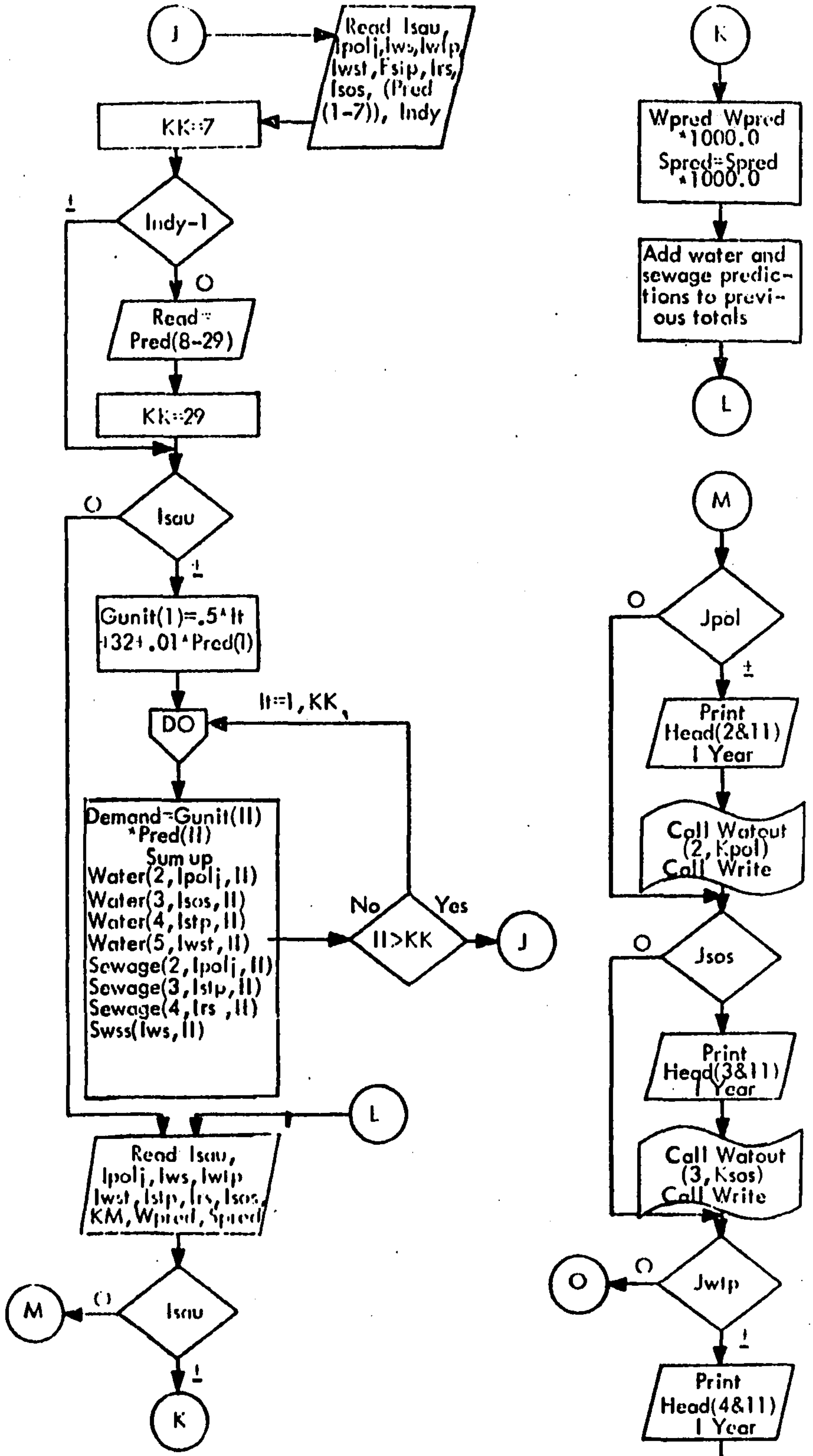


TABLE 4-1 MAIN (DEMAND) Cont.

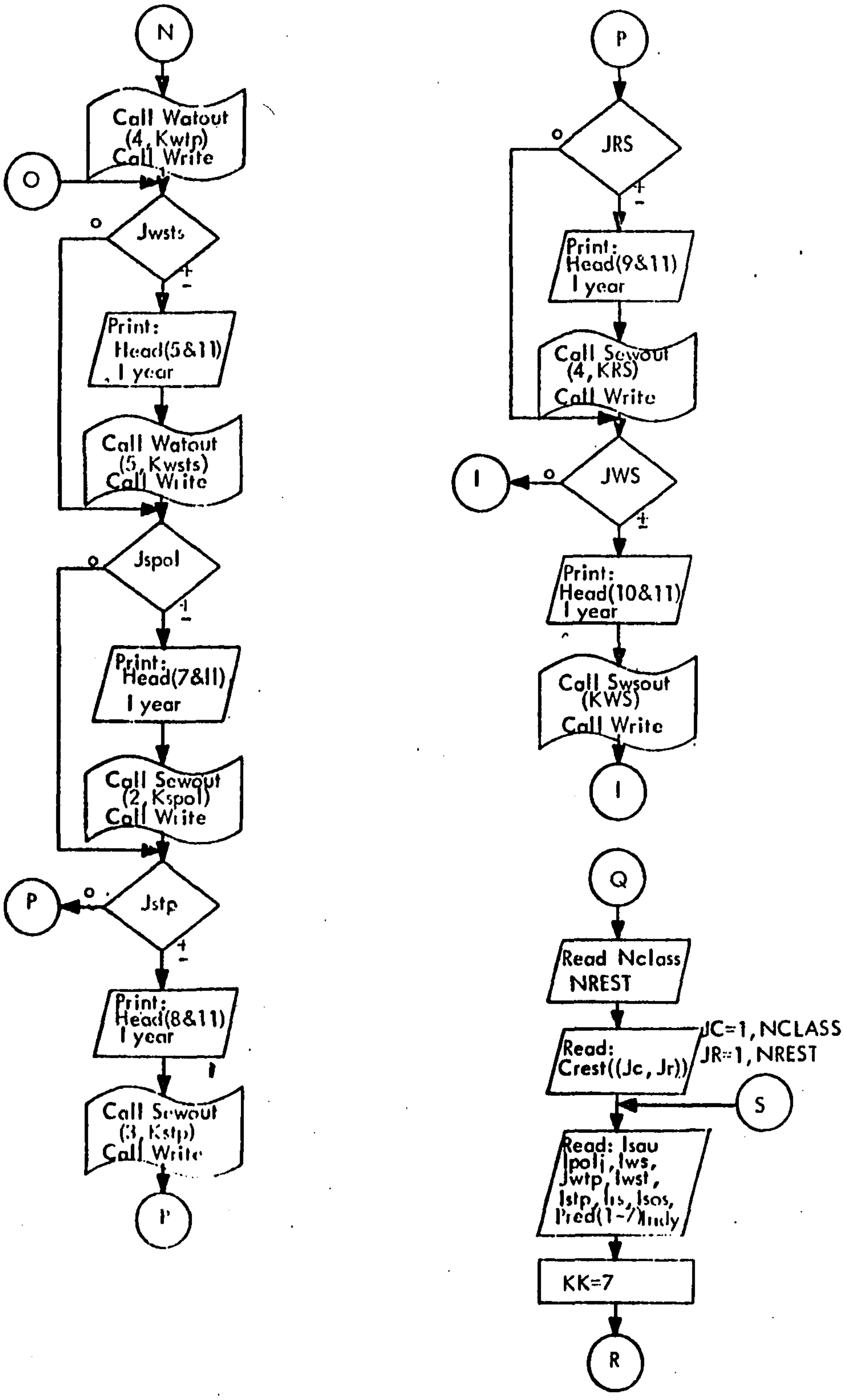


TABLE 4-1 MAIN (DEMAND) Cont.

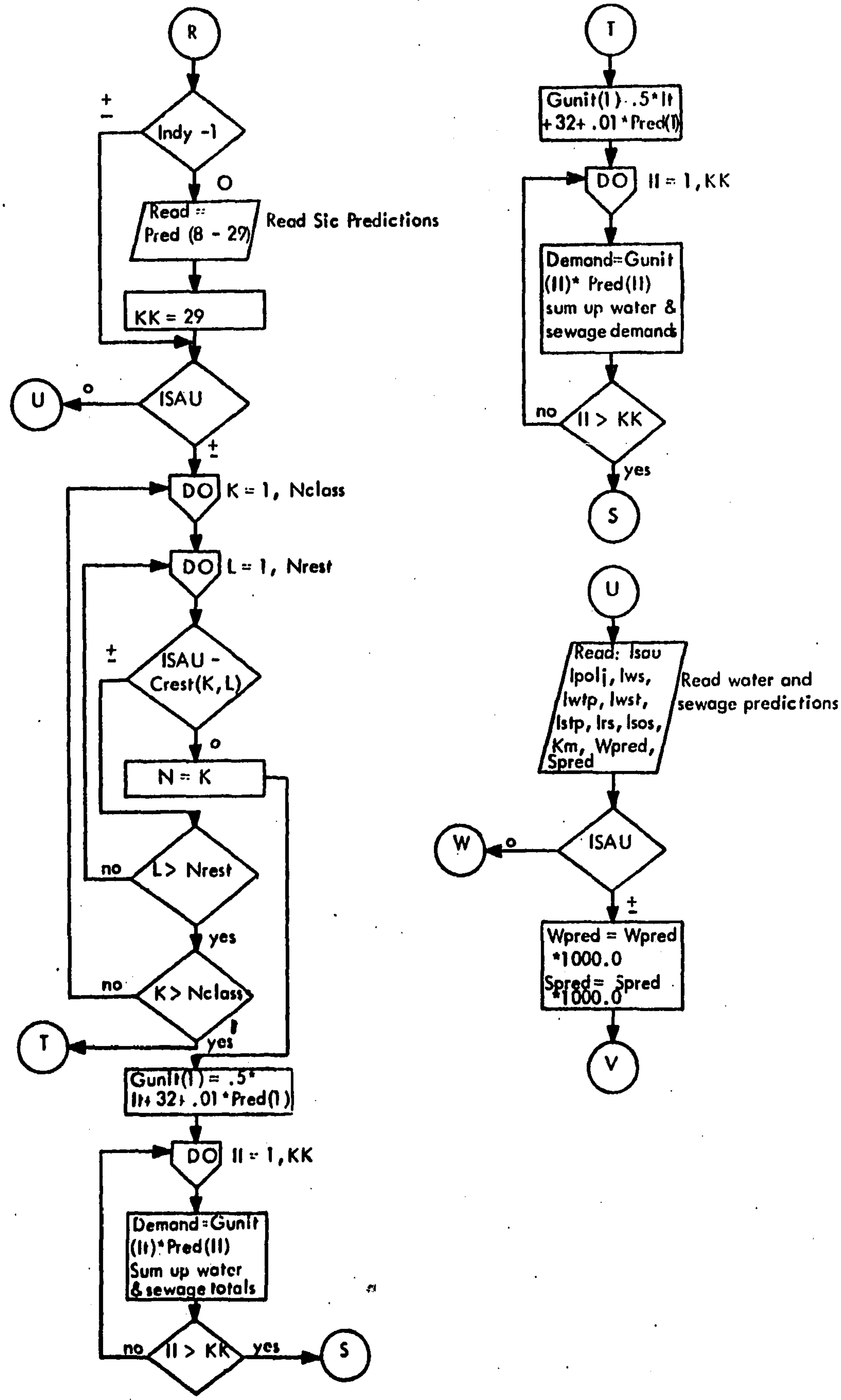


TABLE 4-1 . MAIN (DEMAND) Cont.

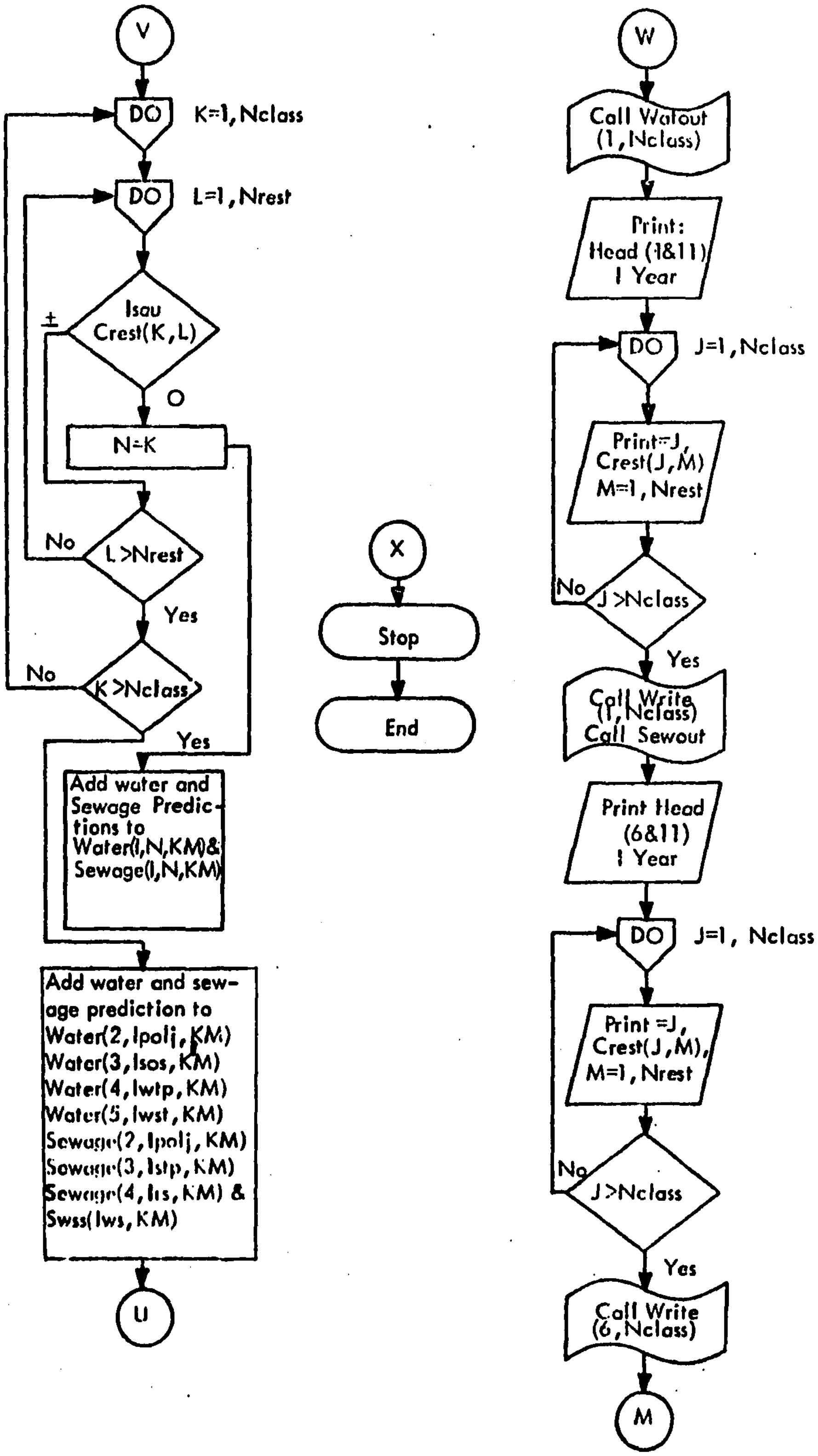


TABLE 4-2. SUBROUTINE WATOUT (KTYP, KKK)

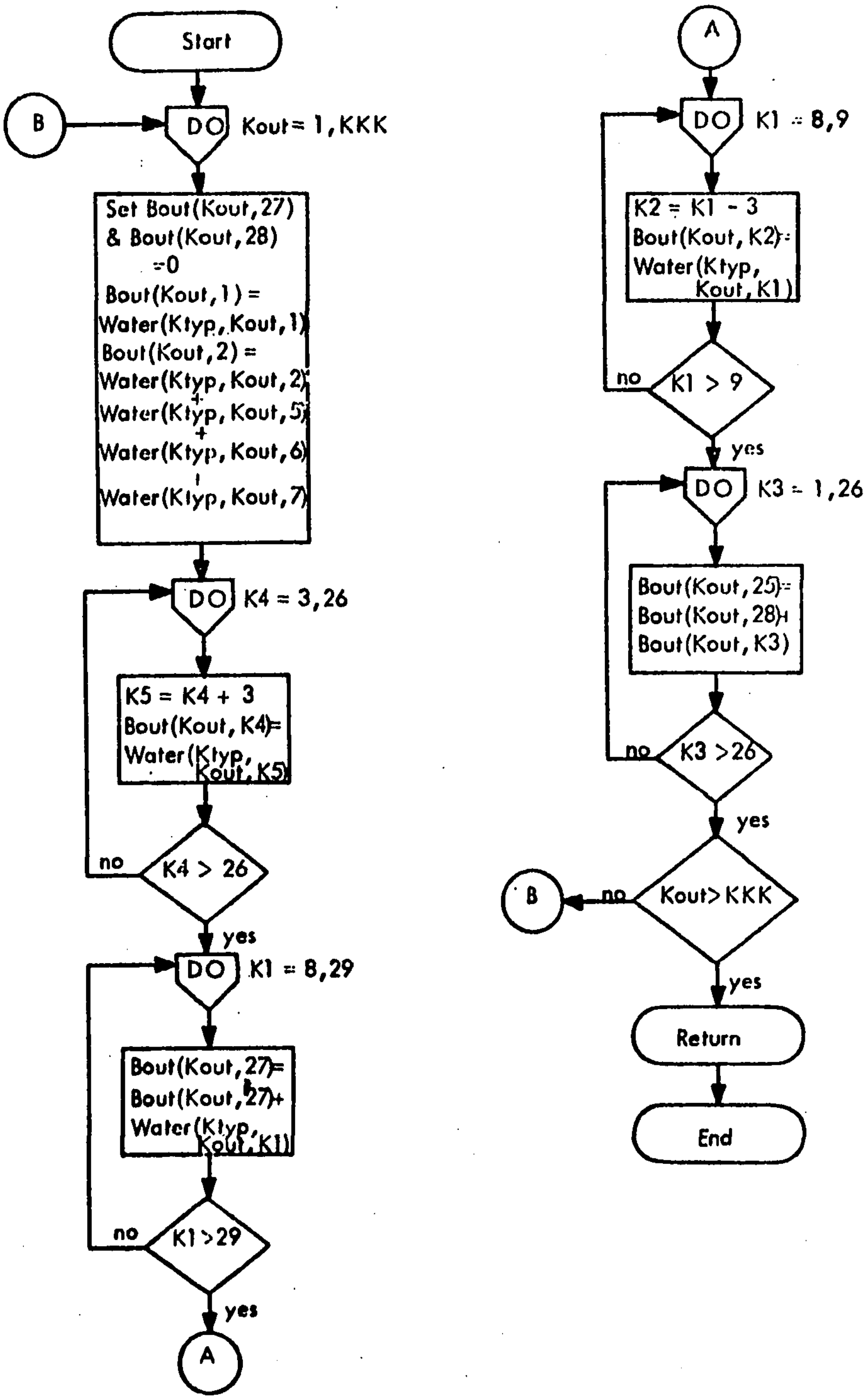


TABLE 4-3. SUBROUTINE WRITE (KH, KL)

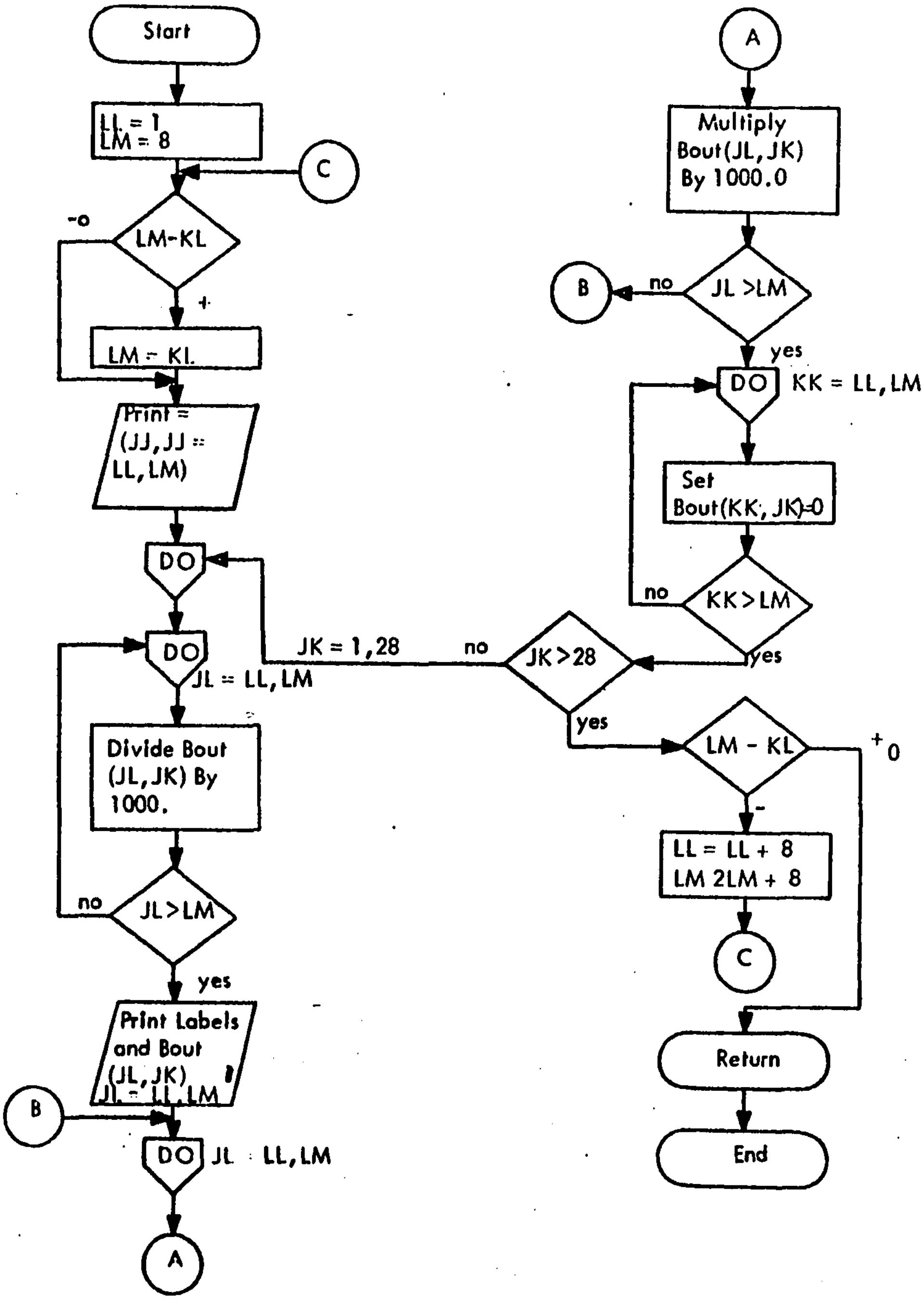


TABLE 4-4. SUBROUTINE (KTYP, KKK)

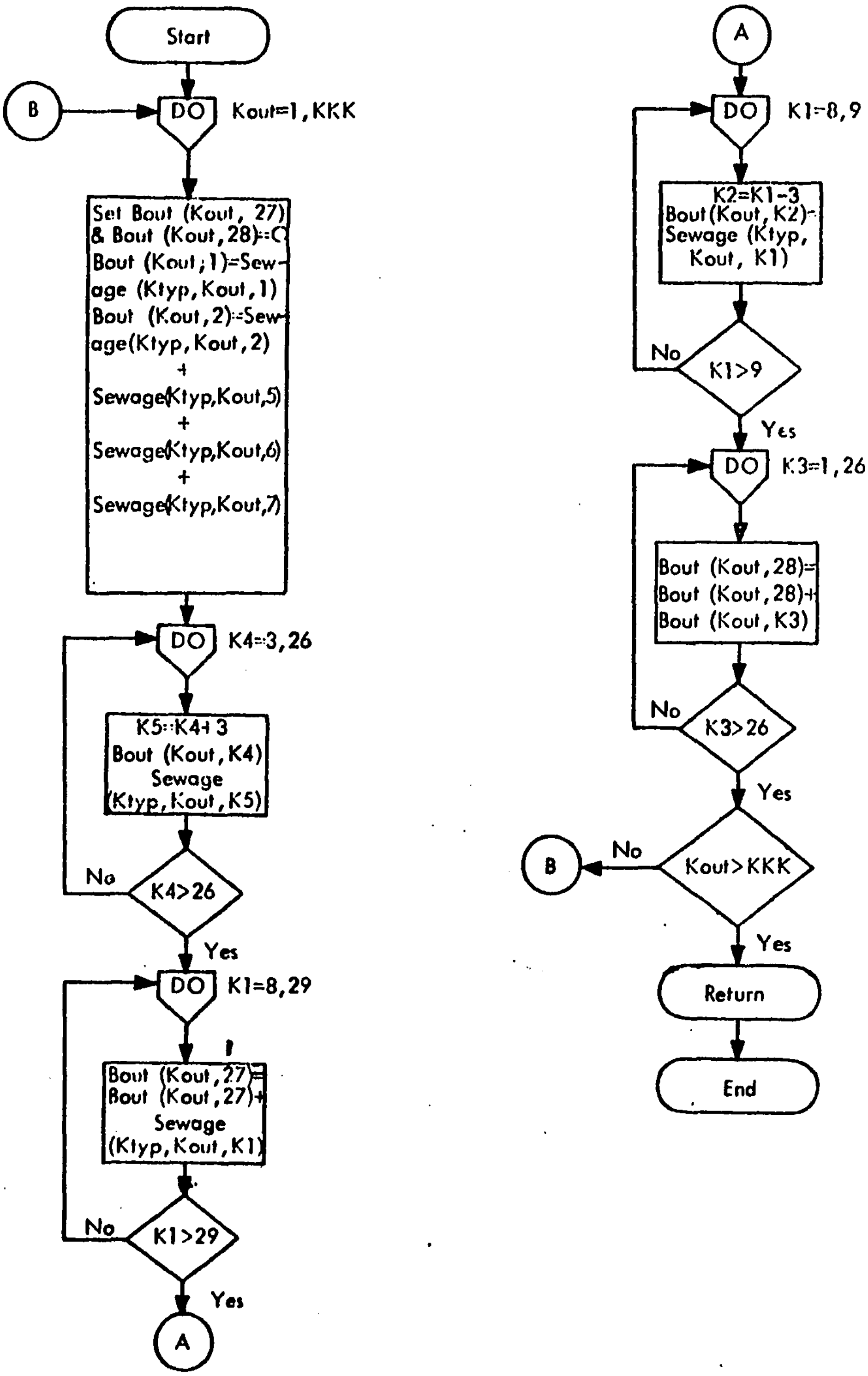
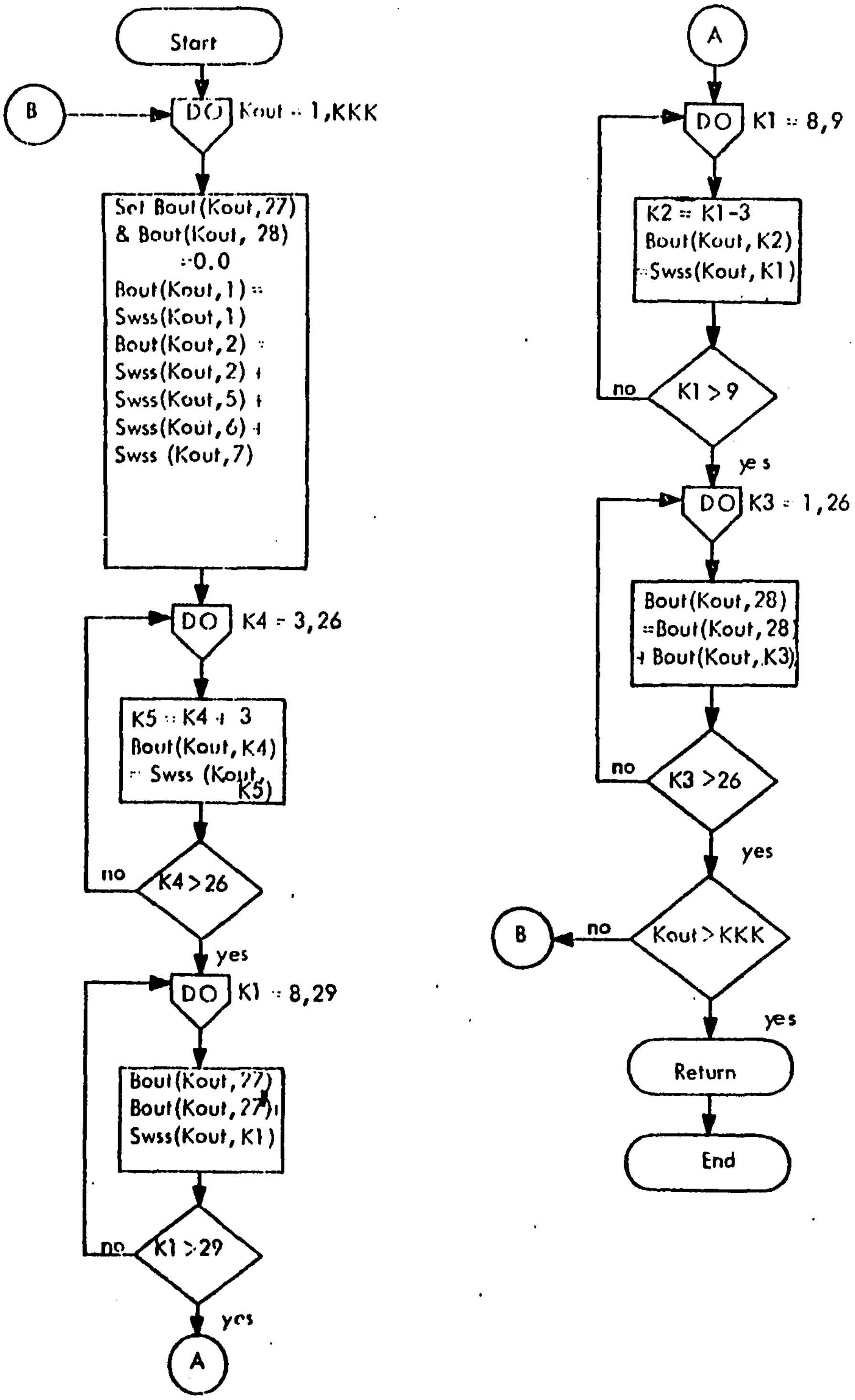


TABLE 4-5. SUBROUTINE SWSOUT (KKK)



4.3 Data Requirements

The demand model is written in Fortran IV for the General Electric Time-Sharing System. The data from this system were stored in files; therefore, the program would have to have minor alteration for other systems.

The data requirements for this system are quite extensive and require good data management to keep it in proper order. The data used in this model was not the correct data from the ACOG area. Specific data about industries by the SIC's code were not available without extensive survey work which was not funded and could not be accomplished in the framework of this study. Some industrial data were added for verification of the model and its sub-routines.

The source and development of the data for this model are explained in Section 4.3.1 of this chapter.

4.3.1 Input

All of the following cards must be presented in the order shown. This data is shown in the listing of the data file in Section 4.4. The sources and formats of the various cards are described as follows:

Card 1, WATER SLOPE-INTERCEPT CARDS

There are 28 of these cards, one for each category of user, except "domestic", which is built into the program. The categories and factors used are listed at the end of this sub-section. The sequence of input by the categories must be maintained throughout the input. Therefore, it starts with institutional and ends with SIC 10-17, 40-50.

Col. 1 - 6 Slope

Col. 7 - 8 Blank

Col. 9 - 14 Intercept

Right justified in field or include decimal point. This input feeds a linear equation of the form

$$y = a \cdot t + b$$

where "b" is the intercept in gallons per unit of input (acre, employee, hospital bed, etc.), and "a" is the slope in gallons per year. The slope provides a rate of change in water use for future years and "t" is the years into the future from the base year (t=0). Source was the Bartone State Water Model (23).

Card 2, SEWAGE FLOW FACTORS

There are 29 of these cards, one for each category in proper sequence. This is the percent of water used by each category that is returned as sewage. It is expressed as the decimal equivalent (99% = 0.99). Source was same as Card 1.

Col. 1 - 6 Flow (decimal)

Card 3, LABELS

These are the labels for each row of output for each specific study. It is in the same sequence order as the previous cards with a few exceptions. The labels are as follows:

1. Domestic
2. Institutional (including sequence order 2,5,6,7)
3. Commercial
4. Irrigated land
5. SIC 19
26. SIC 39
27. Total all SIC's
28. Total all users

There are a total of 28 cards with the labels centered in columns 1-16.

Card 4, HEADINGS

There are eleven headings, one card each, centered in columns 1-40. The headings are the titles for each type of output. The headings are as follows:

1. Water by SAU
2. Water by political jurisdiction
3. Water by source of supply
4. Water by water treatment plant
5. Water by storage system
6. Sewage by SAU
7. Sewage by political jurisdiction
8. Sewage by treatment plant
9. Sewage by receiving stream
10. Sewage by watershed
11. Thousand of gallons per day

Card eleven is the way the model is geared for output.

Card 5, YEAR AND TYPE OF STUDY

Col. 1 - 4	Year of study	
Col. 5	Blank	
Col. 6	Type, where type is:	"1" for special areas only "2" for general study "3" for both studies
Col. 7	Blank	
Col. 8 - 11	Year of earlier study if the data file is a "difference" or incremental file. That is, as shown in Section 4.6 (1990-<u>1970</u>), these columns are left blank if only a one year study is being run.	

Card 6, OUTPUT CONTROL CARD

This card controls the output by the labels as given in Card 4. By placing a "1" in the proper output column, the program will print this output for that label. A "0" in that column deletes that output. The data is right justified.

SAMPLE LISTING

Sequence No	Category	Water Use	Sewage Factor *
1	Domestic	(32 + .01 pop) + 1/2 gal/yr	.70
2	Institutional (general)	1000 gal/acre/day	.70
3	Commercial	1680 gal/acre/day	.70
4	Irrigated land	870 gal/acre/day	.00
5	College	95 gal/student/day + 1 gal/yr	.70
6	Hospital	192 gal/bed/day + 1/2 gal/yr	.70
7	Military	151 gal/cap/day + 1/2 gal/yr	.70
8	SIC 19	204 gal/employee/day	.94
9	SIC 20	1400 g/e/d	.91
10	SIC 21	168 g/e/d	.67
11	SIC 22	644 g/e/d	.91
12	SIC 23	60 g/e/d	.94
13	SIC 24	904 g/e/d	.82
14	SIC 25	79 g/e/d	.94
15	SIC 26	9762 g/e/d	.94
16	SIC 27	260 g/e/d	.94
17	SIC 28	14584 g/e/d	.94
18	SIC 29	25157 g/e/d	.94
19	SIC 30	1130 g/e/d	.95
20	SIC 31	215 g/e/d	.94
21	SIC 32	1434 g/e/d	.88
22	SIC 33	11196 g/e/d	.94
23	SIC 34	249 g/e/d	.93
24	SIC 35	421 g/e/d	.95
25	SIC 36	264 g/e/d	.87
26	SIC 37	551 g/e/d	.95

SAMPLE LISTING (Continued)

Sequence No	Category	Water Use	Sewage Factor
27	SIC 38	363 g/e/d	.90
28	SIC 39	175 g/e/d	.93
29	SIC 10-17,40-50	60 g/e/d	.94

* These sewage factors will not be constant. The new EPA standards will probably cause a reduction in these factors. A program can be developed to predict these factors over time.

Col. 1 - 2 for the water by political jurisdiction output

Col. 3 - 4 for the water by source of supply output

Col. 5 - 6 for the water by water treatment plant output

Col. 7 - 8 for the water by water storage system output

Col. 9 -10 for the sewage by political jurisdiction output

Col. 11-12 for the sewage by watershed output

Col. 13-14 for the sewage by sewage treatment plant output

Col. 15-16 for the sewage by receiving stream output

Card 7, AREA SIZE CONTROL CARD

This card has the same format as Card 6 and is the maximum number of areas entered for each output as listed in Card 6 (for example, if one had 12 water treatment plants, coded 01 through 12, he would enter 12 in columns 5 and 6). The maximum areas for any output are limited to 77.

Card 8, SPECIAL AREA CONTROL CARD

This card is used only if a "1" or "3" is placed in column 6 of Card 5. When special areas are to be used, the card is filled out.

Col. 1 - 3 Number of special areas to be run.

Col. 4 - 5 The maximum number of SAU's that is in any of the special areas. This controls the "Do" loops and the highest number of SAU's that is any one special area is used.

Card 9, SAU'S IN SPECIAL AREAS

This card is used only when Card 8 is present. The cards are stacked in the order of the special areas.

Col.	1 - 6	SAU: The SAU's for the first special area are stacked, one SAU to a card, until all SAU's for that special area are entered. Then the deck is padded with blank cards till the total number of cards is equal to the maximum number entered in column 4-5 of Card 8. Then the SAU's for the next special area are added and padded until all special areas are loaded.

Card 10, DATA OR PREDICTION CARDS FOR EACH SAU

This series of cards is the actual data that were derived from Chapter IV of this study. There can be up to three cards for each SAU, depending on the presence of industry within the SAU. If there is no industry, then there will be only one card per SAU.

Card "A". This card will exist for each SAU.

Col.	1 - 6	SAU
	7	Blank
	8 - 9	Political jurisdiction code
	10-12	Watershed code
	13-18	Blank
	19-20	Water treatment plant code
	21-22	Storage system plant code
	23-24	Waste treatment plant code
	25-26	Receiving stream code
	27-28	Water source code
	29-34	Blank
	35-39	Population in SAU
	40-44	Institutional land use in acres (general)
	45-49	Commercial land use in acres
	50-54	Blank
	55-59	Irrigated land in acres
	60-64	College in number of students
	65-69	Hospital in number of beds
	70-74	Military in number of persons
	75-76	Blank
	77	Code "0" if no industry in SIC's, "1" if using SIC's

Card "B". The number of employees are entered in the column for that SIC that exist in this SAU.

Col.	1 - 5	SIC 19
	6 -10	SIC 20
	11-15	SIC 21

16-20	SIC 22
21-25	SIC 23
26-30	SIC 24
31-35	SIC 25
36-40	SIC 26
41-45	SIC 27
46-50	SIC 28
51-55	SIC 29
56-60	SIC 30
61-65	SIC 31
66-70	SIC 32
71-75	SIC 33
76-80	SIC 34

Card "C". This card is for the remaining SIC's and is always present when Card "B" is used.

Col.	1 - 5	SIC 35
	6 -10	SIC 36
	11-15	SIC 37
	16-20	SIC 38
	21-25	SIC 39
	25-30	SIC 10-17 and 40-50

All data is right-hand justified.

Card 11, GENERAL STUDY TERMINATION CARD

This card is used after all the SAU's have been entered for the general study.

Col. 6 "0"

Card 12, SPECIAL USER CARDS

These cards are added if there exists special water users that do not fit the generalized equations used in the rest of the model. These users have to be specially assigned and are usually the larger industrial complexes.

Col.	1 - 6	SAU
	7	Blank
	8 - 9	Political jurisdiction code
	10-12	Watershed code
	13-18	Blank
	19-20	Water treatment plant code

21-22	Storage system plant code
23-24	Waste treatment plant code
25-26	Receiving stream code
27-28	Water source code
29	Blank
30-31	Type of assignment code (1 through 29)
32-36	Water prediction (gallons per day)
37-41	Sewage prediction (gallons per day)

Card 13, TERMINATION CARD

This card ends program.

Col. 6 "0"

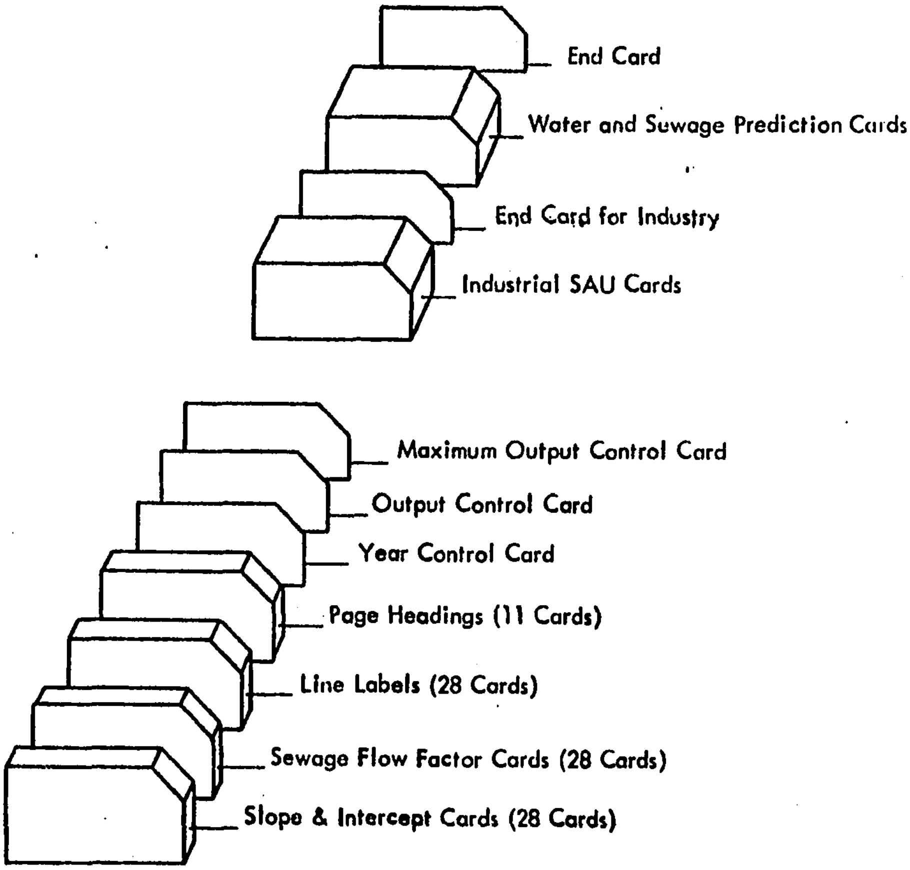
4.4 Data Arrangement

The proper card order is shown in Figure 4-2, "Demand Data Deck Set-Up", on the following page. This card order is for the "general study" and matches the listing of data in Section 4.5.1

4.5 Model Format

The format for the 1970 portion of the validation run is presented in this section. The data format is illustrated in Section 4.4 of this chapter. The actual run is made using 1970 data and 1990 data. Then by deleting all data from the file for the future data above Card 10 and using program DELTA and a data file for a selected base year, a data file for the incremental change in water and sewage is created. This file can then be run with the demand model and the output is the incremental change between the two time periods. An example of the incremental change output is shown in Section 4.6 for the time period 1970-1990.

This added capability will greatly increase the users gaming options to determine how changes increase the actual demands on systems above their



DATA DECK SET-UP FOR GENERAL SOLUTIONS TO DEMAND MODEL

Figure 4-2. Demand Data Deck Set-Up

present operation. The use of equipment with good editing capabilities is mandatory if good use of alternative runs is to be made. This capability gives the user full gaming capabilities of looking at all future alternatives for all areas.

4.5.1 Input Data

The data listed on the following pages are for the 1970 run of the demand model and are listed in the sequence as described in Section 4.4.

0.	1000.	0.9400
0.	1680.	0.9400
0.	870.	0.9400
1.0	95.	0.9400
0.5	192.	0.9500
0.5	151.	0.9400
0.	204.	0.8800
0.	1400.	0.9400
0.	168.	0.9300
0.	644.	0.9500
0.	60.	0.8700
0.	904.	0.9500
0.	79.	0.9000
0.	9762.	0.9300
0.	260.	0.9400
0.	14584.	DOMESTIC
0.	25157.	INSTITUTIONAL
0.	1130.	COMMERCIAL
0.	215.	IRRIGATED LAND
0.	1434.	SIC 19
0.	11196.	SIC 20
0.	249.	SIC 21
0.	421.	SIC 22
0.	264.	SIC 23
0.	551.	SIC 24
0.	363.	SIC 25
0.	175.	SIC 26
0.	60.	SIC 27
0.7000		SIC 28
0.7000		SIC 29
0.7000		SIC 30
0.0000		SIC 31
0.7000		SIC 32
0.7000		SIC 33
0.7000		SIC 34
0.9400		SIC 35
0.9100		SIC 36
0.6700		SIC 37
0.9100		SIC 38
0.9400		SIC 39
0.8200		SIC OTHER
0.9400		TOTAL ALL SIC'S
		TOTAL ALL USER

```
              WATER BY SAU
   WATER BY POLITICAL JURISDICTOION
      WATER BY SOURCE OF SUPPLY
    WATER BY WATER TREATMENT PLANT
    WATER BY WATER STORAGE SYSTEM
            SEWAGE BY SAU
   SEWAGE BY POLITICAL JURISDICTION
   SEWAGE BY SEWAGE TREATMENT PLANT
     SEWAGE BY RECEIVING STREAM
       SEWAGE BY WATERSHED
   THOUSANDS OF GALLONS PER DAY
1970 2
 1 1 1 1 1 1 1 1
3630 8 536304013
062250  2  1       1 1 1 1 1        1.   0.   1.        0.   0.  54.   0.  1
  22.  22.  22.  22.  22.  22.  22.  22.  22.  22.  22. 222.  22.  22.  22.  22.
  22.  22.  22.  22.  22. 662.
072350  1  1       1 1 1 1 1        1.   0.   1.        0. 494.   0.   0.  0
072820  1  1       1 1 1 1 1        1.   0.   1.        0.   0.  31.   0.  1
  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.
  15.  15.  15.  15.  15. 315.
112210 20 20       6 1 9 220       20.   0.   1.        0.   0.   0.   0.  0
112220 20 20       6 1 9 220       20.   0.   1.        0.   0.   0.   0.  0
112230 20 20       6 1 9 220       20.   0.  10.        0.   0.   0.   0.  0
112240 20 20       6 1 9 220       10.   0.   1.        0.   0.   0.   0.  0
112250 20 20       6 1 9 220       10.   0.   1.        0.   0.   0.   0.  0
112260 20 20       6 1 9 220       10.   0.  10.        0.   0.   0.   0.  0
112110 20 20       6 1 9 220        1.   0.   7.        0.   0.   0.   0.  0
112120 20 20       6 1 9 220     5049.   0.  20.        0.   0.   0.   0.  1
  15.  15.  15.  15.  61.  32.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.
  15.  15.  15.  15.  15. 378.
112130 20 20       6 1 9 220     1000.   0.  25.        0.   0.   0.   0.  0
112140 20 20       6 1 9 220       30.   0.   1.        0.   0.   0.   0.  1
  21.  21.  21.  21.  21. 180.  21.  21.  21.  21.  21.  21.  21.  21.  21.  21.
  21.  21.  21.  21.  21. 579.
112150 20 20       6 1 9 220     1000.   0.   8.        0.   0.   0.   0.  1
   8.   8.   8.   8.  34.  71.   8.   8.   8.   8.   8.   8.   8.   8.   8.   8.
   8.   8.   8.   8.   8. 257.
```

112160	20	20	6	1 9	220		50.	0.	3.		0.	0.	0.	0.	0
112010	20	20	6	1 9	220		16.	0.	1.		0.	0.	0.	0.	0
112020	20	20	6	1 9	220		13.	0.	1.		0.	0.	0.	0.	0
112030	20	20	6	1 9	220		4.	0.	1.		0.	0.	0.	0.	0
112040	25	20	7	1 1	225		2.	0.	1.		0.	0.	0.	0.	0
112050	20	20	7	1 9	220		1000.	0.	1.		0.	0.	0.	0.	0
112060	25	20	7	1 9	225		1.	0.	1.		0.	0.	0.	0.	0
111710	30	10	1	110	230		240.	0.	1.		0.	0.	0.	0.	0
111720	30	20	1	110	230		32.	0.	1.		0.	0.	0.	0.	1
21.	21.	21.	21.	21.	180.	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
21.	21.	21.	21.	21.	579.										
111730	30	20	1	110	230		645.	0.	1.		0.	0.	0.	0.	0
111740	30	10	1	110	130		54.	0.	1.		0.	0.	0.	0.	0
111750	30	10	1	110	130		10.	0.	1.		0.	0.	0.	0.	0
111760	30	10	1	110	130		13.	0.	1.		0.	0.	0.	0.	0
122410	25	30	4	131	725		170.	0.	1.		0.	0.	0.	0.	0
122420	25	30	4	131	725		113.	0.	2.		0.	0.	0.	0.	0
122430	25	30	4	131	725		5.	0.	1.		0.	0.	0.	0.	0
122440	25	30	4	131	725		5.	0.	3.		0.	0.	0.	0.	0
122450	25	30	4	111	725		14.	0.	3.		0.	0.	0.	0.	0
122460	25	30	4	131	725		24.	0.	1.		0.	0.	0.	0.	0
122010	25	20	4	111	225		15.	0.	1.		0.	0.	0.	0.	1
0.	0.	0.	0.	0.	233.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	233.										
122020	25	20	4	111	225		74.	0.	1.		0.	0.	0.	0.	1
0.	0.	41.	0.	190.	156.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	387.										
122030	25	20	4	111	225		22.	0.	1.		0.	0.	0.	0.	0
122040	25	20	4	111	225		36.	0.	1.		0.	0.	0.	0.	1
10.	10.	10.	10.	10.	110.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.
10.	10.	10.	10.	10.	300.										
122050	25	20	4	111	225		189.	0.	1.		0.	0.	0.	0.	0
122060	25	20	4	111	225		4.	0.	1.		0.	0.	0.	0.	0
121710	30	20	1	110	230		636.	0.	1.		0.	0.	0.	0.	0
121720	30	20	1	110	230		92.	0.	1.		0.	0.	0.	0.	0
121730	30	20	1	110	230		328.	0.	1.		0.	0.	0.	0.	1
21.	21.	21.	21.	21.	180.	21.	21.	21.	21.	21.	21.	21.	21.	21.	21.
21.	21.	21.	21.	21.	579.										

continued

4.5.2 Main Demand Model

The following is a listing of the main program and the subroutines used in the Demand Model. Also shown is the program used to obtain the delta-change file. These programs are described in Section 4.2 of this chapter.

```
      OPTION LOAD
      INTEGER CREST
      DIMENSION CREST(77,30),PRED(29),SEFF(29),GUNIT(29),
     &SLOPE(29),SEPT(29)
      COMMON LABEL(28),LABEL3(28),LABEL1(28),
     & WATER(5,77,29),SEWAGE(4,77,29),SWSS(77,29),BOUT(77,29),
     &HEAD(11,10),IYEAR,LABEL2(28)
      FILENAME KRD
      INPUT, KRD
      DO 1 N=2,29
 1    READ(KRD,102)SLOPE(N),SEPT(N)
      READ(KRD,103)(SEFF(N),N=1,29)
      READ(KRD,1031)(LABEL(K),LABEL1(K),LABEL2(K),LABEL3(K),K=1,28)
      READ(KRD,108)((HEAD(JH,JK),JK=1,10),JH=1,11)
 5    READ(KRD,100,END=1000) IYEAR,JPROC,IYEAR1
      IT=IYEAR-1969
      DO 1111 N=2,29
 1111 GUNIT(N)=SLOPE(N)*IT+SEPT(N)
      READ(KRD,101)JPOL,JSOS,JWTP,JWSTS,JSPOL,JWS,JSTP,JRS
      PEAD(KRD,101)KPOL,KSOS,KWTP,KWSTS,KSPOL,KWS,KSTP,KRS
      DO 2 K=1,4
      DO 2 L=1,77
      DO 2 J=1,29
      WATER(K,L,J)=0.0
      WATER(K+1,L,J)=0.0
 2    SEWAGE(K,L,J)=0.0
      DO 3 K=1,77
      DO 3 J=1,29
      BOUT(K,J)=0.0
 3    SWSS(K,J)=0.0
      GO TO (50,60,70), JPROC
 50   READ(KRD,104)NCLASS,NREST
      READ(KRD,105)((CREST(JC,JR),JR=1,NREST),JC=1,NCLASS)
 58   READ(KRD,106)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,
     &(PRED(I),I=1,7),INDY
      KK=7
```

```
      IF(INDY-1)40,30,40
 30   READ(KRD,110)(PRED(I),I=8,23)
      READ(KRD,111)(PRED(I),I=24,29)
      KK=29
 40   IF(ISAU)51,52,51
 51   DO 53 K=1,NCLASS
      DO 53 L=1,NREST
      IF(ISAU-CREST(K,L))54,55,54
55    N=K
      GO TO 56
54    CONTINUE
53    CONTINUE
      GO TO 58
56    GUNIT(1)=.5*IT+32.0+.01*PRED(1)
      DO 57 M=1,KK
      DEMAND=GUNIT(M)*PRED(M)
      WATER(1,N,M)=DEMAND+WATER(1,N,M)
57    SEWAGE(1,N,M)=SEFF(M)*DEMAND+SEWAGE(1,N,M)
      GO TO 58
 52   READ(KRD,107)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,KM,
     &WPRED,SPRED
      IF(ISAU)59,590,59
59    CONTINUE
      WPRED=1000.0*WPRED
      SPRED=SPRED*1000.0
      DO 500 K=1,NCLASS
      DO 500 L=1,NREST
      IF(ISAU-CREST(K,L))504,505,504
505   N=K
      GO TO 506
 504  CONTINUE
 500  CONTINUE
      GO TO 52
506   WATER(1,N,KM)=WATER(1,N,KM)+WPRED
      SEWAGE(1,N,KM)=SEWAGE(1,N,KM)+SPRED
      GO TO 52
590   CALL WATOUT(1,NCLASS)
      PRINT 109,(HEAD(1,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
```

```
      DO 591 J=1,NCLASS
  591 PRINT 1081,J,(CREST(J,M),M=1,NREST)
      CALL WRITE(1,NCLASS)
      CALL SEWOUT(1,NCLASS)
      PRINT 109,(HEAD(6,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      DO 592 J=1,NCLASS
  592 PRINT 1081,J,(CREST(J,M),M=1,NREST)
      CALL WRITE(6,NCLASS)
    ~ GO TO 5
   60 READ(KRD,106)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,
     &(PRED(I),I=1,7),INDY
      KK=7
      IF(INDY-1)45,35,45
   35 READ(KRD,110)(PRED(I),I=8,23)
      READ(KRD,111)(PRED(I),I=24,29)
      KK=29
   45 IF(ISAU)62,63,62
   62 GUNIT(1)=.5*IT+32.0+.01*PRED(1)
      DO 61 II=1,KK
      JJ=II
      IF(JJ.GT.7) JJ=JJ+4
      DEMAND=GUNIT(II)*PRED(II)
      WATER(2,IPOLJ,II)=WATER(2,IPOLJ,II)+DEMAND
       WATER(3,ISOS,II)=WATER(3,ISOS,II)+DEMAND
       WATER(4,IWTP,II)=WATER(4,IWTP,II)+DEMAND
       WATER(5,IWST,II)=WATER(5,IWST,II)+DEMAND
       SEWAGE(2,IPOLJ,II)=SEWAGE(2,IPOLJ,II)+DEMAND*SEFF(II)
       SEWAGE(3,ISTP,II)=SEWAGE(3,ISTP,II)+DEMAND*SEFF(II)
       SEWAGE(4,IRS,II)=SEWAGE(4,IRS,II)+DEMAND*SEFF(II)
   61  SWSS(IWS,II)=SWSS(IWS,II)+DEMAND*SEFF(II)
       GO TO 60
   63  READ(KRD,107)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,KM,
      &WPRED,SPRED
       IF(ISAU)69,690,69
   69  CONTINUE
       WPRED=1000.0*WPRED
       SPRED=1000.0*SPRED
```

```
      WATER(2,IPOLJ,KM)=WATER(2,IPOLJ,KM)+WPRED
      WATER(3,ISOS,KM)=WATER(3,ISOS,KM)+WPRED
      WATER(4,IWTP,KM)=WATER(4,IWTP,KM)+WPRED
      WATER(5,IWST,KM)=WATER(5,IWST,KM)+WPRED
      SEWAGE(2,IPOLJ,KM)=SEWAGE(2,IPOLJ,KM)+SPRED
      SEWAGE(3,ISTP,KM)=SEWAGE(3,ISTP,KM)+SPRED
      SEWAGE(4,IRS,KM)=SEWAGE(4,IRS,KM)+SPRED
      SWSS(IWS,KM)=SWSS(IWS,KM)+SPRED
      GO TO 63
690    IF(JPOL)611,610,611
611   PRINT 109,(HEAD(2,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL WATOUT (2,KPOL)
      CALL WRITE(2,KPOL)
610   IF(JSOS)613,612,613
613   PRINT 109,(HEAD(3,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL WATOUT(3,KSOS)
      CALL WRITE(3,KSOS)
612   IF(JWTP)615,614,615
615  PRINT 109,(HEAD(4,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL WATOUT(4,KWTP)
      CALL WRITE(4,KWTP)
614   IF(JWSTS)617,616,617
617   PRINT 109,(HEAD(5,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL WATOUT(5,KWSTS)
      CALL WRITE(5,KWSTS)
616   IF(JSPOL)619,618,619
619   PRINT 109,(HEAD(7,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL SEWOUT(2,KSPOL)
      CALL WRITE(7,KSPOL)
618   IF(JSTP)621,620,621
621   PRINT 109,(HEAD(8,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL SEWOUT(3,KSTP)
      CALL WRITE(8,KSTP)
620   IF(JRS)623,622,623
623   PRINT 109,(HEAD(9,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL SEWOUT(4,KRS)
      CALL WRITE(9,KRS)
```

```
622   IF(JWS)625,624,625
625   PRINT 109,(HEAD(10,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
      CALL SWSOUT(KWS)
      CALL WRITE(10,KWS)
624   CONTINUE
      GO TO 5
70     READ(KRD,104)NCLASS,NREST
      READ(KRD,105)((CREST(JC,JR),JR=1,NREST),JC=1,NCLASS)
78    READ(KRD,106)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,
     &(PRED(I),I=1,7),INDY
      KK=7
      IF(INDY-1)81,82,81
82    READ(KRD,110)(PRED(I),I=8,23)
      READ(KRD,111)(PRED(I),I=24,29)
      KK=29
   81 IF(ISAU)71,72,71
71    DO 73 K=1,NCLASS
      DO 73 L=1,NREST
      IF(ISAU-CREST(K,L))74,75,74
75    N=K
      GO TO 76
74    CONTINUE
73    CONTINUE
      GO TO 780
76    GUNIT(1)=.5*IT+32.0+.01*PRED(1)
      DO 77 II=1,KK
      DEMAND=GUNIT(II)*PRED(II)
      WATER(1,N,II)=WATER(1,N,II)+DEMAND
      WATER(2,IPOLJ,II)=WATER(2,IPOLJ,II)+DEMAND
      SEWAGE(1,N,II)=SEWAGE(1,N,II)+DEMAND*SEFF(II)
      WATER(3,ISOS,II)=WATER(3,ISOS,II)+DEMAND
      WATER(4,IWTP,II)=WATER(4,IWTP,II)+DEMAND
      WATER(5,IWST,II)=WATER(5,IWST,II)+DEMAND
      SEWAGE(2,IPOLJ,II)=SEWAGE(2,IPOLJ,II)+DEMAND*SEFF(II)
      SEWAGE(3,ISTP,II)=SEWAGE(3,ISTP,II)+DEMAND*SEFF(II)
      SEWAGE(4,IRS,II)=SEWAGE(4,IRS,II)+DEMAND*SEFF(II)
77    SWSS(IWS,II)=SWSS(IWS,II)+DEMAND*SEFF(II)
      GO TO 78
```

```
 780  GUNIT(1)=.5*IT+32.0+.01*PRED(I)
      DO 777 II=1,KK
      DEMAND=GUNIT(II)*PRED(II)
      WATER(2,IPOLJ,II)=WATER(2,IPOLJ,II)+DEMAND
      WATER(3,ISOS,II)=WATER(3,ISOS,II)+DEMAND
      WATER(4,IWTP,II)=WATER(4,IWTP,II)+DEMAND
      WATER(5,IWST,II)=WATER(5,IWST,II)+DEMAND
      SEWAGE(2,IPOLJ,II)=SEWAGE(2,IPOLJ,II)+DEMAND*SEFF(II)
      SEWAGE(3,ISTP,II)=SEWAGE(3,ISTP,II)+DEMAND*SEFF(II)
      SEWAGE(4,IRS,II)=SEWAGE(4,IRS,II)+DEMAND*SEFF(II)
 777  SWSS(IWS,II)=SWSS(IWS,II)+DEMAND*SEFF(II)
      GO TO 78
 72   READ(KRD,107)ISAU,IPOLJ,IWS,IWTP,IWST,ISTP,IRS,ISOS,KM,
     &WPRED,SPRED
      IF(ISAU)79,790,79
 79   CONTINUE
      WPRED=WPRED*1000.0
      SPRED=SPRED*1000.0
      DO 700 K=1,NCLASS
      DO 700 L=1,NREST
      IF(ISAU-CREST(K,L))704,705,704
 705  N=K
      GO TO 706
 704  CONTINUE
 700  CONTINUE
      GO TO 770
 706  WATER(1,N,KM)=WATER(1,N,KM)+WPRED
      SEWAGE(1,N,KM)=SEWAGE(1,N,KM)+SPRED
 770  WATER(2,IPOLJ,KM)=WATER(2,IPOLJ,KM)+WPRED
      WATER(3,ISOS,KM)=WATER(3,ISOS,KM)+WPRED
      WATER(4,IWTP,KM)=WATER(4,IWTP,KM)+WPRED
      WATER(5,IWST,KM)=WATER(5,IWST,KM)+WPRED
      SEWAGE(2,IPOLJ,KM)=SEWAGE(2,IPOLJ,KM)+SPRED
      SEWAGE(3,ISTP,KM)=SEWAGE(3,ISTP,KM)+SPRED
      SEWAGE(4,IRS,KM)=SEWAGE(4,IRS,KM)+SPRED
      SWSS(IWS,KM)=SWSS(IWS,KM)+SPRED
      GO TO 72
```

```
790     CALL WATOUT(1,NCLASS)
        PRINT 109,(HEAD(1,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
        DO 791 J=1,NCLASS
791     PRINT 1081,J,(CREST(J,M),M=1,NREST)
        CALL WRITE(1,NCLASS)
        CALL SEWOUT(1,NCLASS)
        PRINT 109,(HEAD(6,JK),JK=1,10),(HEAD(11,JK),JK=1,10),IYEAR,IYEAR1
        DO 792 J=1,NCLASS
792     PRINT 1081, J,(CREST(J,M),M=1,NREST)
        CALL WRITE(6,NCLASS)
        GO TO 690
100     FORMAT(I4,1X,I1,I5)
101     FORMAT(8I2)
102     FORMAT(F6.0,2X,F6.0)
103     FORMAT(F6.0)
104     FORMAT(I3,I2)
105     FORMAT(I6)
1031    FORMAT(4A4)
106     FORMAT    (I6,1X,I2,I3,6X,5I2,6X,3F5.0,5X,4F5.0,2X,I1)
107     FORMAT(I6,1X,I2,I3,6X,5I2,1X,I2,2F5.0)
1081    FORMAT(1H0,"CLASS",2X,I3,6X,10(I6,3X)/10(I6,3X)/10(I6,3X))
108     FORMAT(10A4)
109     FORMAT(15(/),20A4,5X,4HYEAR,2X,I4,"-",I4)

110     FORMAT(16F5.0)
111     FORMAT(6F5.0)
 1000   STOP
         END

READY
```

```
      SUBROUTINE SEWOUT(KTYP,KKK)
      COMMON LABEL(28),LABEL3(28),LABEL1(28),
     & WATER(5,77,29),SEWAGE(4,77,29),SWSS(77,29),BOUT(77,29),
     &HEAD(11,10),IYEAR,LABEL2(28)
      DO 901 KOUT=1,KKK
      BOUT(KOUT,27)=0.0
      BOUT(KOUT,28)=0.0
      BOUT(KOUT,1)=SEWAGE(KTYP,KOUT,1)
      BOUT(KOUT,2)=SEWAGE(KTYP,KOUT,2)+SEWAGE(KTYP,KOUT,5)+
     &SEWAGE(KTYP,KOUT,6)+SEWAGE(KTYP,KOUT,7)
      DO 905 K4=3,26
      K5=K4+3
  905 BOUT(KOUT,K4)=SEWAGE(KTYP,KOUT,K5)
      DO 904 K1=8,29
  904 BOUT(KOUT,27)=BOUT(KOUT,27) + SEWAGE(KTYP,KOUT,K1)
      DO 903 K1=8,9
      K2=K1-3
  903 BOUT(KOUT,K2)=SEWAGE(KTYP,KOUT,K1)
      DO 902 K3=1,26
  902 BOUT(KOUT,28)=BOUT(KOUT,28)+BOUT(KOUT,K3)
  901 CONTINUE
      RETURN
      END

READY
```

```
      SUBROUTINE WATOUT(KTYP,KKK)
      COMMON LABEL(28),LABEL3(28),LABEL1(28),
     & WATER(5,77,29),SEWAGE(4,77,29),SWSS(77,29),BOUT(77,29),
     &HEAD(11,10),IYEAR,LABEL2(28)
      DO 901 KOUT=1,KKK
      BOUT(KOUT,27)=0.0
      BOUT(KOUT,28)=0.0
      BOUT(KOUT,1)=WATER(KTYP,KOUT,1)
      BOUT(KOUT,2)=WATER(KTYP,KOUT,2)+WATER(KTYP,KOUT,5)+
     &WATER(KTYP,KOUT,6)+WATER(KTYP,KOUT,7)
      DO 905 K4=3,26
      K5=K4+3
  905 BOUT(KOUT,K4)=WATER(KTYP,KOUT,K5)
      DO 904 K1=8,29
  904 BOUT(KOUT,27)=BOUT(KOUT,27) + WATER(KTYP,KOUT,K1)
      DO 903 K1=8,9
      K2=K1-3
  903 BOUT(KOUT,K2)=WATER(KTYP,KOUT,K1)
      DO 902 K3=1,26
  902 BOUT(KOUT,28)=BOUT(KOUT,28)+BOUT(KOUT,K3)
  901 CONTINUE
      RETURN
      END

READY
```

```
EDI LIS

      SUBROUTINE SWSOUT(KKK)
      COMMON LABEL(28),LABEL3(28),LABEL1(28),
     & WATER(5,77,29),SEWAGE(4,77,29),SWSS(77,29),BOUT(77,29),
     &HEAD(11,10),IYEAR,LABEL2(28)
      DO 901 KOUT=1,KKK
      BOUT(KOUT,27)=0.0
      BOUT(KOUT,28)=0.0
      BOUT(KOUT,1)=SWSS(KOUT,1)
      BOUT(KOUT,2)=SWSS(KOUT,2)+SWSS(KOUT,5)+
     &SWSS(KOUT,6)+SWSS(KOUT,7)
      DO 905 K4=3,26
      K5=K4+3
  905 BOUT(KOUT,K4)=SWSS(KOUT,K5)
      DO 904 K1=8,29
  904 BOUT(KOUT,27)=BOUT(KOUT,27) + SWSS(KOUT,K1)
      DO 903 K1=8,9
      K2=K1-3
  903 BOUT(KOUT,K2)=SWSS(KOUT,K1)
      DO 902 K3=1,26
  902 BOUT(KOUT,28)=BOUT(KOUT,28)+BOUT(KOUT,K3)
  901 CONTINUE
      RETURN
      END

READY
```

```
      SUBROUTINE WRITE(KH,KL)
      COMMON LABEL(28),LABEL3(28),LABEL1(28),
     & WATER(5,77,29),SEWAGE(4,77,29),SWSS(77,29),BOUT(77,29),
     &HEAD(11,10),IYEAR,LABEL2(28)
      LL=1
      LM=8
  890 PRINT 100
  891 IF(LM-KL) 804,804,806
  806 LM=KL
  804 PRINT 101,(JJ,JJ=LL,LM)
      DO 802 JK=1,28
      DO 997 JL=LL,LM
  997 BOUT(JL,JK) = BOUT(JL,JK) / 1000.
      PRINT 102, LABEL(JK),LABEL1(JK),LABEL2(JK),LABEL3(JK),(BOUT(JL,JK),JL=LL,LM)
      DO 996 JL=LL,LM
  996 BOUT(JL,JK) = BOUT(JL,JK) * 1000.
      DO 802 KK=LL,LM
  802 BOUT(KK,JK)=0.0
      IF(LM-KL) 807,808,808
  807 LL=LL+8
      LM=LM+8
  894 CONTINUE
      GO TO 890
  808 RETURN
  100 FORMAT(1H0)
  101 FORMAT(1H ,26X,8(I3,8X))
  102 FORMAT(1H ,4A4,4X,8(   F9.1,2X))
      END

READY
```

```
      DIMENSION SLOPE(29),SEPT(29),PRED(29),SEFF(29),LABEL2(28),HEAD(11,10)
     &,LABEL(28),LABEL1(28),LABEL3(28),IJK(9),JKI(9),TRED(29)
      FILENAME KRD,KRK,KTP
      INPUT, KRD
      INPUT, KRK
      INPUT, KTP
      DO 1 K=2,29
1     READ(KRD,102)SLOPE(K),SEPT(K)
 102  FORMAT(F6.0,2X,F6.0)
1021  FORMAT(F6.0,2X,F6.2)
      DO 2 K=2,29
   2  WRITE(KTP,1021)SLOPE(K),SEPT(K)
      READ(KRD,103)(SEFF(N),N=1,29)
 103  FORMAT(F6.0)
      WRITE(KTP,1032)(SEFF(N),N=1,29)
1032  FORMAT(F6.2)
      READ(KRD,1031)(LABEL(K),LABEL1(K),LABEL2(K),LABEL3(K),K=1,28)
 1031 FORMAT(4A4)
      WRITE(KTP,1031)(LABEL(K),LABEL1(K),LABEL2(K),LABEL3(K),K=1,28)
      READ(KRD,108)((HEAD(JH,JK),JK=1,10),JH=1,11)
 108  FORMAT(10A4)
      WRITE(KTP,108)((HEAD(JH,JK),JK=1,10),JH=1,11)
      READ(KRD,100)IYEAR,JPROC
      IYEAR=IYEAR+20
 100  FORMAT(I4,1X,I1)
      WRITE(KTP,100)IYEAR,JPROC
      DO 65 JJ=1,2
      READ(KRD,101)JPOL,JSOS,JWTP,JWSTS,JSPOL,JWS,JSTP,JRS
 101  FORMAT(8I2)
      WRITE(KTP,101)JPOL,JSOS,JWTP,JWSTS,JSPOL,JWS,JSTP,JRS
  65  CONTINUE
60    READ(KRD,106)(IJK(I),I=1,8),(PRED(I),I=1,7),INDY
```

```
      READ(KRK,106)(JKI(I),I=1,8),(TRED(I),I=1,7),INDZ
      KKK=7
      IF(INDY-1)45,35,45
35    READ(KRC,110)(PRED(I),I=8,23)
      READ(KRD,111)(PRED(I),I=24,29)
      READ(KRK,110)(TRED(I),I=8,23)
      READ(KRK,111)(TRED(I),I=24,29)
      KKK=29
45    IF(IJK(1).EQ.0) GO TO 63
      DO 50 I=1,KKK
      PRET=TRED(I)-PRED(I)
50    PRED(I)=PRET
      WRITE(KTP,106)(IJK(I),I=1,8),(PRED(I),I=1,7),INDY
      IF(KKK.EQ.7) GO TO 51
      WRITE(KTP,110)(PRED(I),I=8,23)
      WRITE(KTP,111)(PRED(I),I=24,29)
51    GO TO 60
106   FORMAT(I6,1X,I2,I3,6X,5I2,6X,3F5.0,5X,4F5.0,2X,I1)
107   FORMAT(I6,1X,I2,I3,6X,5I2,1X,I2,2F5.0)
110   FORMAT(16F5.0)
111   FORMAT(6F5.0)
63    READ(KRD,107)(IJK(I),I=1,8),KM,WPRED,SPRED
      READ(KRK,107)(JKI(I),I=1,8),KN,WPRDD,SPRDD
      IF(IJK(1).EQ.0) GO TO 71
      W=WPRDD-WPRED
      WPRED=W
      S=SPRDD-SPRED
      SPRED=S
      IF(KM.EQ.0) KM=1
      WRITE(KTP,107)(IJK(I),I=1,8),KM,WPRED,SPRED
      GO TO 63
71    STOP
      END
```

4.6 Model Validation

The output of the model is shown in this section for the year 1970. Also shown is the output from the data file developed by subtracting the 1970 data file from the 1990 data file. This output is the change in water requirements and sewage output over this time period. This output is extremely valuable in examining the delta change in the specific study areas.

It should be noted that this output is not meant to be used for planning in the ACOG area, since some of the data were unavailable and were added from unreliable sources for explanatory and demonstrative purposes.

WATER BY POLITICAL JURISDICTOION THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	11.8	109.9	3555.8	1399.3	4380.3	876.9	17.0	78.8
INSTITUTICNAL	200.5	10.4	2262.6	23.0	403.6	0.	0.	0.
COMMERCIAL	33.3	10.4	391.2	11.9	53.9	0.	0.	0.
IRRIGATED LAND	0.	0.	0.	0.	0.	0.	0.	0.
SIC 19	3.1	6.5	6.1	4.1	4.1	4.1	10.2	10.2
SIC 20	21.0	44.8	42.0	28.0	28.0	28.0	70.0	70.0
SIC 21	2.5	5.4	5.0	3.4	3.4	3.4	8.4	8.4
SIC 22	9.7	20.6	19.3	12.9	12.9	12.9	32.2	32.2
SIC 23	0.9	1.9	1.8	1.2	1.2	1.2	3.0	3.0
SIC 24	13.6	28.9	27.1	18.1	18.1	18.1	45.2	45.2
SIC 25	1.2	2.5	2.4	1.6	1.6	1.6	3.9	3.9
SIC 26	146.4	312.4	292.9	195.2	195.2	195.2	488.1	488.1
SIC 27	3.9	8.3	7.8	5.2	5.2	5.2	13.0	13.0
SIC 28	218.8	466.7	437.5	291.7	291.7	291.7	729.2	729.2
SIC 29	377.4	805.0	754.7	503.1	503.1	503.1	1257.9	1257.9
SIC 30	17.0	262.2	33.9	22.6	22.6	22.6	56.5	56.5
SIC 31	3.2	6.9	6.4	4.3	4.3	4.3	10.7	10.7
SIC 32	21.5	45.9	43.0	28.7	28.7	28.7	71.7	71.7
SIC 33	167.9	358.3	335.9	223.9	223.9	223.9	559.8	559.8
SIC 34	3.7	8.0	7.5	5.0	5.0	5.0	12.5	12.5
SIC 35	6.3	13.5	12.6	8.4	8.4	8.4	21.0	21.0
SIC 36	4.0	8.4	7.9	5.3	5.3	5.3	13.2	13.2
SIC 37	8.3	17.6	16.5	11.0	11.0	11.0	27.5	27.5
SIC 38	5.4	11.6	10.9	7.3	7.3	7.3	18.2	18.2
SIC 39	2.6	5.6	5.2	3.5	3.5	3.5	8.7	8.7
SIC OTHER	18.9	52.3	37.8	25.2	25.2	25.2	63.0	63.0
TOTAL ALL SIC"S	1057.2	2493.4	2114.4	1409.6	1409.6	1409.6	3524.0	3524.0
TOTAL ALL USER	1302.9	2624.1	8323.9	2843.8	6247.4	2286.5	3541.0	3602.8

WATER BY SOURCE OF SUPPLY THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	0.2	0.	0.	7.9	0.	0.	0.	0.
INSTITUTIONAL	210.9	0.	0.	0.	0.	0.	0.	0.
COMMERCIAL	43.7	0.	0.	0.	0.	0.	0.	0.
IRRIGATED LAND	0.	0.	0.	0.	0.	0.	0.	0.
SIC 19	7.5	0.	0.	2.0	0.	0.	0.	0.
SIC 20	51.8	0.	0.	14.0	0.	0.	0.	0.
SIC 21	6.2	0.	0.	1.7	0.	0.	0.	0.
SIC 22	23.8	0.	0.	6.4	0.	0.	0.	0.
SIC 23	2.2	0.	0.	0.6	0.	0.	0.	0.
SIC 24	33.4	0.	0.	9.0	0.	0.	0.	0.
SIC 25	2.9	0.	0.	0.8	0.	0.	0.	0.
SIC 26	361.2	0.	0.	97.6	0.	0.	0.	0.
SIC 27	9.6	0.	0.	2.6	0.	0.	0.	0.
SIC 28	539.6	0.	0.	145.8	0.	0.	0.	0.
SIC 29	930.8	0.	0.	251.6	0.	0.	0.	0.
SIC 30	267.8	0.	0.	11.3	0.	0.	0.	0.
SIC 31	8.0	0.	0.	2.2	0.	0.	0.	0.
SIC 32	53.1	0.	0.	14.3	0.	0.	0.	0.
SIC 33	414.3	0.	0.	112.0	0.	0.	0.	0.
SIC 34	9.2	0.	0.	2.5	0.	0.	0.	0.
SIC 35	15.6	0.	0.	4.2	0.	0.	0.	0.
SIC 36	9.8	0.	0.	2.6	0.	0.	0.	0.
SIC 37	20.4	0.	0.	5.5	0.	0.	0.	0.
SIC 38	13.4	0.	0.	3.6	0.	0.	0.	0.
SIC 39	6.5	0.	0.	1.7	0.	0.	0.	0.
SIC OTHER	58.6	0.	0.	12.6	0.	0.	0.	0.
TOTAL ALL SIC"S	2845.8	0.	0.	704.8	0.	0.	0.	0.
TOTAL ALL USER	3100.6	0.	0.	712.7	0.	0.	0.	0.

WATER BY WATER TREATMENT PLANT THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	9767.3	3456.0	1834.8	19736.1	0.9	510.7	6536.2	2676.9
INSTITUTIONAL	3731.2	1656.1	0.	1313.6	0.	0.	433.8	34.7
COMMERCIAL	544.8	53.9	0.	717.4	0.	0.	169.2	23.7
IRRIGATED LAND	0.	1252.5	0.	0.	0.	0.	0.	0.
SIC 19	36.7	12.0	4.1	16.3	2.0	9.0	2.0	69.8
SIC 20	252.0	82.6	28.0	112.1	14.0	61.6	14.0	478.8
SIC 21	30.2	9.9	3.4	20.3	1.7	7.4	1.7	57.5
SIC 22	115.9	38.0	12.9	51.6	6.4	28.3	6.4	220.2
SIC 23	56.0	3.5	1.2	234.8	0.6	7.0	0.6	20.5
SIC 24	2400.1	15487.3	18.1	7589.1	9.0	255.8	9.0	309.2
SIC 25	14.2	4.7	1.6	6.3	0.8	3.5	0.8	27.0
SIC 26	1757.2	576.0	195.2	781.9	97.6	429.5	97.6	3338.6
SIC 27	46.8	15.3	5.2	20.8	2.6	11.4	2.6	88.9
SIC 28	2625.1	860.5	291.7	1168.2	145.8	641.7	145.8	4987.7
SIC 29	4528.3	1484.3	503.1	2015.1	251.6	1106.9	251.6	8603.7
SIC 30	429.4	66.7	22.6	90.5	11.3	49.7	11.3	366.9
SIC 31	38.7	12.7	4.3	17.2	2.2	9.5	2.2	73.5
SIC 32	258.1	84.6	28.7	114.9	14.3	63.1	14.3	490.4
SIC 33	2015.3	660.6	223.9	896.8	112.0	492.6	112.0	3829.0
SIC 34	44.8	14.7	5.0	19.9	2.5	11.0	2.5	85.2
SIC 35	75.8	24.8	8.4	33.7	4.2	18.5	4.2	144.0
SIC 36	47.5	15.6	5.3	21.1	2.6	11.6	2.6	90.3
SIC 37	99.2	32.5	11.0	44.1	5.5	24.2	5.5	[illegible]
SIC 38	65.3	21.4	7.3	29.1	3.6	16.0	3.6	124.1
SIC 39	31.5	10.3	3.5	14.0	1.7	7.7	1.7	63.0
SIC OTHER	419.1	1098.7	25.2	832.9	12.6	72.8	12.6	432.0
TOTAL ALL SIC'S	15387.3	20616.7	1409.6	14131.0	704.8	3338.9	704.8	24108.4
TOTAL ALL USER	29430.6	27035.1	3244.4	35898.1	705.7	3849.6	7844.0	[illegible]

WATER BY WATER STORAGE SYSTEM THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5
DOMESTIC	38445.2	1465.9	2877.5	1657.4	72.5
INSTITUTIONAL	6332.9	23.0	313.5	0.	0.
COMMERCIAL	1327.9	11.9	169.2	0.	0.
IRRIGATED LAND	1252.5	0.	0.	0.	0.
SIC 19	120.2	2.0	5.1	12.2	12.4
SIC 20	824.7	14.0	35.0	84.0	85.4
SIC 21	105.9	1.7	4.2	10.1	10.2
SIC 22	379.4	6.4	16.1	38.6	39.3
SIC 23	314.0	0.6	1.5	3.6	3.7
SIC 24	25936.7	9.0	22.6	54.2	55.1
SIC 25	46.5	0.8	2.0	4.7	4.8
SIC 26	5750.8	97.6	244.0	585.7	595.5
SIC 27	153.2	2.6	6.5	15.6	15.9
SIC 28	8591.4	145.8	364.6	875.0	889.6
SIC 29	14820.0	251.6	628.9	1509.4	1534.6
SIC 30	891.7	11.3	28.2	67.8	68.9
SIC 31	126.7	2.2	5.4	12.9	13.1
SIC 32	844.8	14.3	35.8	86.0	87.5
SIC 33	6595.6	112.0	279.9	671.8	683.0
SIC 34	146.7	2.5	6.2	14.9	15.2
SIC 35	243.0	4.2	10.5	25.3	25.7
SIC 36	155.5	2.6	6.6	15.8	16.1
SIC 37	324.6	5.5	13.8	33.1	33.6
SIC 38	213.8	3.6	9.1	21.8	22.1
SIC 39	104.7	1.7	4.4	10.5	12.2
SIC OTHER	2708.9	12.6	31.5	75.6	77.4
TOTAL ALL SIC'S	69404.4	704.8	1762.0	4228.8	4301.4
TOTAL ALL USER	117262.9	2205.6	5122.3	5886.2	4373.9

SEWAGE BY POLITICAL JURISDICTION THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	8.3	76.9	2489.1	979.5	3066.2	615.2	11.9	55.2
INSTITUTIONAL	140.4	7.3	1583.8	16.1	282.5	0.	0.	0.
COMMERCIAL	23.3	7.3	273.8	8.4	37.7	0.	0.	0.
IRRIGATED LAND	0.	0.	0.	0.	0.	0.	0.	0.
SIC 19	2.9	6.1	5.8	3.8	3.8	3.8	9.6	9.6
SIC 20	19.1	40.8	38.2	25.5	25.5	25.5	63.7	63.7
SIC 21	1.7	3.6	3.4	2.3	2.3	2.3	5.6	5.6
SIC 22	8.8	18.8	17.6	11.7	11.7	11.7	29.3	29.3
SIC 23	0.8	1.8	1.7	1.1	1.1	1.1	2.8	2.8
SIC 24	11.1	23.7	22.2	14.8	14.8	14.8	37.1	37.1
SIC 25	1.1	2.4	2.2	1.5	1.5	1.5	3.7	3.7
SIC 26	137.6	293.6	275.3	183.5	183.5	183.5	458.8	458.8
SIC 27	3.7	7.8	7.3	4.9	4.9	4.9	12.2	12.2
SIC 28	205.6	438.7	411.3	274.2	274.2	274.2	685.4	685.4
SIC 29	354.7	756.7	709.4	473.0	473.0	473.0	1182.4	1182.4
SIC 30	16.1	249.1	32.2	21.5	21.5	21.5	53.7	53.7
SIC 31	3.0	6.5	6.1	4.0	4.0	4.0	10.1	10.1
SIC 32	18.9	40.4	37.9	25.2	25.2	25.2	63.1	63.1
SIC 33	157.9	336.8	315.7	210.5	210.5	210.5	526.2	526.2
SIC 34	3.5	7.4	6.9	4.6	4.6	4.6	11.6	11.6
SIC 35	6.0	12.8	12.0	8.0	8.0	8.0	20.0	20.0
SIC 36	3.4	7.3	6.9	4.6	4.6	4.6	11.5	11.5
SIC 37	7.9	16.8	15.7	10.5	10.5	10.5	26.2	26.2
SIC 38	4.9	10.5	9.8	6.5	6.5	6.5	16.3	16.3
SIC 39	2.4	5.2	4.9	3.3	3.3	3.3	8.1	8.1
SIC OTHER	17.8	49.2	35.5	23.7	23.7	23.7	59.2	59.2
TOTAL ALL SIC'S	989.0	2335.9	1978.0	1318.7	1318.7	1318.7	3296.7	3296.7
TOTAL ALL USER	1161.0	2427.4	6324.7	2322.6	4705.2	1933.9	3308.6	3351.8

SEWAGE BY SEWAGE TREATMENT PLANT THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	34.8	76.9	2489.1	989.9	172.7	0.	0.	0.
INSTITUTIONAL	147.7	0.	1583.8	16.1	0.	0.	0.	0.
COMMERCIAL	30.6	0.	273.8	8.4	0.	0.	0.	0.
IRRIGATED LAND	0.	0.	0.	0.	0.	0.	0.	0.
SIC 19	11.9	1.9	5.8	3.8	5.8	0.	0.	0.
SIC 20	79.0	12.7	38.2	25.5	38.2	0.	0.	0.
SIC 21	7.0	1.1	3.4	2.3	3.4	0.	0.	0.
SIC 22	36.3	5.9	17.6	11.7	17.6	0.	0.	0.
SIC 23	3.5	0.6	1.7	1.1	9.0	0.	0.	0.
SIC 24	46.0	7.4	22.2	14.8	379.5	0.	0.	0.
SIC 25	4.6	0.7	2.2	1.5	2.2	0.	0.	0.
SIC 26	568.9	91.8	275.3	183.5	275.3	0.	0.	0.
SIC 27	15.2	2.4	7.3	4.9	7.3	0.	0.	0.
SIC 28	850.0	137.1	411.3	274.2	411.3	0.	0.	0.
SIC 29	1466.1	236.5	709.4	473.0	709.4	0.	0.	0.
SIC 30	231.3	10.7	32.2	21.5	32.2	0.	0.	0.
SIC 31	12.5	2.0	6.1	4.0	6.1	0.	0.	0.
SIC 32	78.2	12.6	37.9	25.2	37.9	0.	0.	0.
SIC 33	652.5	105.2	315.7	210.5	315.7	0.	0.	0.
SIC 34	14.4	2.3	6.9	4.6	6.9	0.	0.	0.
SIC 35	24.8	4.0	12.0	8.0	12.0	0.	0.	0.
SIC 36	14.2	2.3	6.9	4.6	6.9	0.	0.	0.
SIC 37	32.5	5.2	15.7	10.5	15.7	0.	0.	0.
SIC 38	20.3	3.3	9.8	6.5	9.8	0.	0.	0.
SIC 39	10.1	1.6	4.9	3.3	4.9	0.	0.	0.
SIC OTHER	84.7	11.8	35.5	23.7	70.0	0.	0.	0.
TOTAL ALL SIC'S	4313.9	659.3	1978.0	1318.7	2377.2	0.	0.	0.
TOTAL ALL USER	4526.9	736.3	6324.7	2333.0	2549.9	0.	0.	0.

SEWAGE BY RECEIVING STREAM THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	2687.1	17076.2	871.0	4058.5	1374.5	0.	8.3	2022.5
INSTITUTIONAL	1731.5	1898.0	108.9	84.2	171.2	0.	215.6	0.
COMMERCIAL	304.4	409.6	13.5	0.	8.4	0.	215.6	0.
IRRIGATED LAND	0.	876.7	0.	0.	0.	0.	0.	0.
SIC 19	23.4	77.9	2.9	20.1	6.1	0.	0.	3.5
SIC 20	155.4	517.2	19.1	133.8	40.8	0.	0.	22.9
SIC 21	13.7	50.3	1.7	11.8	3.6	0.	0.	2.0
SIC 22	71.5	237.9	8.8	61.5	18.8	0.	0.	10.5
SIC 23	14.2	251.3	2.9	11.4	1.8	0.	0.	13.1
SIC 24	447.7	17704.7	158.6	521.9	37.1	0.	14.8	1349.5
SIC 25	9.1	30.1	1.1	7.8	2.4	0.	0.	1.3
SIC 26	1119.5	3725.6	137.6	963.5	293.6	0.	0.	165.2
SIC 27	29.8	99.2	3.7	25.7	7.8	0.	0.	4.4
SIC 28	1672.5	5565.8	205.6	1439.4	438.7	0.	0.	246.8
SIC 29	2885.0	9600.9	354.7	2483.0	756.7	0.	0.	425.7
SIC 30	345.7	435.8	16.1	112.7	34.4	0.	0.	19.3
SIC 31	24.7	82.1	3.0	21.2	6.5	0.	0.	3.6
SIC 32	154.0	512.3	18.9	132.5	40.4	0.	0.	22.7
SIC 33	1284.0	4272.8	157.9	1105.0	336.8	0.	0.	189.4
SIC 34	28.3	94.0	3.5	24.3	7.4	0.	0.	4.2
SIC 35	48.8	162.4	6.0	42.0	12.8	0.	0.	7.2
SIC 36	28.0	93.3	3.4	24.1	7.3	0.	0.	4.1
SIC 37	63.9	212.5	7.9	55.0	16.8	0.	0.	9.4
SIC 38	39.9	132.6	4.9	34.3	10.5	0.	0.	5.9
SIC 39	19.9	67.5	2.4	18.6	5.2	0.	0.	2.9
SIC OTHER	190.3	2030.7	26.8	161.9	38.2	0.	1.1	171.5
TOTAL ALL SIC'S	8669.0	45957.3	1147.6	7411.6	2123.6	0.	16.0	3185.2
TOTAL ALL USER	13392.0	66217.8	2141.0	11554.2	3677.7	0.	455.5	5207.8

SEWAGE BY WATERSHED THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	0.2	0.	0.	0.	0.	0.	0.	0.
INSTITUTIONAL	147.7	0.	0.	0.	0.	0.	0.	0.
COMMERCIAL	30.6	0.	0.	0.	0.	0.	0.	0.
IRRIGATED LAND	0.	0.	0.	0.	0.	0.	0.	0.
SIC 19	7.1	0.	0.	0.	0.	0.	0.	0.
SIC 20	47.1	0.	0.	0.	0.	0.	0.	0.
SIC 21	4.2	0.	0.	0.	0.	0.	0.	0.
SIC 22	21.7	0.	0.	0.	0.	0.	0.	0.
SIC 23	2.1	0.	0.	0.	0.	0.	0.	0.
SIC 24	27.4	0.	0.	0.	0.	0.	0.	0.
SIC 25	2.7	0.	0.	0.	0.	0.	0.	0.
SIC 26	339.5	0.	0.	0.	0.	0.	0.	0.
SIC 27	9.0	0.	0.	0.	0.	0.	0.	0.
SIC 28	507.2	0.	0.	0.	0.	0.	0.	0.
SIC 29	875.0	0.	0.	0.	0.	0.	0.	0.
SIC 30	254.4	0.	0.	0.	0.	0.	0.	0.
SIC 31	7.5	0.	0.	0.	0.	0.	0.	0.
SIC 32	46.7	0.	0.	0.	0.	0.	0.	0.
SIC 33	389.4	0.	0.	0.	0.	0.	0.	0.
SIC 34	8.6	0.	0.	0.	0.	0.	0.	0.
SIC 35	14.8	0.	0.	0.	0.	0.	0.	0.
SIC 36	8.5	0.	0.	0.	0.	0.	0.	0.
SIC 37	19.4	0.	0.	0.	0.	0.	0.	0.
SIC 38	12.1	0.	0.	0.	0.	0.	0.	0.
SIC 39	6.0	0.	0.	0.	0.	0.	0.	0.
SIC OTHER	55.1	0.	0.	0.	0.	0.	0.	0.
TOTAL ALL SIC'S	2665.5	0.	0.	0.	0.	0.	0.	0.
TOTAL ALL USER	2843.9	0.	0.	0.	0.	0.	0.	0.

CHAPTER V

WATER NETWORK MODEL

5.1 Introduction

The previous chapters of this report have been concerned with the development of needs, and exploring the alternate worlds, and creating the data for the analysis of these worlds. It is the purpose of Chapters V and VI to detail the procedures for the elimination of the unfeasible, the simplification of the decisions and models that are needed to analyze the area, and finally the tying of these needs to the supplies by an optimal network.

It is always a great temptation at this point for a systems analyst to create yet another model of the complete network and facilities which requires a tremendous computer capability that is not available to most areas, mainly because of finances, that would, without intervention, run to the optimum solution. This is not necessary and is detrimental to the process. Actual experience by the author has shown that the network alternatives to examine for the future are rather limited by comparison. The feasible solutions are bounded due to the physical, political, and socio-economic nature of the study area and the previously built systems. Many of the so called "possible" solutions are in reality unfeasible and are not available for evaluation. These must be identified and removed from the area of consideration.

The rest of this chapter is devoted to the process of identifying the "real" networks (actually, most water source systems are simply additive) based on these future demands. All of the concerned agencies must evaluate the existing network and that which has already been programmed and identify which of these options are available. In other words, is a source, treatment plant, or pipeline that is not at capacity, available for other users? If it is available, for how long and at what cost? This then becomes another primary node for operational gaming intervention in this interstitial process. The group must reduce the network to a feasible condition.

After the network has been reduced to this "workable state", the group then decides what alternatives are to be analyzed. These alternatives are evaluated by a cost model. This process is done for each five year interval until the study period has been evaluated. This once through process becomes the "plan" for the area over that time interval. This process is extremely flexible for impact analysis. Most of the alternatives have already been evaluated, and very little effort and time has to be expended to update the plan.

5.2 Network Formulation

The network that will be formulated is a regional network. This network will vary greatly with each region but will be structured by political and corporate jurisdictions, sources, pipelines, treatment plants, storage facilities, etc. The region will be composed of several communities and metropolitan areas. Many of these political jurisdictions will have independent networks and some, mainly the metropolitan areas, will probably have an interconnected water system with several sources and treatment plants.

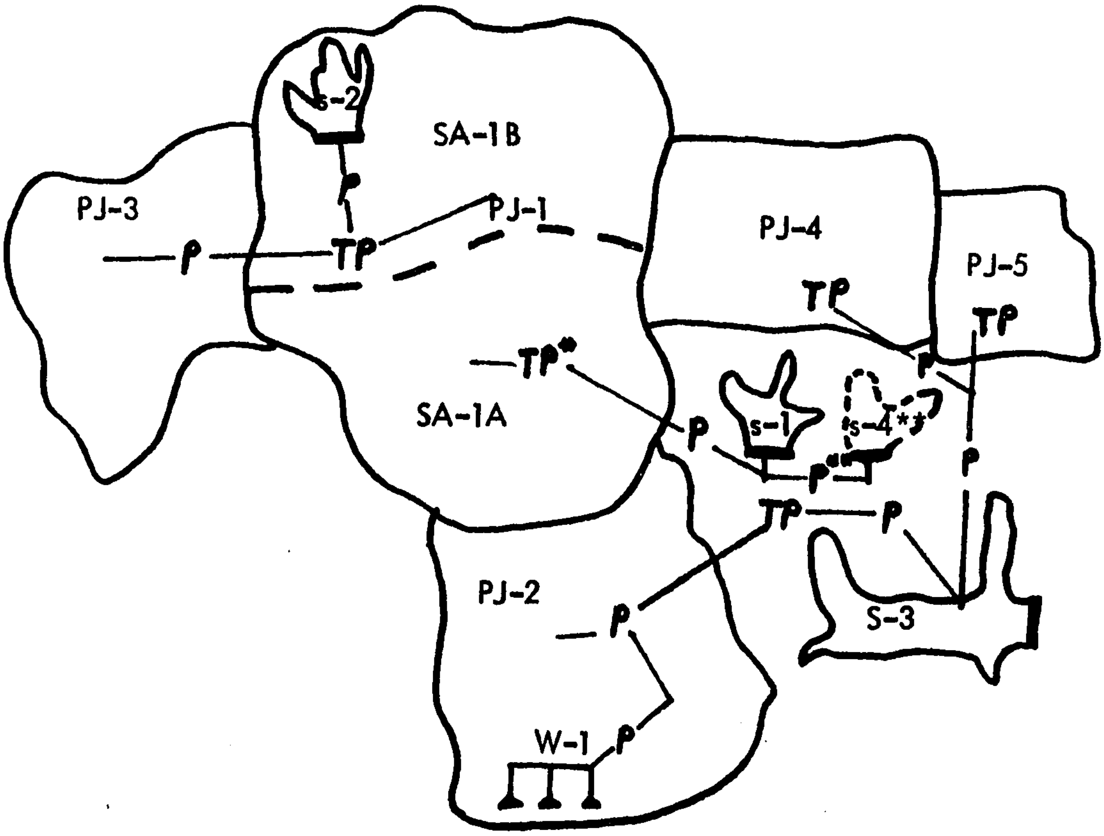
The object will be to formulate these varied networks into one system for the whole region. This does not imply that the whole region should be made into one interconnected network, although this usually is a desirable goal. It does imply that the whole region has to be formulated as one problem and evaluated as a complete system.

The network consists, therefore, of all sources that are available to the region, although some of these may be some distance from this region. It also includes the necessary raw and fresh water storage facilities, treatment plants and the connecting lines that provide the transportation links for this water. It does not include the local networks, those inside of the corporate limits, that distribute the water to the user. These are evaluated using the procedures outlined in Appendix C, Water, Sewer, and Storm Drainage Micro Area Requirements (14). The formulation is for a system like that shown in Figures 5-1 and 5-2.

The first step is to formulate the current network out of the inventory data. This network is evaluated against the projected demand for the next five year interval. Next, the requirements are compared to the existing and programmed capabilities. This determines the actual network that will be under consideration. This is accomplished by the procedure detailed in the following paragraphs.

The existing facilities were evaluated in the inventory and analysis phase of the study. The forms used are shown in Appendix B (14). These forms were originally developed for the Indian Nations Council of Governments (INCOG). This data,plus the inventory of the sources and major pipelines both existing and those that are programmed within this five year time interval, provide the existing network, see Figure 5-1.

As can be seen from this figure, the sources, treatment plants, and pipelines for the existing and programmed network are identified. Each political jurisdiction that receives its water supply from a particular source is noted, and if it is from separate sources, the political juris-



PJ - Political Jurisdictions
S - Water Source Surface
W - Water Source Subsurface
SA - Special Area of Political Jurisdiction
TP - Treatment Plant
* - Programmed for Expansion
** - Programmed New Facility

Figure 5 -1. Existing Metropolitan Study Area.

diction is divided into special areas.

The capabilities, cost, and liabilities of each portion of the existing network have been identified. This established the existing network. The demand model is run with this existing network data to validate the model to this metropolitan area. If it is off for any area, the technical coefficients and equations should be revalidated.

At this point in the study procedure, the existing network has been evaluated and identified. It was then used to validate the coefficients in the demand model. This now allows the user agency to evaluate the first five year time interval for the study area.

The demand model is set for the network by coding each SAU to its proper group (political jurisdiction, sources, special area, treatment plant, etc.) that coincides to the existing network. The demand model is run for the next five-year interval for each alternative under consideration. The future land use of the existing area is coded into the same land use procedure as the current land use. The land use to be developed is added to the existing scheme as visualized by the user agency. It is also entered as a special area. This is done to preclude having to revaluate this area if it becomes incompatible with the existing network and needs to be supplied by an addition to the network. This is done for each of the future alternatives that the user agency wishes to explore. The option that the demand model has to evaluate the delta increase in water demand should also be run. This gives the increases and the new requirements as a separate output which makes evaluation of these networks easier.

After the run of the demand model and the inventory, the using agency now has enough data to evaluate the existing and programmed networks for time equal to plus five years.

The first step is to examine each source of water by each of the user codes. Can the existing and programmed sources take care of their respective users? The sources that can are noted and their excesses in capacity are evaluated. The sources that cannot take care of their future requirements are examined next, and the reason for the deficiency is evaluated. Has it reached full capacity because of growth of the old users alone or because of growth and new development? If it is because of new development then this new area is examined as a special area requiring a new source. The old area is then checked to see if it can be handled by the old source. The deficiency or excess is noted and recorded.

The source data is then compiled for the study area. The excess of water by each source is evaluated first. The controlling agency is contacted to determine if the excess is available for use in other areas. If it is being held in reserve and is not available, then it is removed from the excess roles. If it is available, then the cost per million gallons, amount available, and duration of the availability are determined. The above procedure includes those sources which have already been programmed for completion prior to the end of this five-year interval.

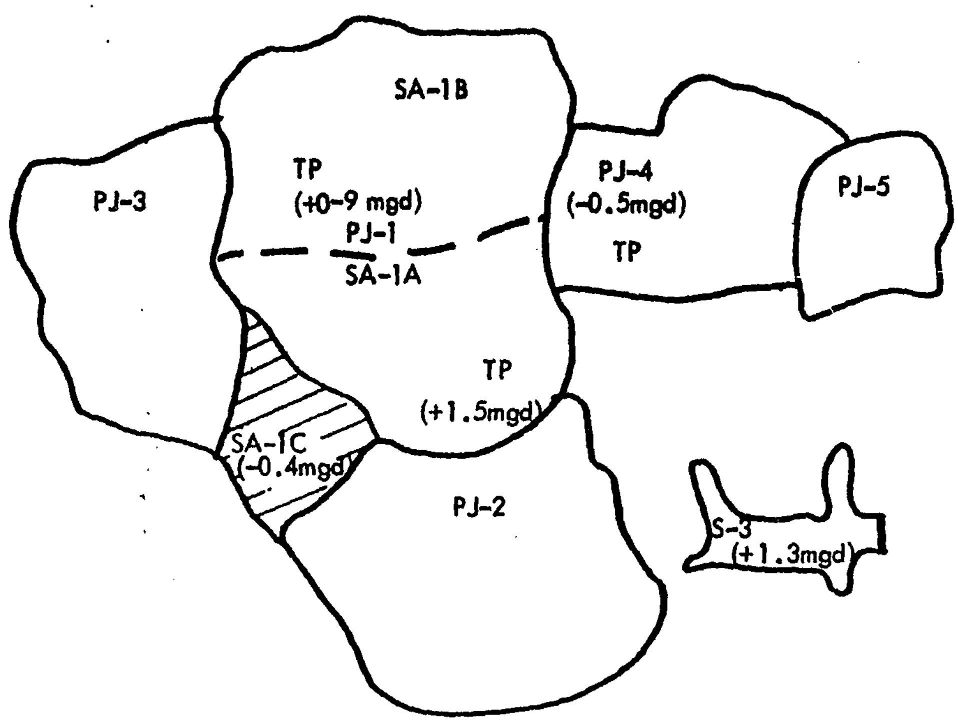
The second step is to evaluate the treatment facilities and their capabilities. The procedure is very much the same as that of the sources as far as identifying the excesses and deficiencies. The exceptions to the above procedures are the evaluations of the treatment plants themselves. Each plant that has a deficiency has to be examined individually. Can the plant be expanded to a capability that would take care of the needed water supply? This decision is based on the current condition of that facility. We must carefully examine the expansion of a facility versus the construction of a new one.

The final step is the evaluation of the pumping and pipeline facilities that interconnect the sources, treatment plants and the user networks. Again these facilities are evaluated for their excesses, deficiencies, and availabilities. The procedure is the same as that described above for the sources and treatment plants. The completion of this phase concludes the information needed for the network formulation.

The next phase of the network formulation is to set this data down on a map or a tabulation that can be easily understood (see Figure 5-2). This then gives the planning agency its first real look at the future requirements. Above all else, it has reduced the problem to the actual network that needs to be evaluated. Rather than a maze of plants, pipelines, pumping stations, etc., the user agency now has a mapping of the actual problem with which the agency is faced. This rather simplified version of the problem can be easily visualized and explained to all other concerned agencies.

As shown in Figure 5-2, the study area, this being one of the future alternatives under consideration, has the new political jurisdiction and special area boundaries shown for the inclusion of the projected growth. The special areas, old and new, and political jurisdictions that have deficiencies have been identified and their deficiencies noted. The facilities that do not have adequate capacity are also shown. This then becomes the requirements for the time interval under study.

The process is repeated for each new increment of time until the complete study period has been evaluated. This procedure gives the user agency an incremental analysis of the excesses and deficiencies of the study area for the "desired" alternative. The accumulation of the future data for the formulation of this desired network is now complete. If there is more than



Excesses

1. Source 3 - 1.3 mgd
2. TP (SA-1A) - 1.5 mgd*
3. TP (SA-1B) - 0.9 mgd*

Deficiencies

1. TP (PJ-4) - 0.5 mgd
2. SA-16 - 0.4 mgd

* Available for PJ-1 only

New Special Area

Figure 5-2. Future Requirements.

one "desired world" that is to be analyzed, then the process is repeated for each alternative in turn.

It was at this point that, for each "desired world", the author found it beneficial to group this data into individual categories. This made it easier to present to the Council of Governments for selection of the network alternatives that will be modeled for the final plan selection. It was determined that for each political jurisdiction, source, treatment plant, and storage facility, an individual data sheet for these categorical increments gave a much clearer picture of the excesses and deficiencies, expecially when accompanied by each individual mapping of category (See page 96). (Norman is used as an example, since it is one political jurisdiction in ACOG and is currently one of the independent networks within the system.)

It can easily be seen from this data sheet that Norman's water supply is adequate until the period 1985-1990. Since Norman is blessed with an adequate groundwater supply of exceptional quality, this requirement can easily be met by the development of approximately six new wells. The treatment plant, on the other hand, will be at full capacity shortly before 1985. The treatment plant at Norman is new and has the built-in capability to be easily expanded to double its present capacity of 6. MGD.

Since the groundwater supply requires no treatment and is added directly to the water network and Thunderbird's capacity is only 8.55 MGD, then the actual needed capacity for treatment is 2.55 MGD. This can be accomplished by increasing the capacity of the plant by only 50%. This procedure gives a good picture of the water requirements and possible solutions for the political jurisdiction of Norman. The process is repeated for all other groupings to be analyzed.

WATER - EXCESSES AND DEFICIENCIES FOR NORMAN					
	Time Intervals				
	1970	1975	1980	1985	1990
POPULATION	52,117	59,500	68,000	76,500	87,000
Water Usage-GPCD***	118	120	124	129	137
Water Usage-MGD	6.15	7.14	8.43	9.87	11.92
Industrial Water Usage-MGD	1.65	7.42	3.81	5.47	7.12
Total USAGE MGD	7.80	9.56	12.24	25.34	19.04
SOURCE					
Thunderbird Lake AVG-MGD	8.55	8.55	8.55	8.55	8.55
Ground supply* AVG-MGD	30 wells** 9.00	30 wells 9.00	30 wells 9.00	30 wells 9.00	30 wells 9.00
Total MGD	17.55	17.55	17.55	17.55	17.55
Excess/Deficiency MGD	9.75	7.99	5.31	2.21	-1.49
Treatment plant-MGD	6.0	6.0	6.0	6.0	6.0
Excess/Deficiency-MGD	up to 6.0	up to 5.44	up to 2.76	-6.34	-2.55

* Ground supply requires no treatment other than chlorination.

** Avg. yield = 0.30 MGD/well

*** Maximum Daily Demand

Water - Excesses and Deficiencies for Norman

It must be pointed out that many of the water networks in a metropolitan area are independent and are not interconnected. The interconnection of all the networks into a regional system that serves the metropolitan area is a desirable goal and greatly helps the study area in meeting future water needs, as well as providing for emergency flows. This goal is usually difficult to meet due to the political and socio-economical nature of the system.

This fact allows the using agency to develop a future plan for much, if not all, of the networks based on a simple cost analysis of the few alternatives of each network without using any computerized network model. Due to the nature of these network models, as much of the analysis of the future alternatives should be accomplished by this procedure as possible.

This concludes the section on network formulation. After this procedure has been carried out for the study area, the user agency should have a complete understanding of the networks, their requirements, and the alternatives that are feasible. The agency also will have reduced the problem to the simplest version possible and will now be ready to present it to the committee of concerned agencies for final selection of the alternatives that are to be finalized.

5.3 Model Description

Using the term "model" for the next phase of this study is, in a sense, a misnomer. The step is actually made up of a set of alternatives based upon the network under consideration. The "model" may be as simple as applying derived cost functions or the use of a computerized model for the determination of the useful permutations of the network. These permutations are then used with the cost functions to derive the possible networks. A review of literature has failed to reveal any model that can effectively handle this phase of the problem on a general basis. It does not seem possible that a general "model" can be developed for the user agencies. One that can be easily understood, run, and not require larger computer capabilities than are generally available is desirable.

There are available a wide assortment of linear programs for a network analysis. The one that has had the greatest success with our requirements is the Fulkerson's out-of-kilter algorithm and several of its variations (21, 22). These variations will be covered later in this section along with their capabilities and restrictions.

After the completion of the model intervention by the committee of concerned agencies, which has resolved the networks down to the alternatives that they wish to consider, the process of network analysis is begun. The first step is to identify all of the independent networks and their alternatives. These are simple in nature and require analysis by standard engineering procedures. As used in Section 4.2, Norman, Oklahoma, is such a system.

This network is independent of the metropolitan area and has the capability, within the time frame of this study, of fulfilling its future requirements without the creation of new sources or new treatment plants. Although, when the demand reaches 24.5 MGD, new sources will have to be located somewhere between years 1995 and 2000. Depending upon the quality and type of source, a treatment plant will also be needed.

All networks that fall into this category are analyzed using a procedure that applies the derived cost functions to each of the possible alternatives. The cost functions used in this portion were derived by C. R. Bartone (20). The application of these cost functions on the independent networks constitutes the "model" for this portion of the study.

The "model" consists of the employment of the different types of cost functions that are incurred in the development of water supplies. Basically they can be categorized into four components:

1. Water source costs for either surface or groundwater which include costs for reservoirs, stream diversions and well fields.

2. Transmission costs which include costs for pumping stations and pipelines used to convey the water from its source to the area of use.

3. Treatment costs which include costs for raw water storage, treatment plants and pumping plants.

4. Distribution costs, which include costs for pumping stations, storage tanks and water mains.

In this study each of these costs has been analyzed and estimated. In general the costs are broken down into capital expenditures and operation and maintenance costs. Capital expenditures include costs for engineering design, land and right-of-way, water rights, construction, administration and financing. Operation and maintenance costs include labor, materials administration and overheads, chemicals and power. In some cases chemical and/or power costs are shown separately.

Capital costs are presented as equivalent annual costs using an interest rate of 6 per cent and a period of 25 years. Operation and maintenance costs are presented as annual costs. Both costs are presented in 1970 dollars. Adjustment to a new base year is accomplished by use of the Engineering News-Record Building Cost Index 5 for the Southwest region (Dallas)(24).

The cost data was obtained from previous studies of generalized costs for water supply systems by the Tulsa Metropolitan Area Planning Commission (25), Black and Veatch (26), and Dawes (27).

It should be recognized that the cost estimating procedures provided here are only valid for making preliminary comparisons and serve only to measure costs to a degree which will assist in evaluating planning alternatives. Cost estimates derived by these procedures should not be used in actual facilities design since they should not take the place of detailed engineering estimates for specific projects. Cost equations are valid for facilities based on use rates from 0.1 to 100 million gallons per day. For use rates in excess of 100 MGD proportionate increases in cost estimates are suggested (26).

The cost estimating procedures applicable to this model are described below. Note that all costs given are unit annual costs and to arrive at the total annual costs it is necessary to multiply by a design capacity variable. Design capacities of future facilities are always intended to be the capacities required based on water requirements at the end of the design period, i.e., the long range forecasts.

5.3.1 Water Source Costs

Unit capital costs for impounding reservoirs, including intake and pumping station, are given by

$$C_R = 74.2 \, X_R^{-.38} \qquad (26)$$

where, C_R = annual unit costs of impounding reservoirs in thousands of dollars per billion gallons.

X_R = design capacity of reservoir in billion gallons.

The minimum design capacity of future reservoirs will be that capacity capable of supplying the total average daily water requirements for all users of the reservoir.

For well development the equivalent annual costs are $2,780 per MGD capacity (26). This figure includes the development of the entire well field and should be equal to the maximum daily requirement of the user.

Natural supplies, such as lakes and rivers, require only an intake and pumping station. The capital costs for these facilities are given by

$$C_R = 3.95\, X_S^{-.178} \tag{26}$$

where, C_R = equivalent annual unit cost in thousand of dollars per MGD.

X_S = design capacity in MGD.

The design capacity is based on the maximum daily water requirement of the user.

Operation and maintenance costs, exclusive of pumping power, are $7.75 per million gallons produced (26) regardless of source. To arrive at an annual production multiply the average daily use by 365. Power costs are $5.24 per million gallons produced per 100 feet of head (26). Head requirements for wells are taken at 400 feet, and for surface supplies 100 feet of head is required. Again, a multiplier of 365 should be used to get annual production.

Finally, associated with each individual source there may be a water rights cost. This cost should be ascertained separately by a review of legal agreements and local practices. The cost will generally be expressed in dollars per million gallons used where the amount of total use is 365 times the average daily use.

5.3.2 Transmission Costs

Equivalent annual cost for capital investment in pipelines is given by

$$C_p = 41.3\ X_p^{-.49} \tag{25}$$

where, C_p = equivalent annual cost for pipelines in thousands of dollars per mile per MGD.

X_p = pipeline design capacity in MGD.

Pipeline design capacity is based on the maximum daily water requirement of the user. Note that the use of this cost equation for estimating pipeline costs requires an estimate of pipeline distance in miles. This is generally taken as the straight line distance between source intake point and the water treatment plant or discharge point.

Not included in the above capital costs is the cost of right-of-way for pipelines. An average cost figure for right-of-way is \$3200 per mile (26). Amortizing this and reducing it to an equivalent annual cost yields \$247 per mile per year. This is a fixed cost, and it should not be included in this equation since it is independent of design capacity.

Annual operation and maintenance costs for pipelines can be expressed as

$$A_p = 1.32\ X_p'^{-.49} \tag{25}$$

where, A_p = annual operation and maintenance cost in thousands of dollars per mile per MGD of flow.

X_p' = pipeline utilization level in MGD.

Note that the annual operating level and not the design capacity determines costs in this instance. These will be different except at the end of the design period.

Pumping station costs are dependent upon the number of pumping stations located along the pipeline. To arrive at this number both the available head and friction losses must be taken into account. Friction losses are assumed to be 4 feet per 1,000 feet of pipe. Available head is the difference in elevation between the intake and discharge points. Positive head, by convention, will mean that the intake is higher than the discharge point. Letting

h_f = elevation difference between intake and discharge points in feet.

d = distance between intake and discharge points in thousand feet.

Then if $h_f - 4d \geq 0$, there is enough head available to overcome friction losses and gravity flow will suffice (i.e. no pumping stations are needed). If $h_f - 4d \leq 0$ the number of pumping stations required is

$$n = \frac{h_f - 4d}{400}$$

rounded to the next higher whole number.

The unit capital cost for each pumping station is given by

$$C_n = 6.65\, X_p^{-.314} \qquad (26)$$

where, C_n = equivalent annual unit cost of pumping stations in thousands dollars per station per MGD.

X_p = design capacity of pipeline.

Annual operation and maintenance costs for pumping stations are given by

$$A_n = 2.12\, X_p'^{-.314} \tag{26}$$

where, A_n = annual operation and maintenance cost in thousands of dollars per station per MGD of flow.

X_p' = pipeline flow level in MGD.

In addition to the operation and maintenance costs, the cost of pumping power must be included. As already stated pumping power is priced at $5.37 per million gallons of flow per hundred feet of head. The head requirements will be $|h_f - 4d|$ as defined above where $h_f - 4d < 0$. The annual flow is 365 X_p'.

5.3.3 <u>Treatment Costs</u>

To assure a reliable supply of water, raw water storage at the discharge end of the pipeline may be provided.

The capital cost for raw water storage is

$$C_{rs} = 1.55\, X_{rs}^{-.201} \tag{26}$$

where, C_{rs} = equivalent annual unit costs for raw water storage in thousands of dollars per million gallons.

X_{rs} = Raw water storage design capacity in million gallons.

The design capacity for reliable supply should be ten times the average daily requirement. For pipelines of less than 5 miles length this capacity can be reduced proportionately.

The operation and maintenance costs for raw water storage are

$$A_{rs} = 0.10\, X_{rs}^{-.201} \tag{26}$$

where, A_{rs} = annual operation and maintenance cost in thousands of dollars per million gallons.

Treatment plant costs include the costs of the treatment plant and treated water pumping plant. Unit capital costs are given by

$$C_T = 25.6\ X_T^{-.257} \qquad (25)$$

where, C_T = equivalent annual unit cost of treatment plant in thousands of dollars per MGD.

X_T = design capacity of treatment plant in MGD.

The design capacity is based on the maximum daily water requirement of the user.

Operation and maintenance costs of the treatment plant, exclusive of chemical and power costs, are given by

$$A_T = 7.25\ X_T'^{-.257} \qquad (25)$$

where, A_T = annual operation and maintenance of treatment plant in thousands of dollars per MGD.

X_T' = operating level of plant in MGD.

The operating level of the treatment plant is based on the average daily requirements for the year of operation.

Chemical costs vary widely depending on the quality of the source water. Therefore, these costs should be determined individually for each source. This can most easily be done by preparing a schedule showing costs versus water quality by type of use. These costs should be given in dollars per million gallons treated where the total amount of treated water will be 365 X_T'.

5.3.4 Distribution Costs

Treated water storage requires a capital investment of

$$C_{ts} = 14.3\ X_{ts}^{-.274} \qquad (26)$$

where, C_{ts} = equivalent annual unit cost for treated water storage in thousands of dollars per million gallons.

X_{ts} = design capacity of treated water storage facilities in million gallons.

The design capacity is estimated as 25 per cent of the maximum daily use. Operation and maintenance costs for treated water storage are given by

$$A_{ts} = 1.80\ X_{ts}^{-.274}$$

where, A_{ts} = annual operation and maintenance costs in thousands of dollars per million gallons

The distribution system network costs can be estimated at $800,000 to $1,000,000 per square mile of development. Distribution pumping power requirements assume a head of 250 feet, thus the power costs are $14.50 per million gallons of flow, and the total flow is 365 times the average daily flow.

5.3.5 Total Costs

Using the above cost data, the annual total of any water supply systems for any use can be estimated in 1970 dollars. It should be recognized that each system will have its own special requirements, so that no generalized total cost equations will be attempted. For example, one town may develop a surface supply requiring treatment while an industry may develop its own well water sources requiring no treatment. For each identifiable future water use an individual total annual cost can be developed by the above-described procedures.

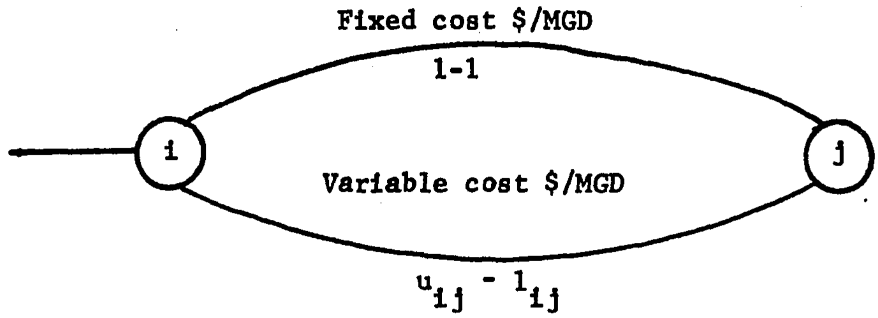
The cost data shown here demonstrate the effect of economies of scale on water system development. As the size of the system increases, the level of service is improved, and the unit cost of providing that service is reduced - a fact verified by the negative exponents on design capacity terms in the various unit cost equations. Water systems have long lives and require large capital investments, two factors that make consideration of scale economies imperative.

With the total costs of each alternative in the independent networks now derived, the decision as to the best alternative can now be made by the committee of concerned agencies. This then concludes the "model" of independent networks.

The next step is much more complicated by comparison (see flow charts at the end of this section). This is the examination of the networks that are interconnected form multiple sources and treatment plants. The formulation of a model to accomplish this task was derived from the basic description of the out-of-kilter algorithm by Fulkerson (26). This method was then developed into a program by R. J. Clasen (29). The basic description of this model can be reviewed in these publications if a detailed analysis is required.

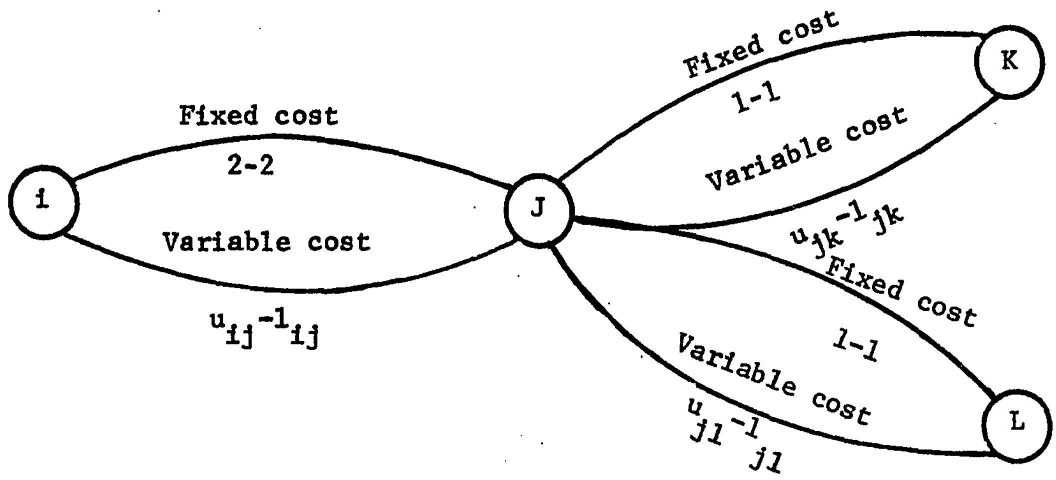
This model was then altered so that it can handle both sewer and water networks. The model is the same for both networks and will be used again in Chapter VI for the analysis of sewer networks. This was done to simplify the modeling requirements of this study and has proved to be adequate for planning purposes. It was also done when studies revealed that true cost functions are not linear. In fact, they are usually functions, if they can truly be derived, that are of a high order. It was then determined that the cost functions be disaggregated and simplified to linear functions that would give good approximations. This would allow a program to be run that was relatively simple and would derive the feasible permutations which could be analyzed in detail.

The model starts with a "super source", which is basically the environment, and feeds the water sources that supply the network. These sources are the first series of nodes. Since each node can be interconnected with one or more arcs, the cost functions can be disaggregated by the user. This is accomplished by determining the fixed cost, the cost incurred by the using agency no matter whether the facility is used or not, and assigning a flow of 1 MGD to this arc.



In other words, the fixed costs of a link in the network are assigned to an arc that connects the two nodes which denote the entrance and exit of that facility. Then a flow of 1 MGD is assigned as the upper and lower limits.

These "1 MGD fake flows" have to be added to the "super source" link for each arc of fixed costs that are assigned to the network. They must also be balanced in the network starting with the "super sink" and working backwards to the "super source".



The variable costs, which are linear in this model, are then assigned to another arc that describes the facility and the proper upper and lower bounds are also designated. By using this technique, the cost functions can be closely approximated for each link.

The network is made up of a system of nodes and arcs that are interconnected by arcs. Each node represents an intake or exhaust of some facilities. Depending on the degree of accuracy needed, computer capabilities and available cost data, this network can be as detailed as needed. An arc-node grouping can represent a complete treatment plant or each of the steps through the plant. The usual procedure is to simplify the network as much as possible, depending primarily on cost data, for the initial runs. When flows have been determined, then unfeasible or undesirable permutations of the network can be removed and new networks in detail can be derived and run.

By following this basic procedure, a very good flow and costing analysis can be run on any type of network. This procedure may even be enhanced by using some new techniques like those developed by H. A. Reeder and Dr. P. A. Jensen, who developed a version that uses a convex cost function in the program (30). The capabilities of this technique are only limited by the versatility and imagination of the user. The flow charts are presented in Tables 5-1 through 5-15.

TABLE5-1. MAIN

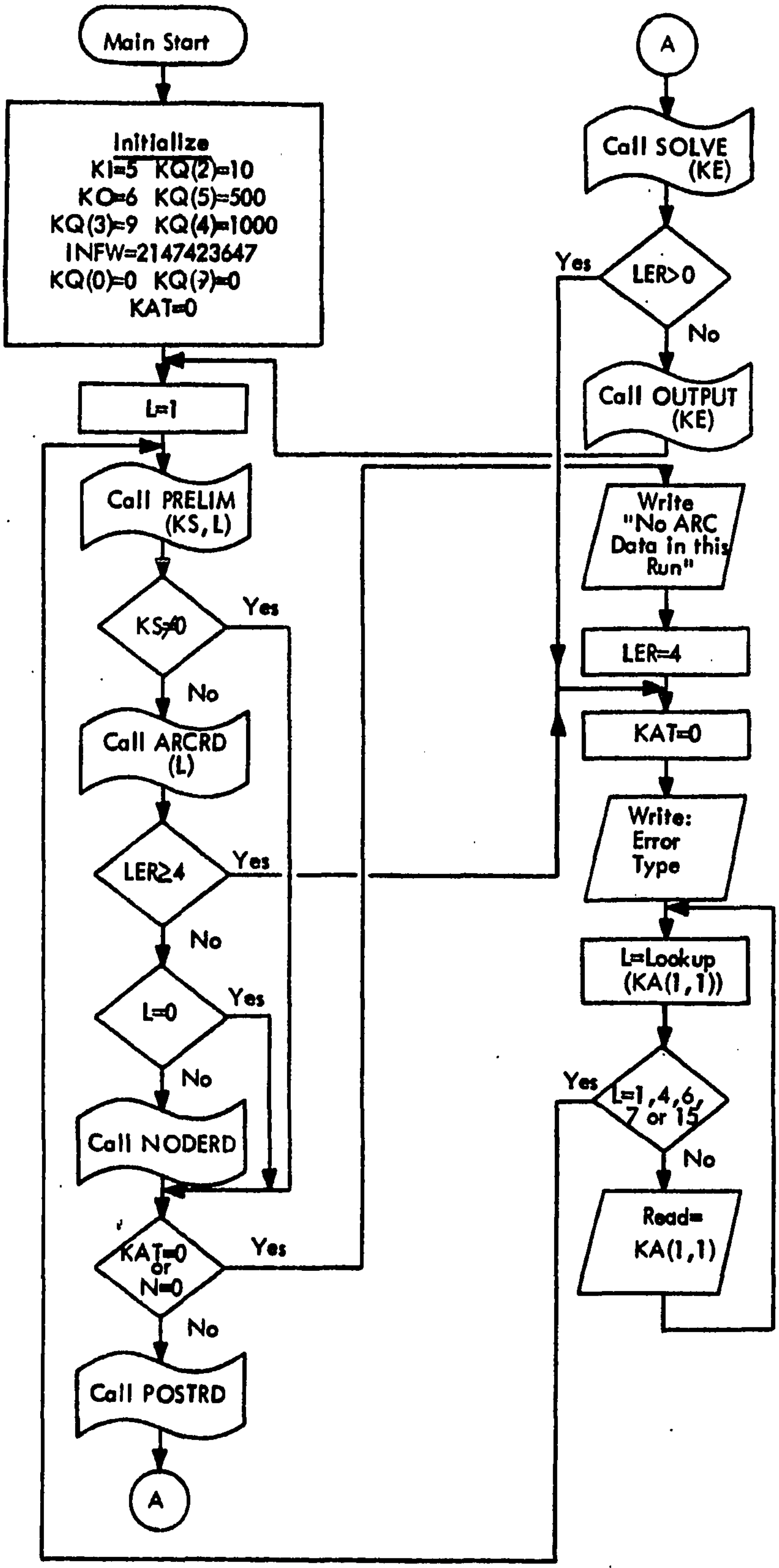


TABLE 5-2. SUBROUTINE PRELIM

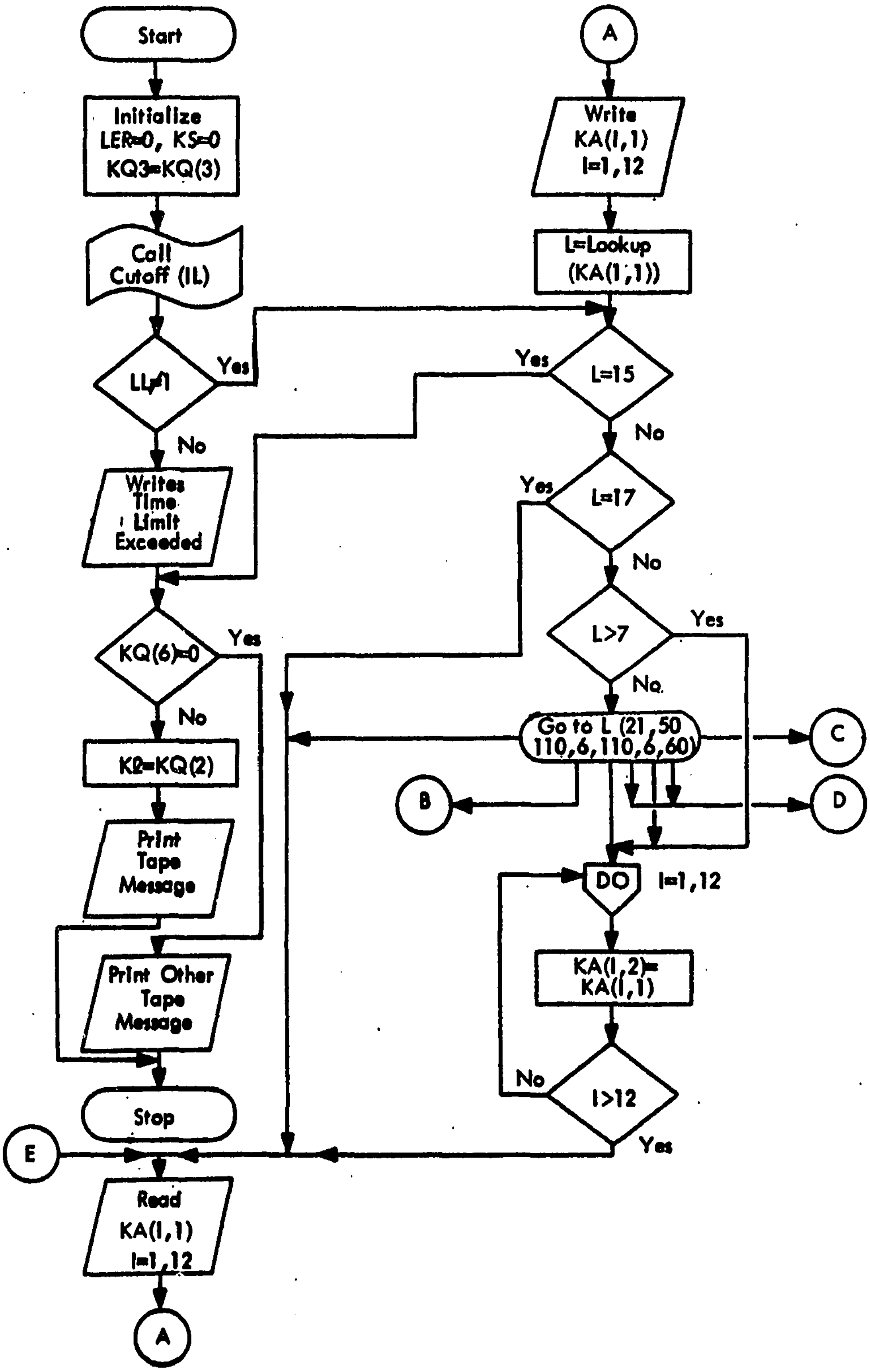
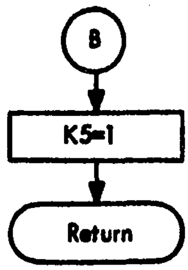
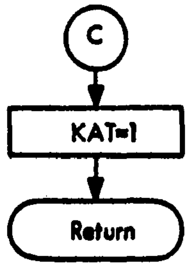


TABLE 5-2. SUBROUTINE PRELIM (Cont.)





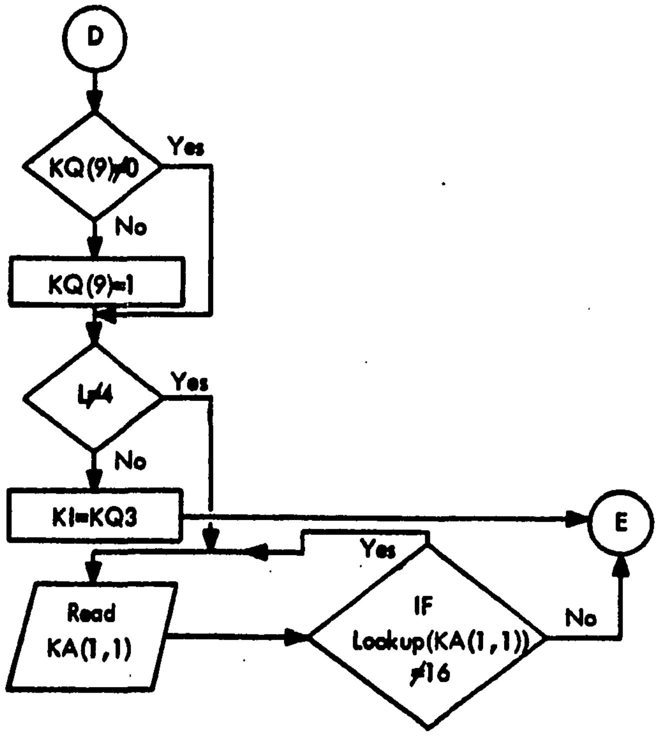


TABLE 5-3. SUBROUTINE CUTOFF

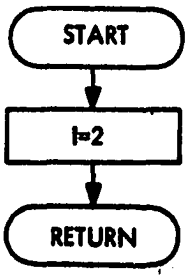


TABLE 5-4. SUBROUTINE ARCRD

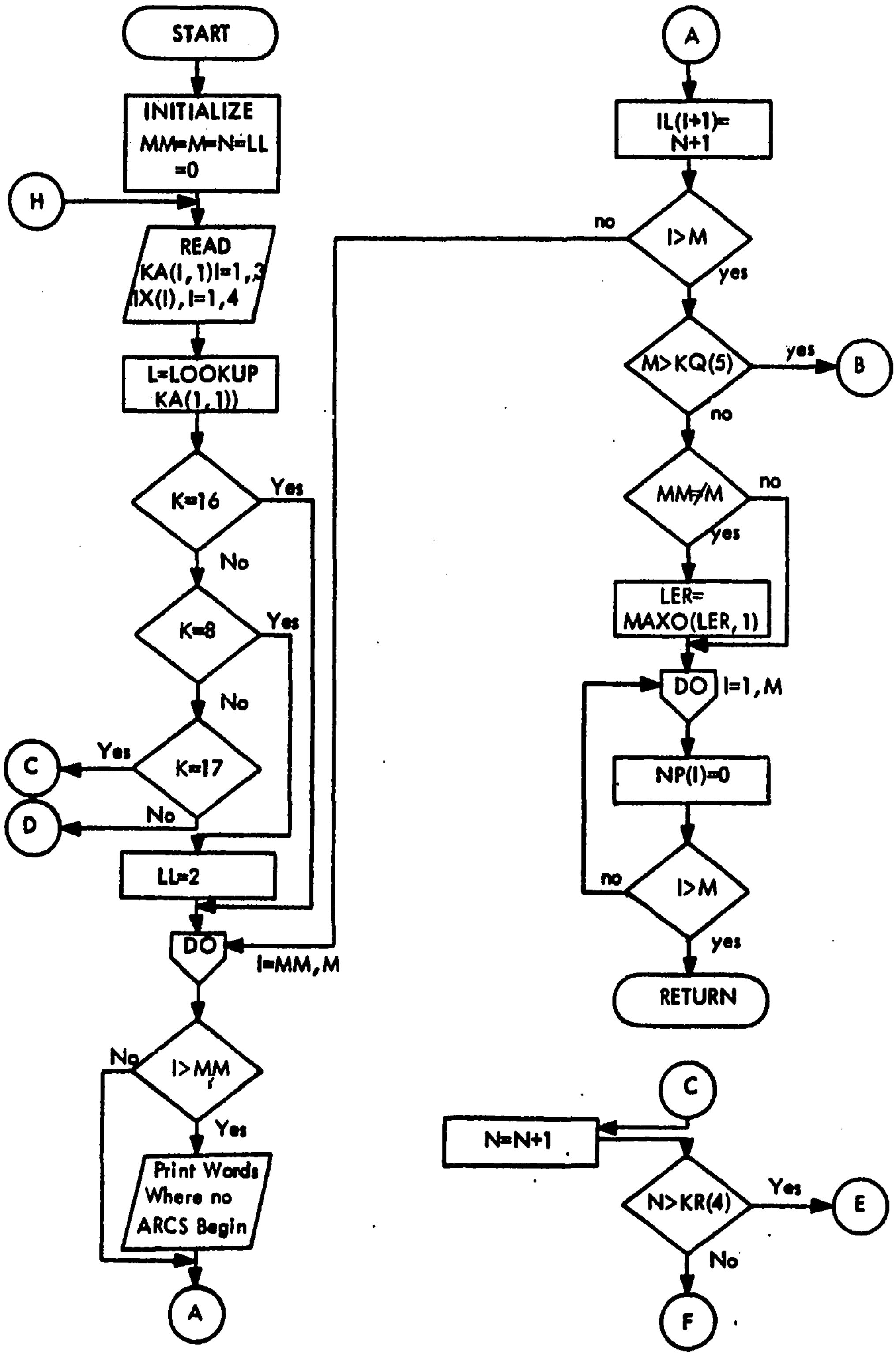


TABLE 5-4. SUBROUTINE ARCRD (Cont.)

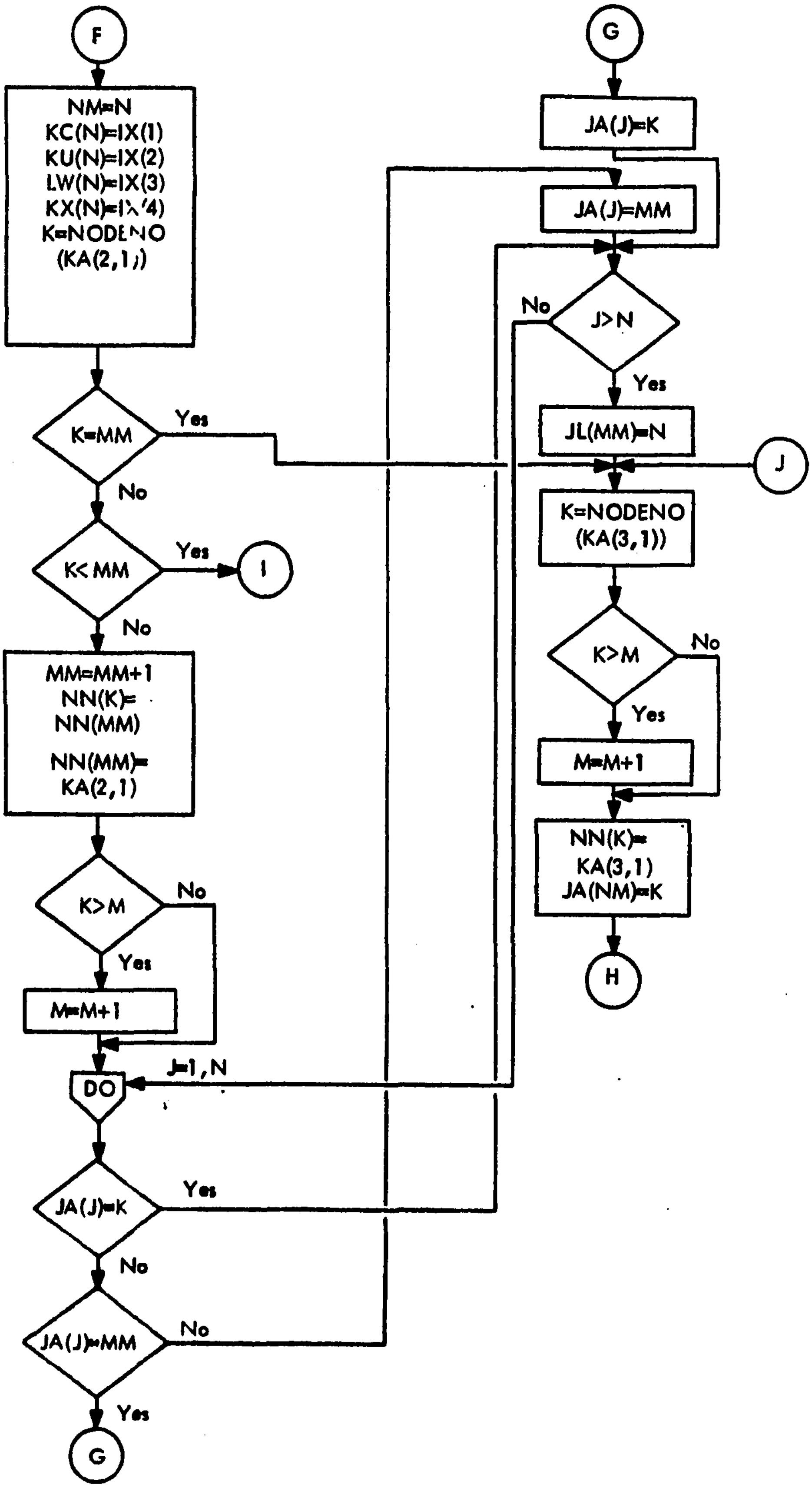


TABLE 5-4. SUBROUTINE ARCRD (Cont.)

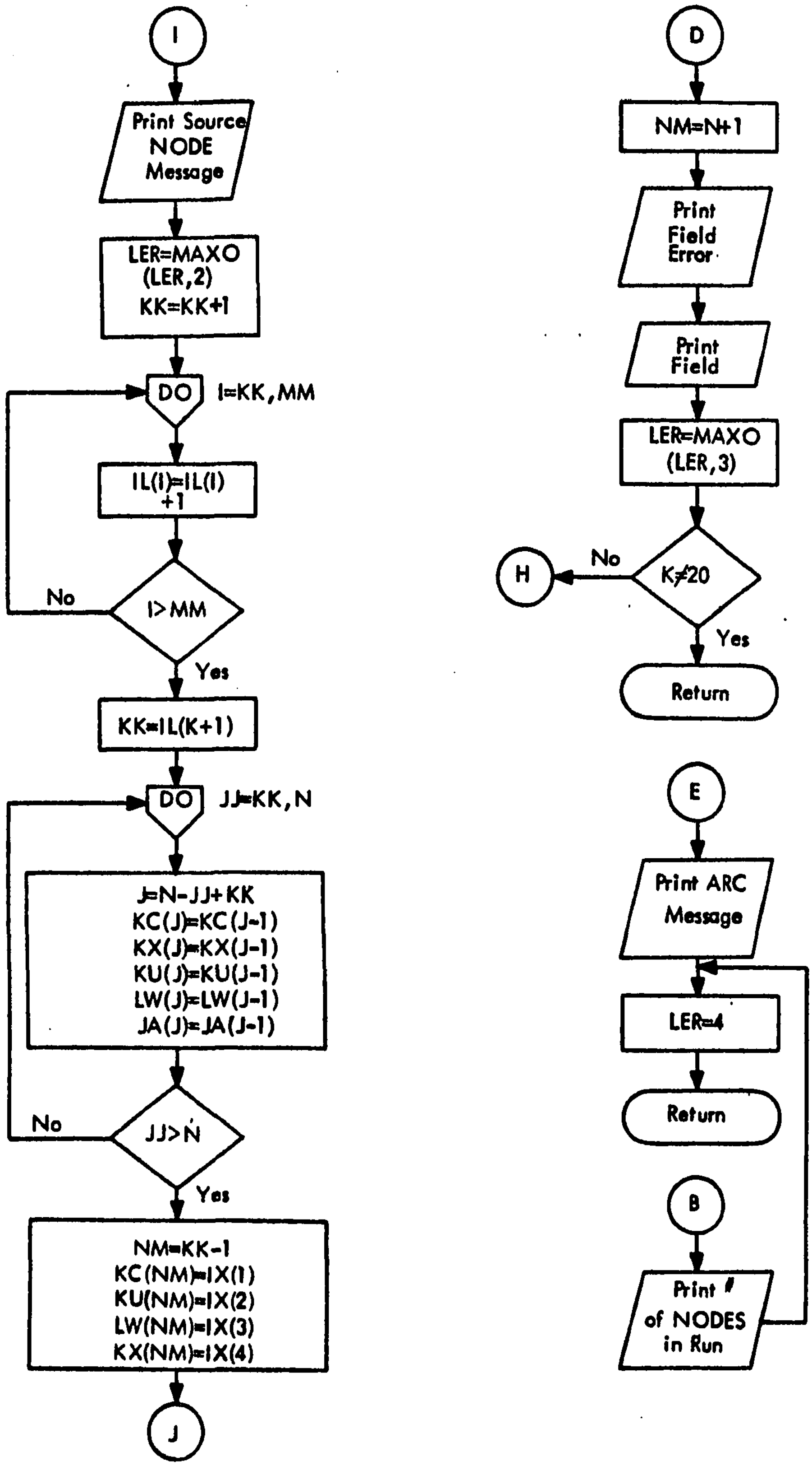


TABLE 5-5. SUBROUTINE NODERD

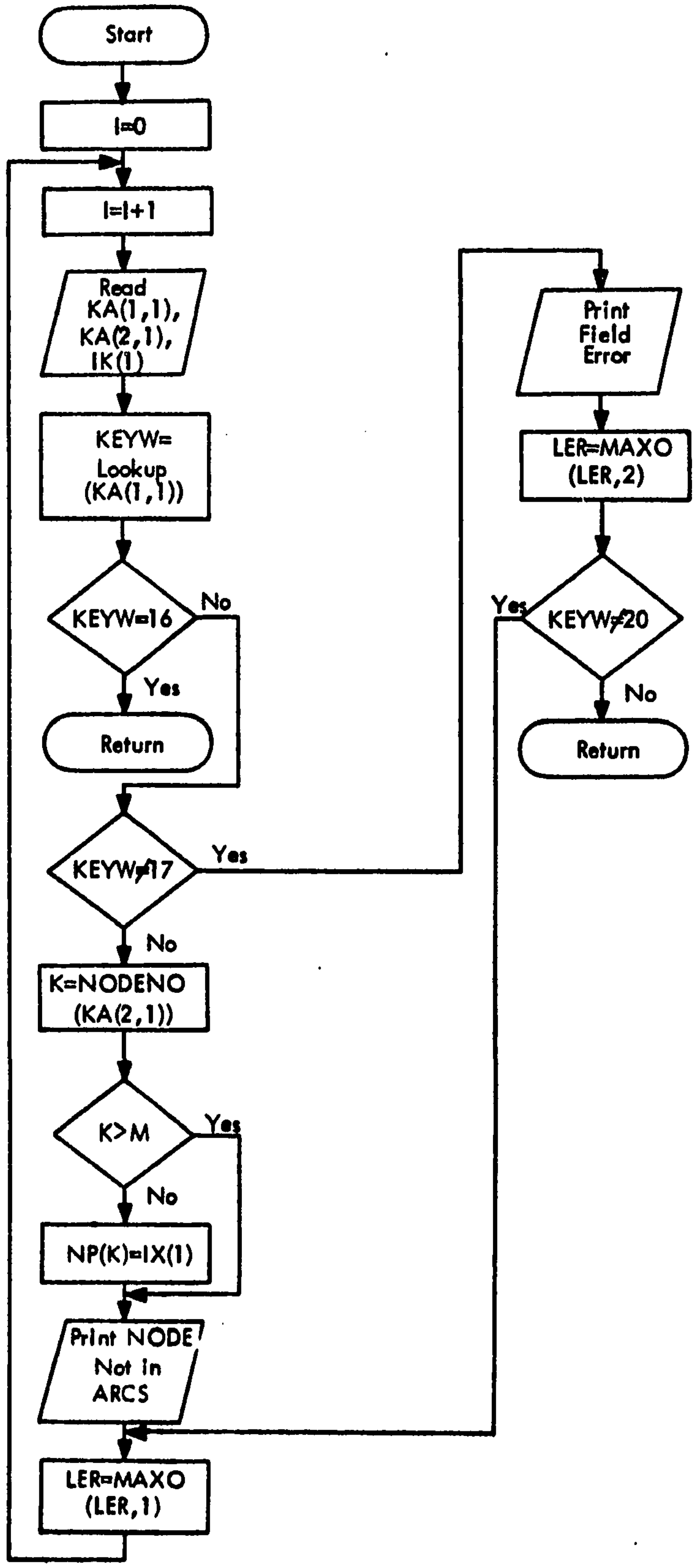


TABLE 5-6. SUBROUTINE POSTRD

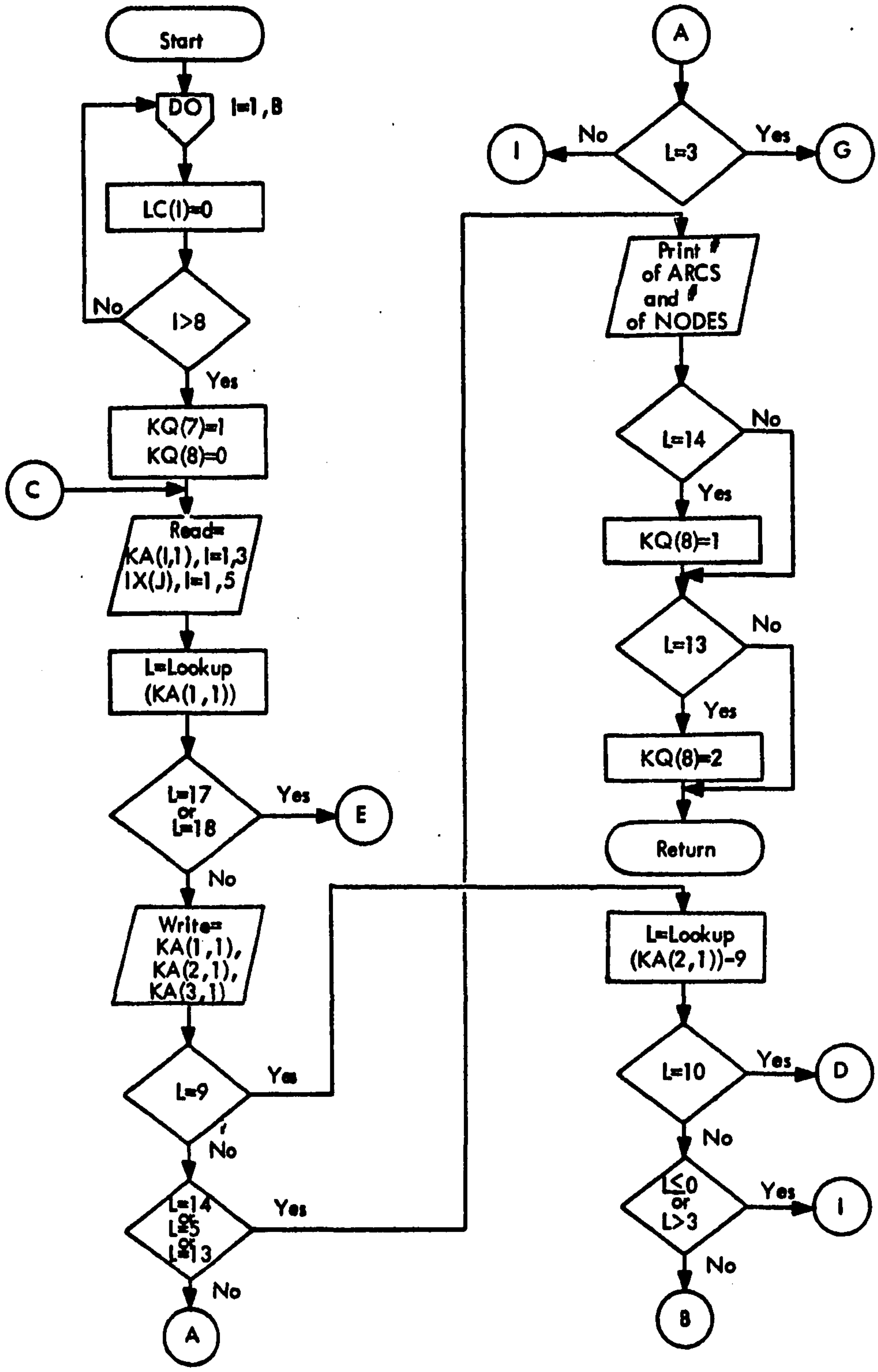


TABLE 5-6. SUBROUTINE POSTRD (Cont.)

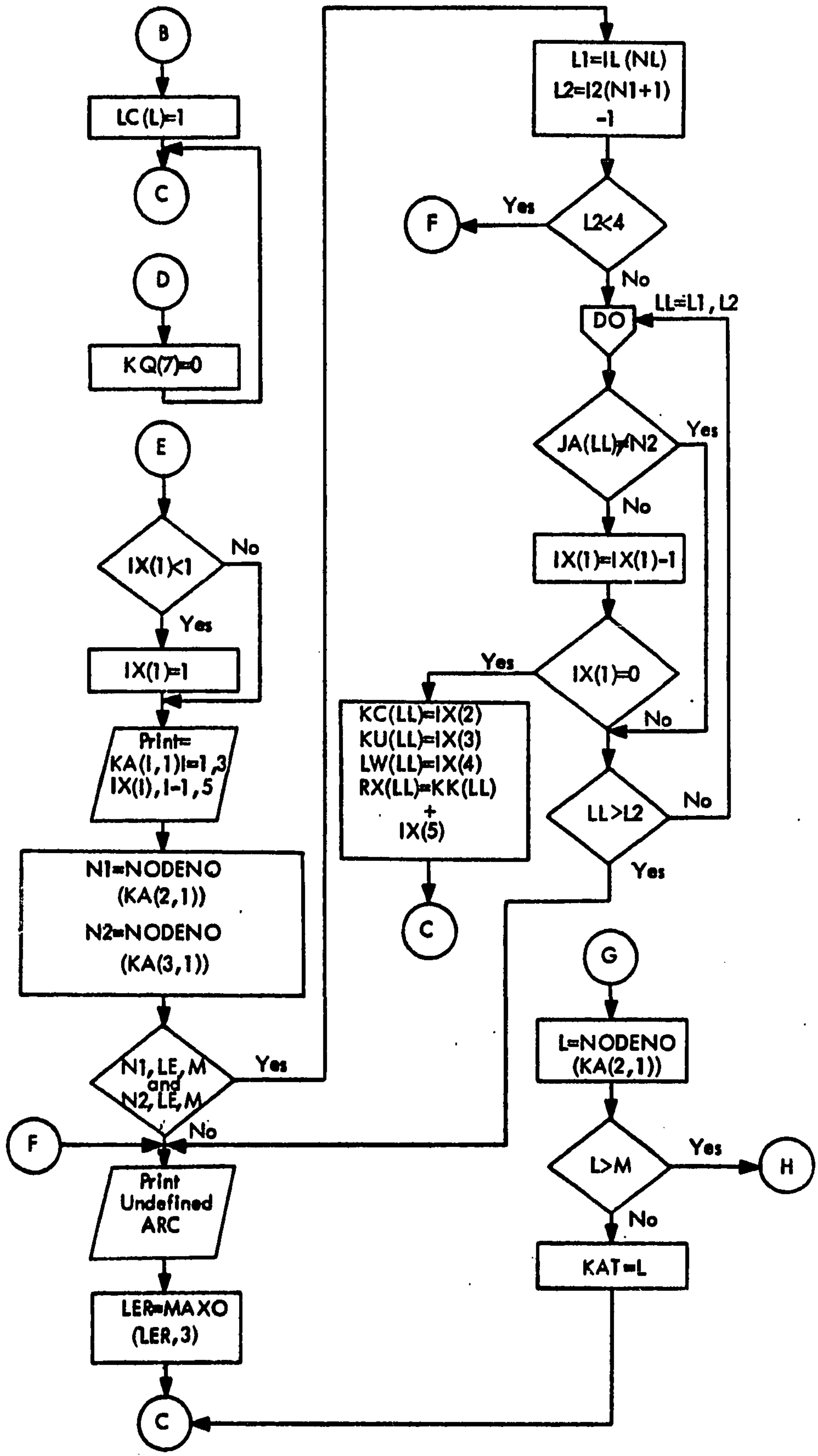


TABLE 5-6. SUBROUTINE POSTRD (Cont.)

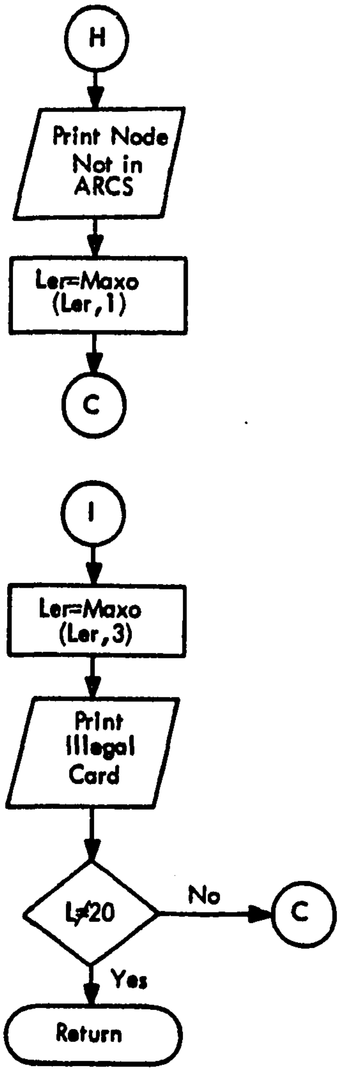


TABLE 5-7. SUBROUTINE SOLVE

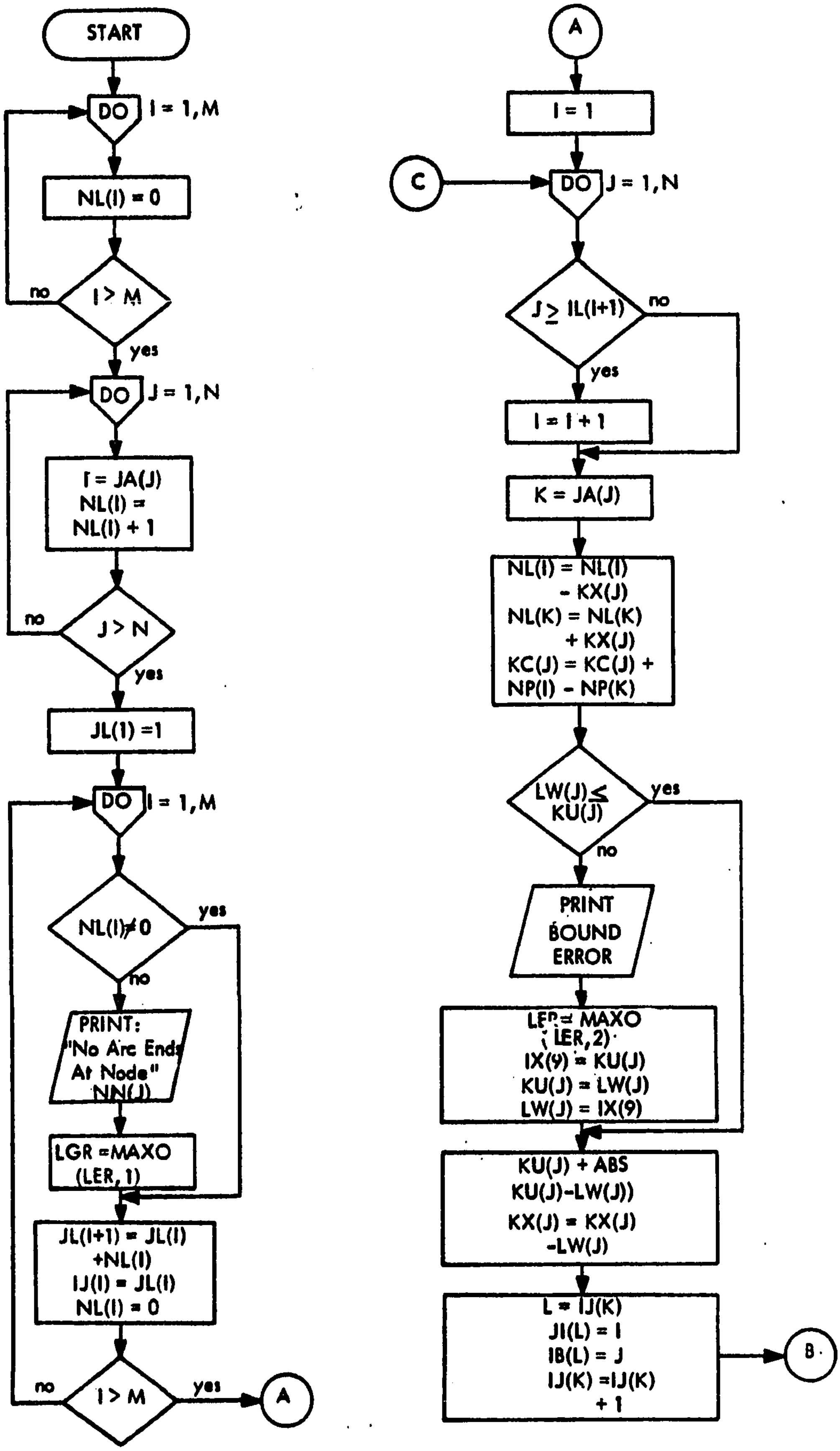


TABLE 5-7. SUBROUTINE SOLVE (Cont.)

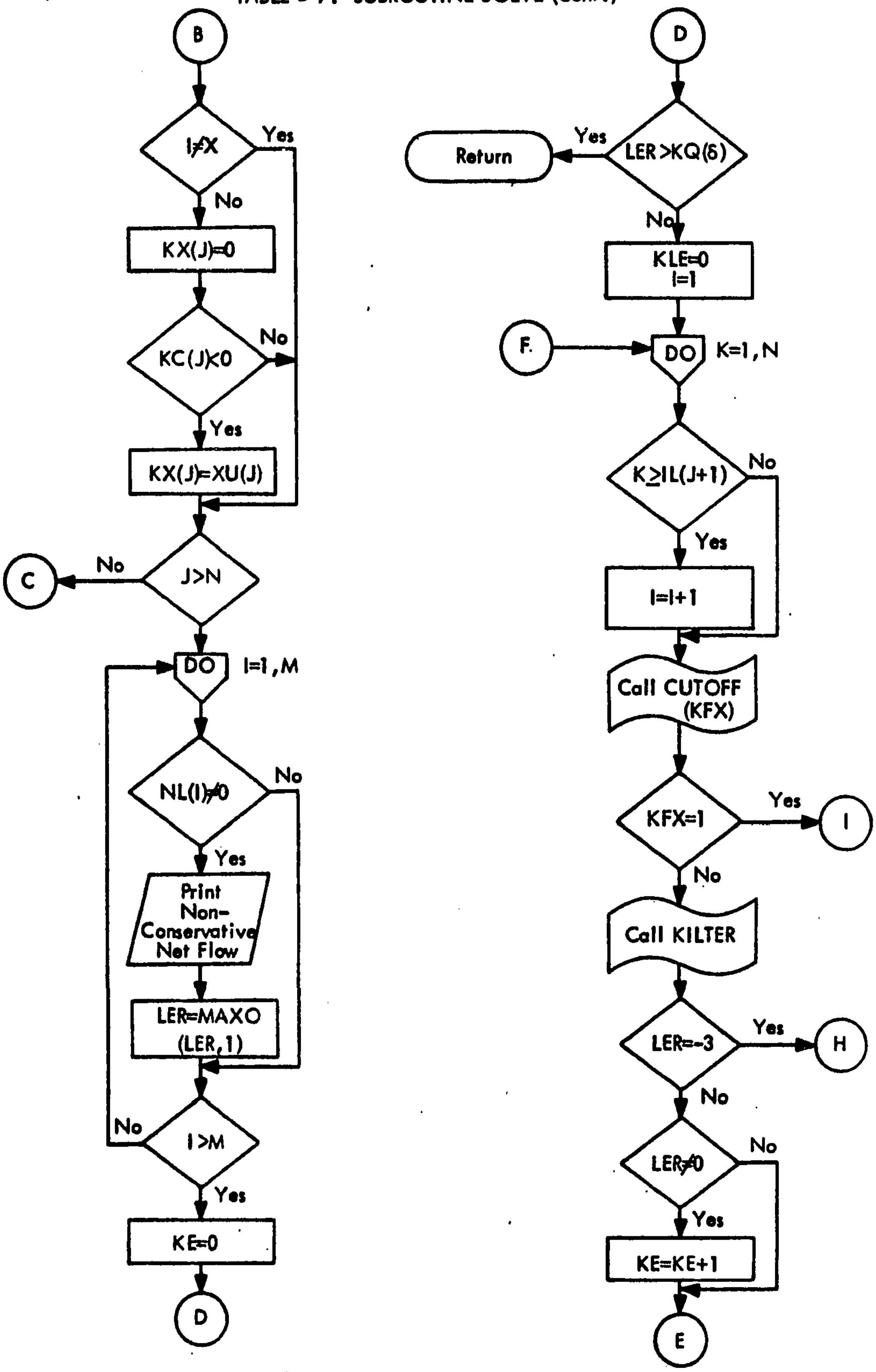


TABLE 5-7. SUBROUTINE SOLVE (Cont.)

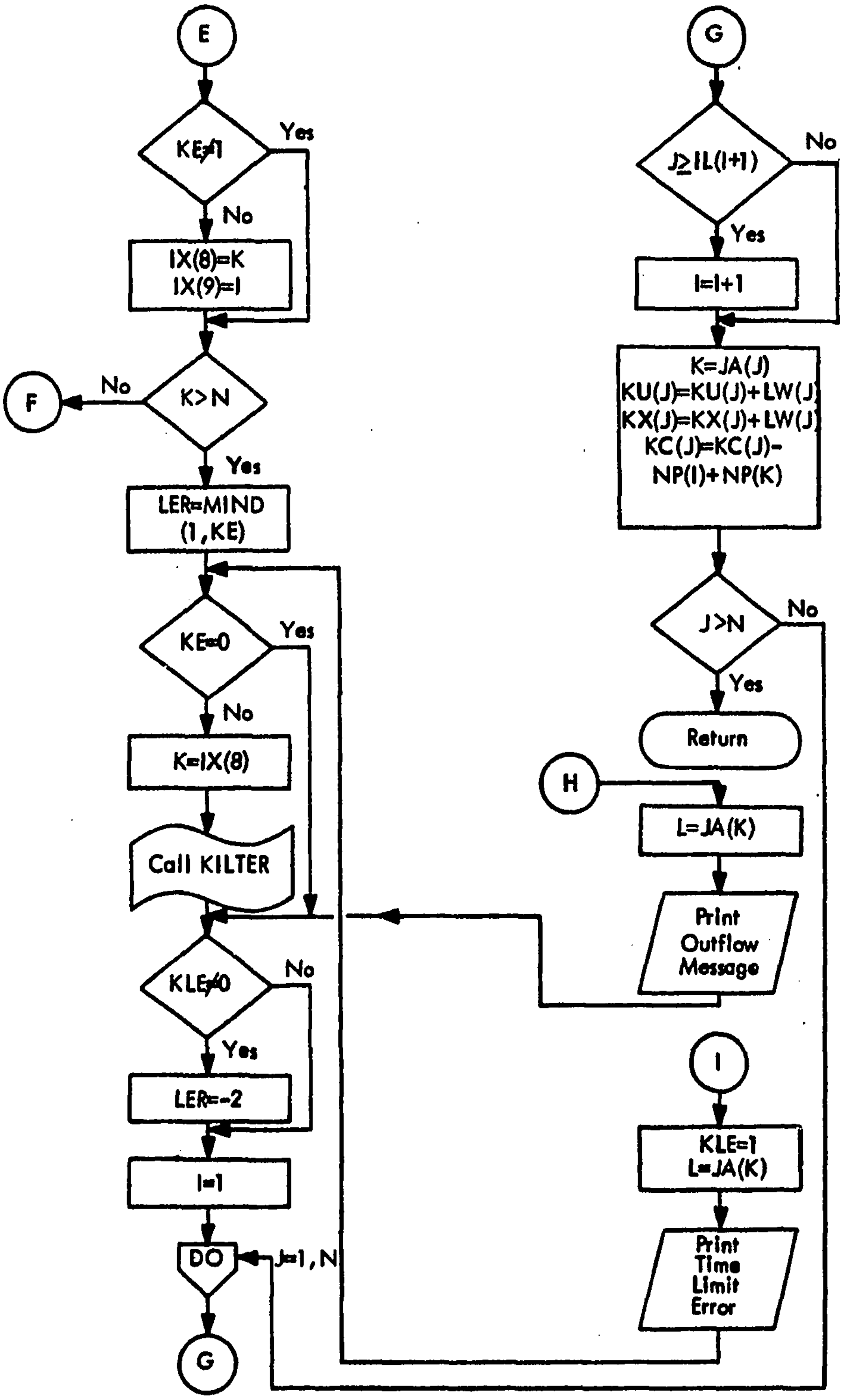


TABLE 5-8. SUBROUTINE KILTER

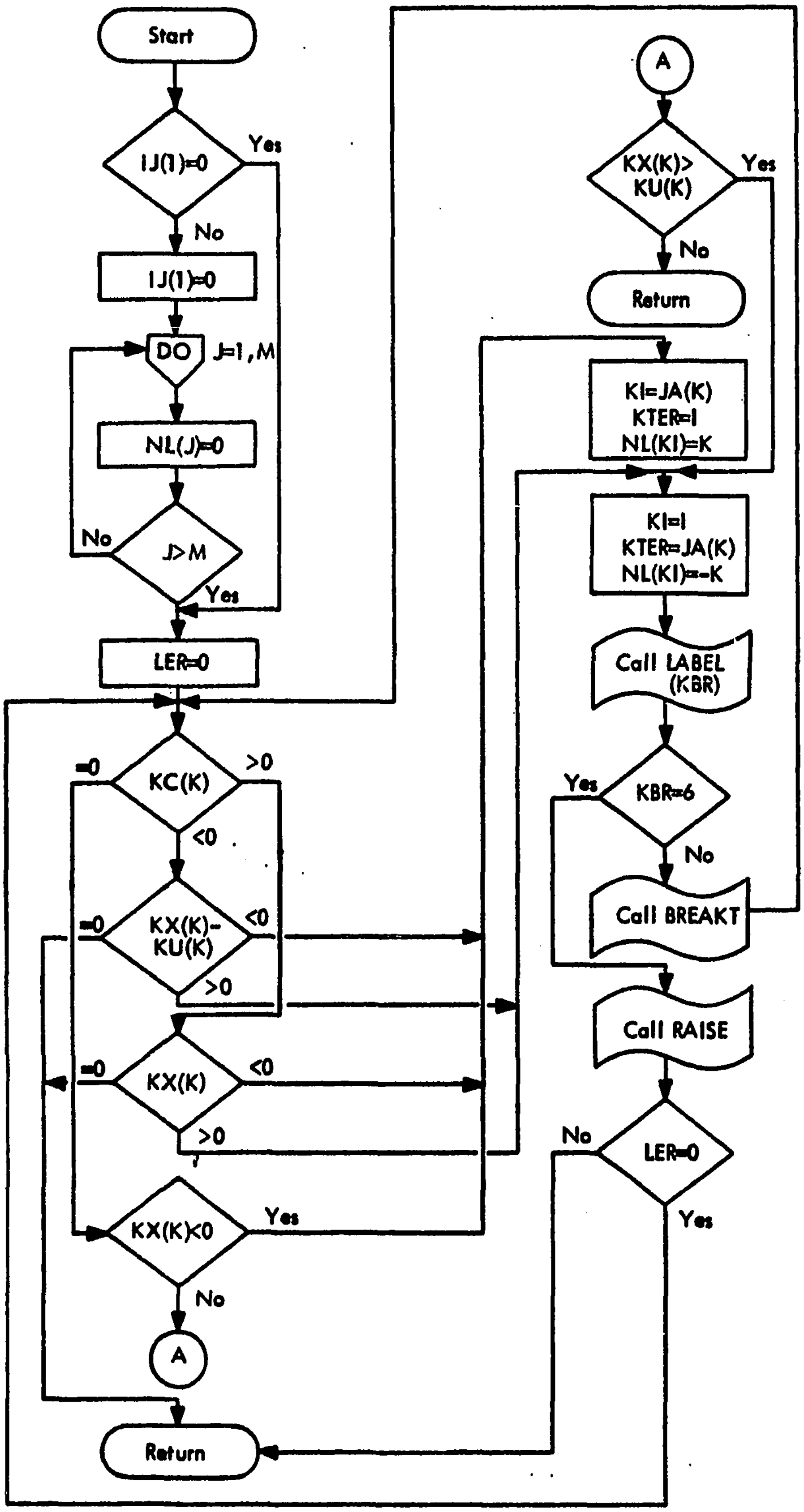


TABLE 5-9. SUBROUTINE BREAKT

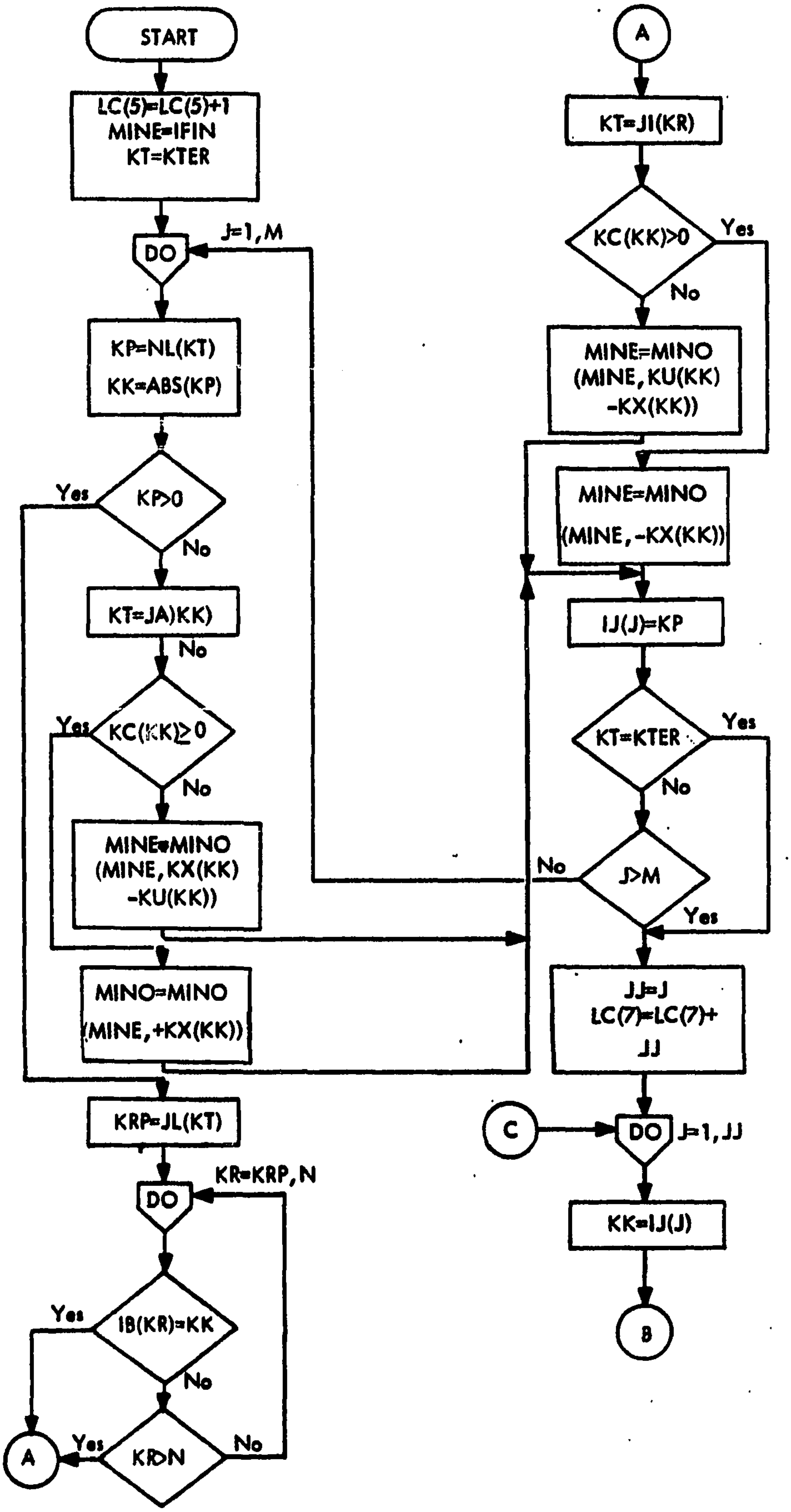


TABLE 5-9. SUBROUTINE BREAKT (Cont.)

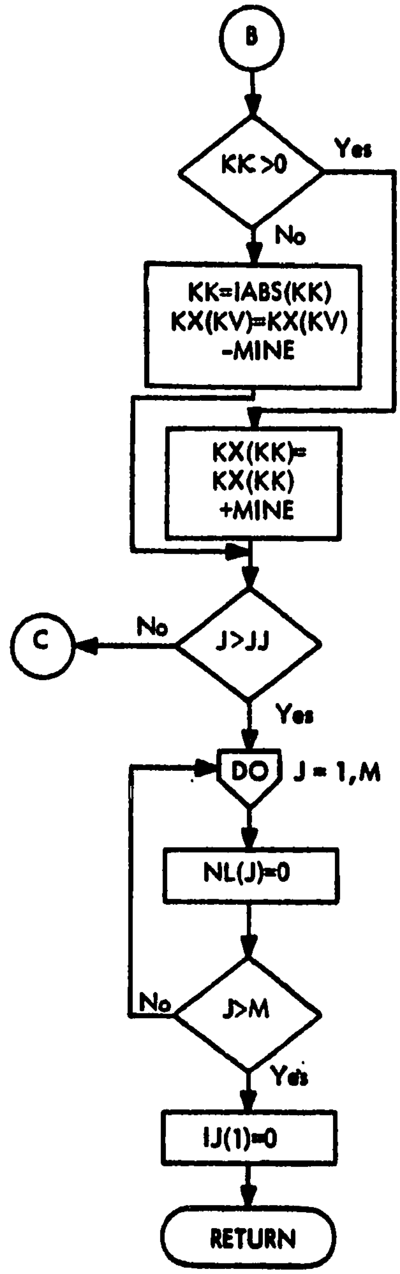


TABLE 5-10. SUBROUTINE RAISE

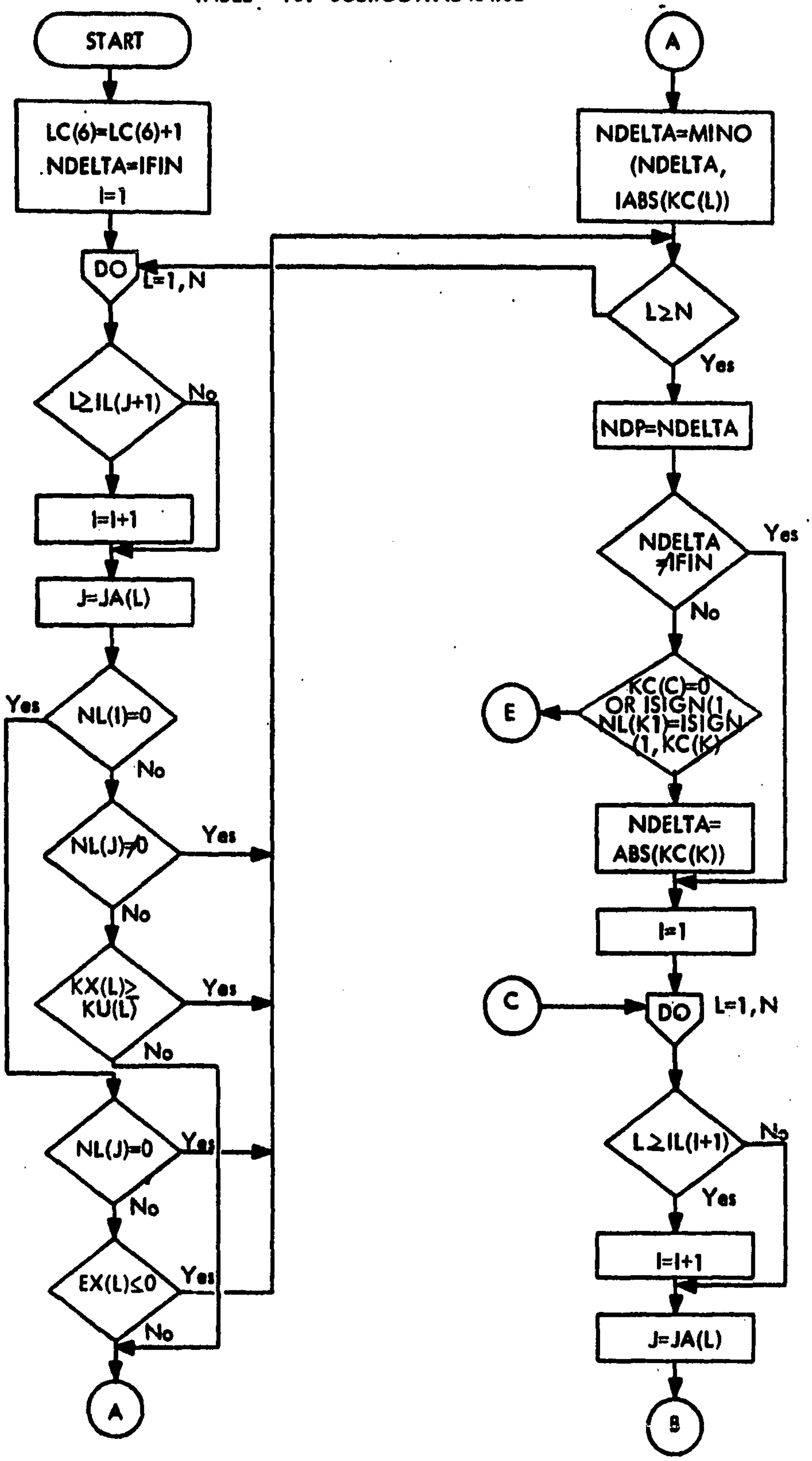


TABLE 5-10. SUBROUTINE RAISE (Cont.)

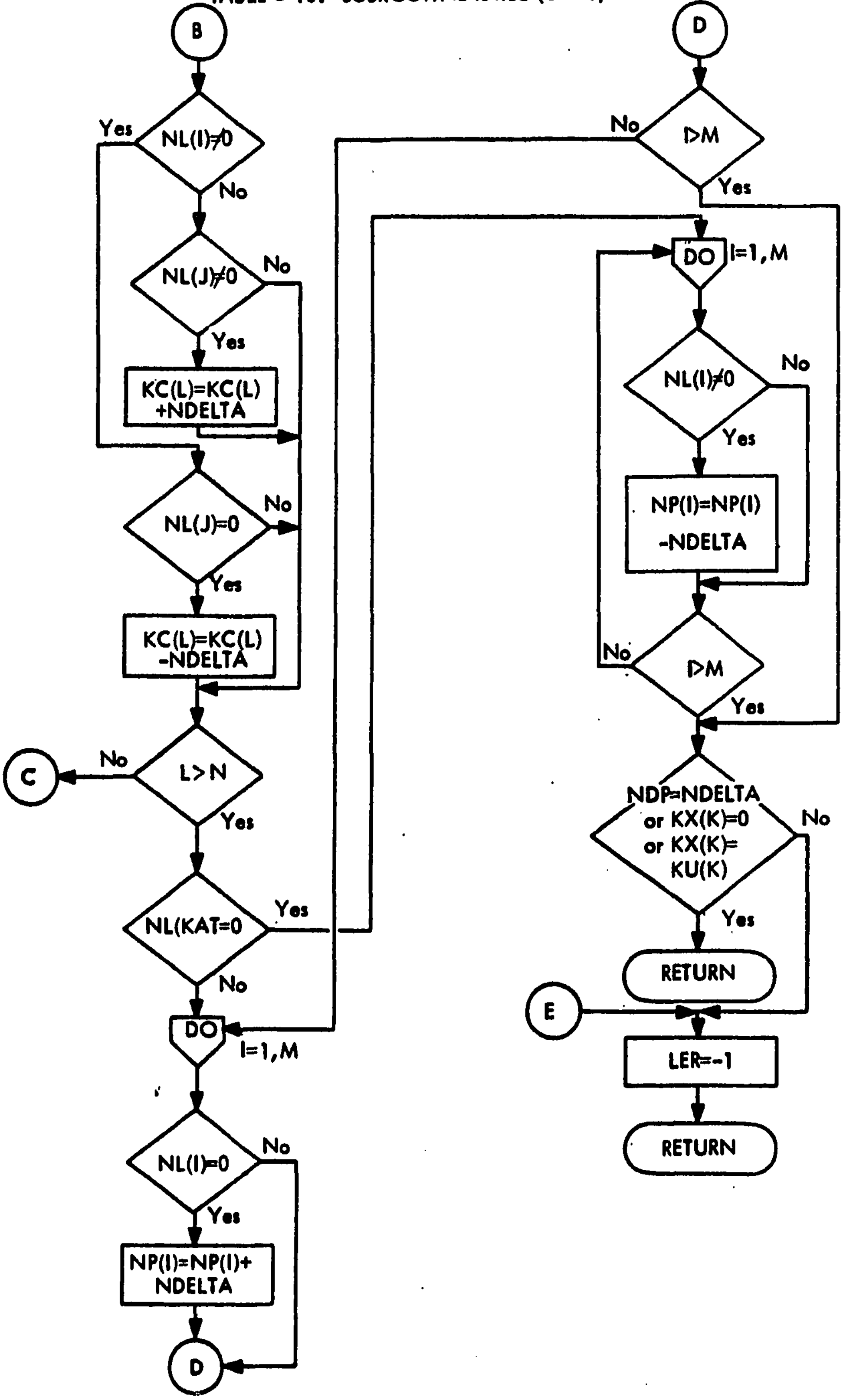


TABLE 5-11. SUBROUTINE OUTPUT

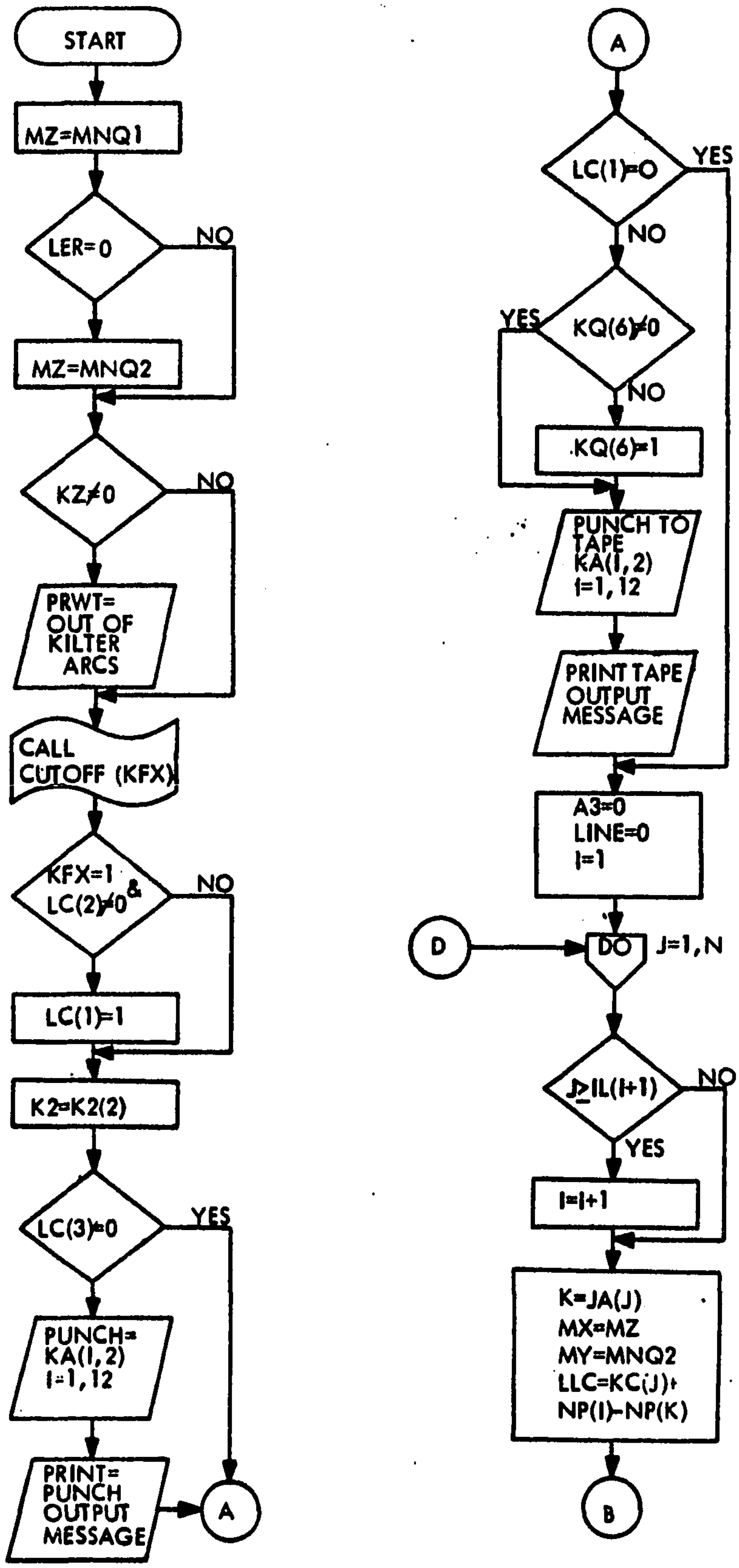


TABLE 5-11. SUBROUTINE OUTPUT (Cont.)

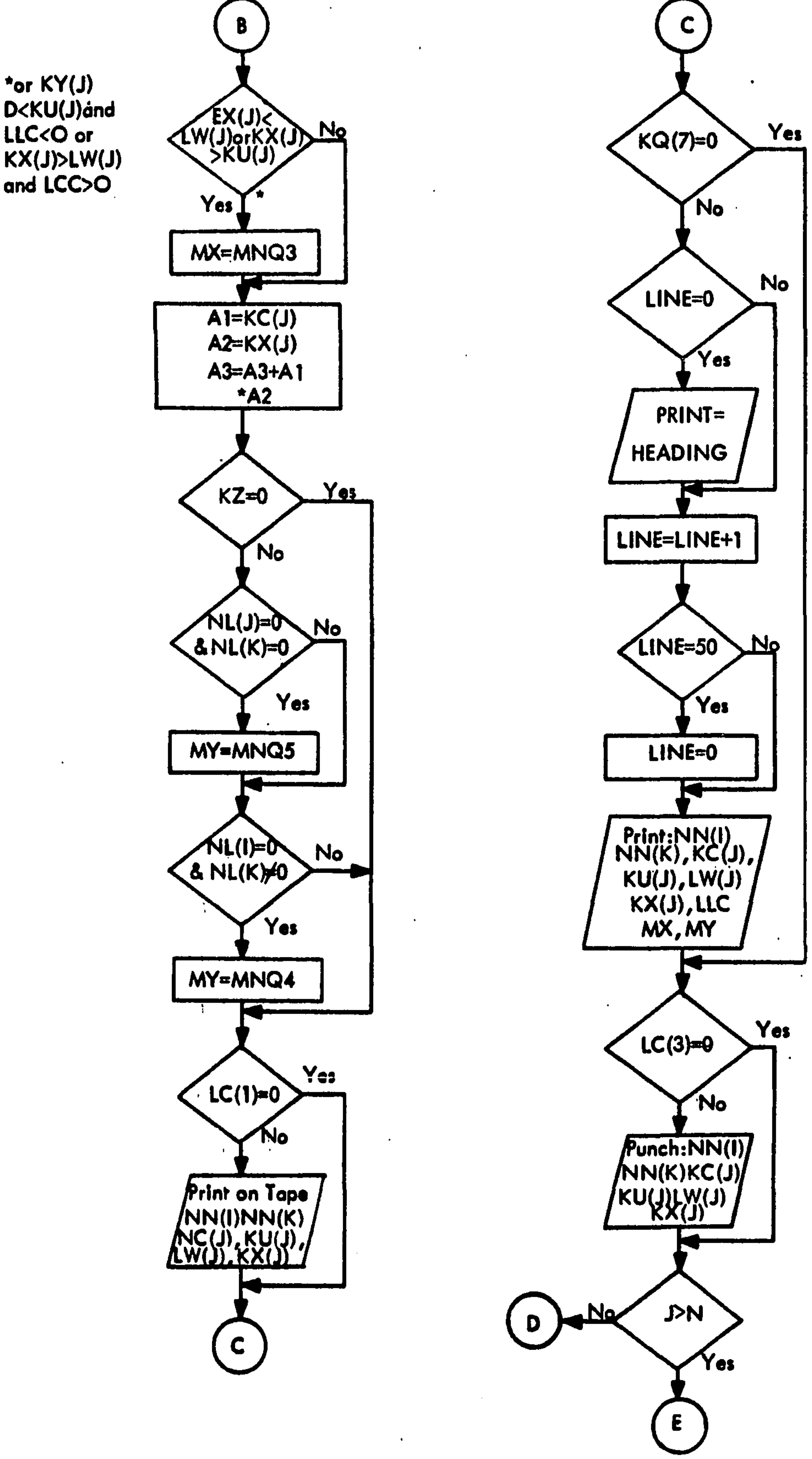


TABLE 5-11. SUBROUTINE OUTPUT (Cont.)

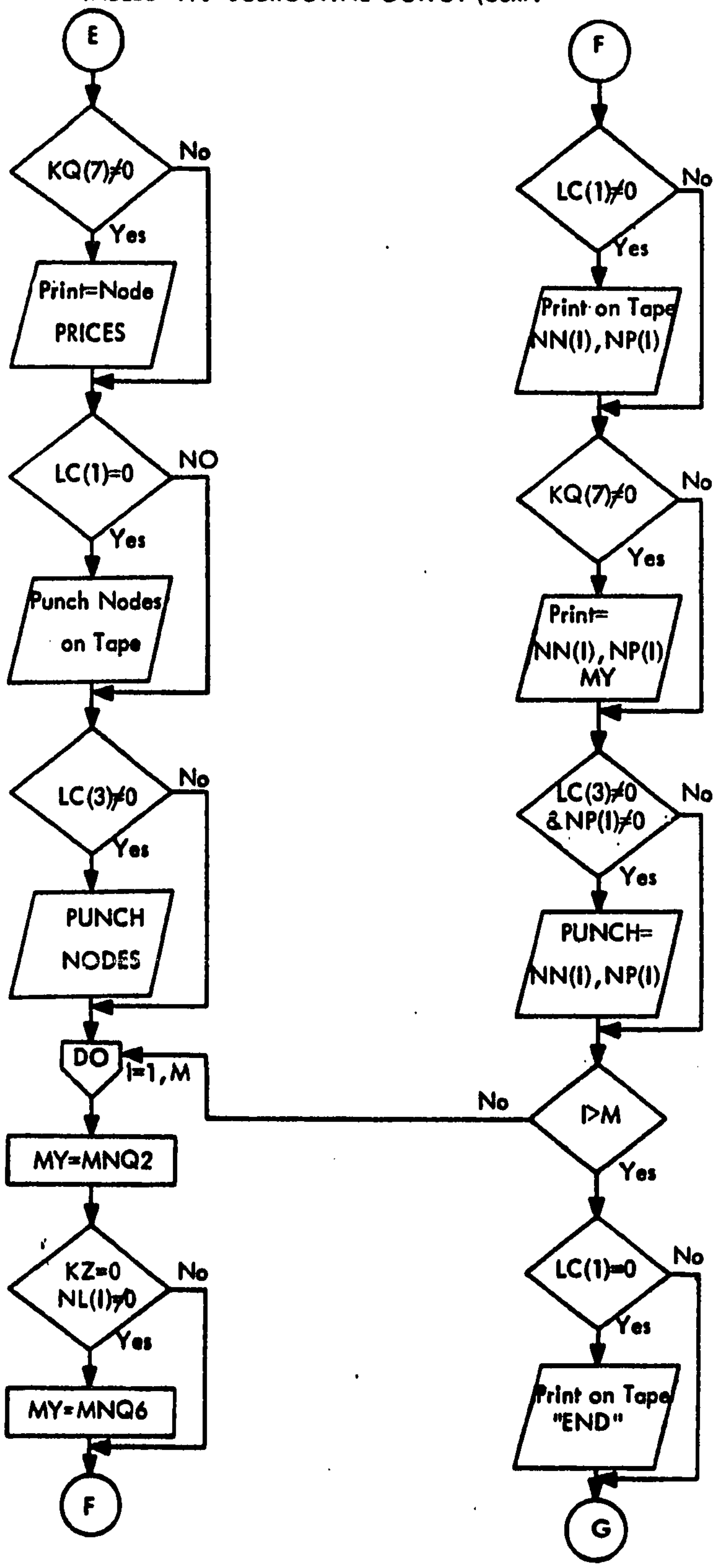


TABLE5-11. SUBROUTINE OUTPUT (Cont.)

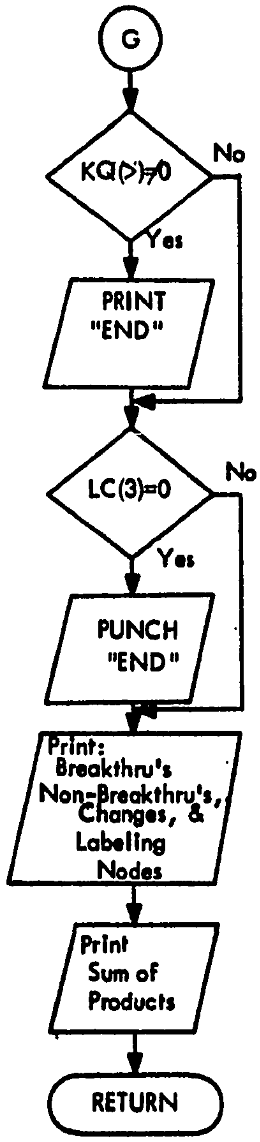


TABLE 5-12. SUBROUTINE LABEL

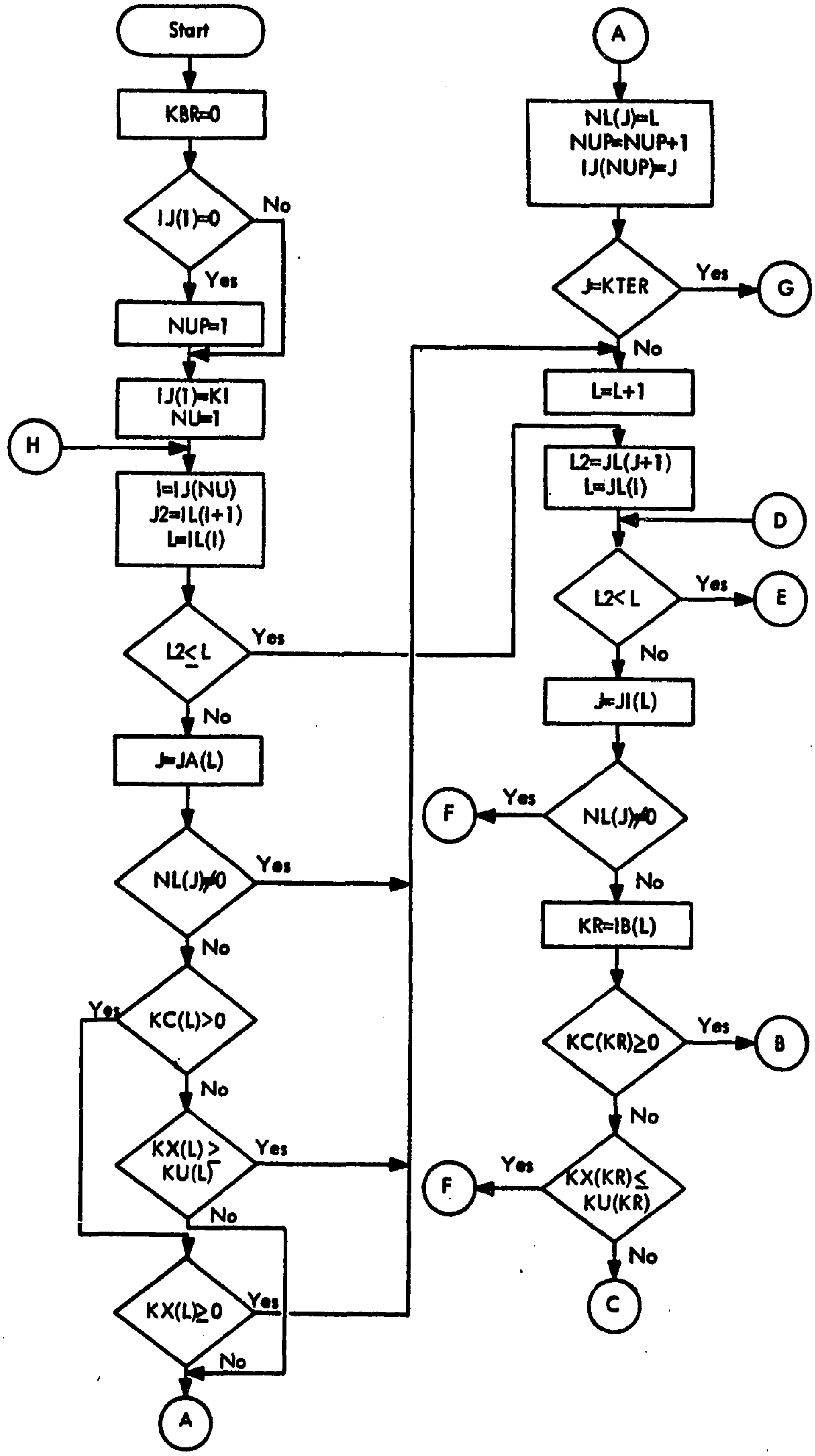


TABLE 5-12. SUBROUTINE LABEL (Cont.)

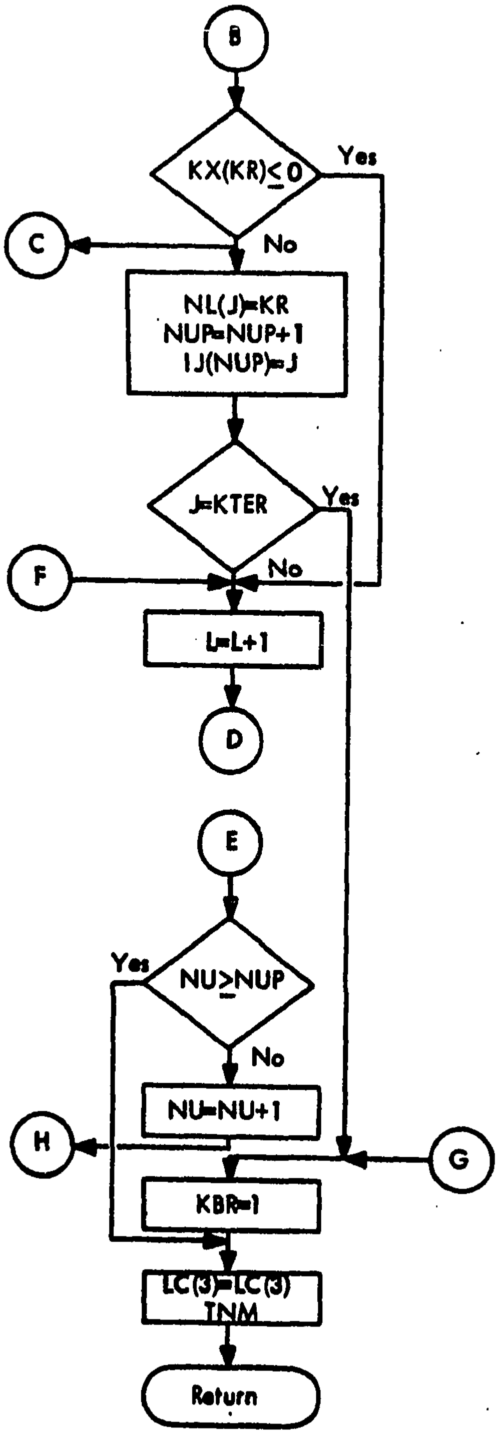


TABLE 5-13. FUNCTION NODENO

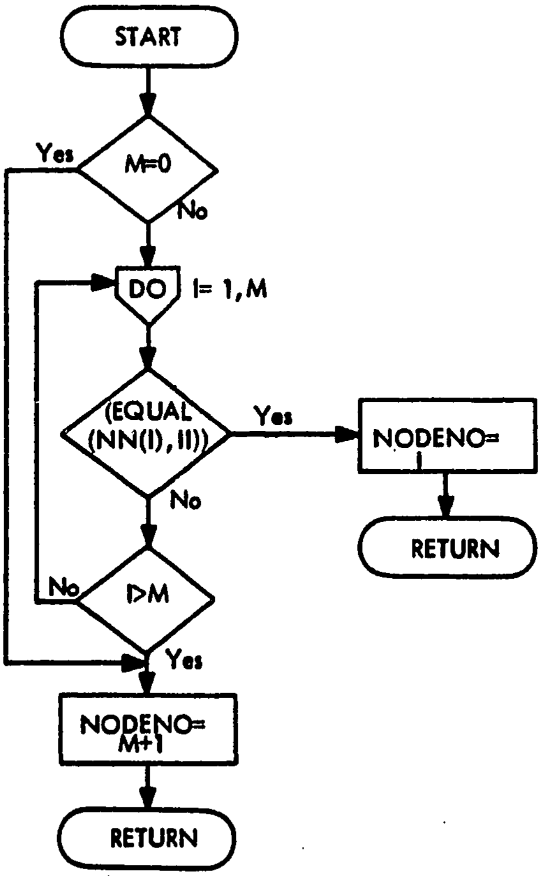


TABLE 5-14. FUNCTION LOOKUP

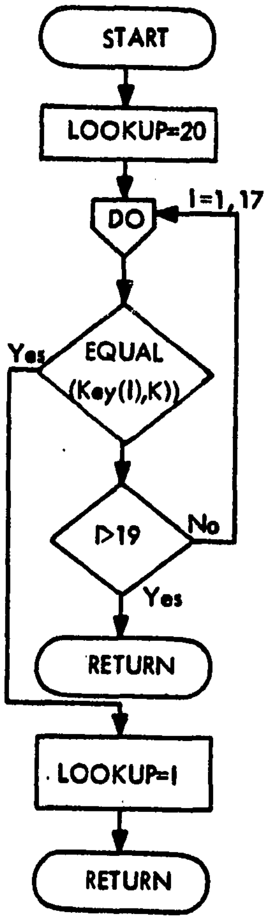
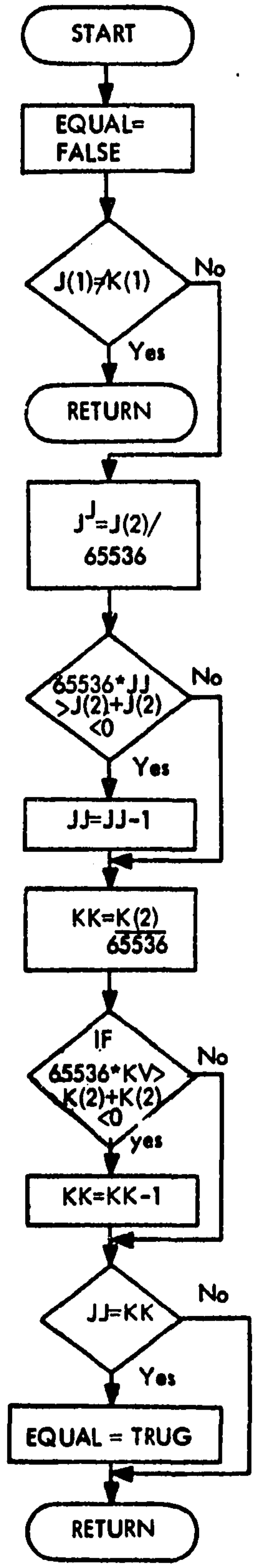


TABLE 5-15. LOGICAL FUNCTION EQUAL



5.4 Data Requirements

The basic objective of this model is to determine how the desired level of network service can be most efficiently provided to the metropolitan area at the least cost. In the accomplishment of this objective, there are certain primary considerations that have to be made. First the selection of sources and treatment plants can be modified depending on quality and treatment required. The selection of sources and the required treatment can be modified in part to fit the network.

Secondly, the cost indebtedness of existing facilities is fully considered as is the obsolescence of these same facilities.

Thirdly, if alternatives are to be considered, then the feasible locations for these facilities, within the network, must be known prior to a model run. By establishing the minimum flow, certain constraints on the network can be exercised on the network when considering proposed and existing facilities. The use of a zero minimum flow is used to explore the feasibility of proposed links. Since the solution may indicate a zero flow on a proposed link, which means that it is not economically feasible, the determination of obsolescence or feasibility of each link can be determined. Also, by establishing a set minimum, political jurisdictions can be held to providing a certain level of service within the network. The reverse is also available when one wishes to examine the economics of relaxing one or more political constraints in favor of metropolitan source and treatment plants.

Finally, the maximum flow or capacity can also be used to explore alternatives and constraint resources. The maximum flow of each link can be set at the existing capacity of each link or that capacity after a planned expansion. The maximum flow can also be used to control the desired loading of a natural resource without exceeding its capabilities.

The data requirements for the running of the model are fed into the model by each arc. The arcs are also grouped for each pair of nodes within the network. This procedure gives the model a high gaming capability when alternatives are being explored.

The first step in the establishment of the data requirements of this model is to set the nodes of the network. The nodes are established for each facility within the network. The facilities, primarily pipelines, can be broken apart to fit SAU, political jurisdictions, or basins if desired for complete analysis. It must be remembered that a detailed network is built using successive runs, and the network should be kept as simple as possible with each step (see Figure 5-3).

A super source and super sink are provided and connected, at no cost to ensure continuity of flow, or in other words, the flow into and out of a node has to be accounted for. An arc is established for each of the inputs and exhausts for each node. The capacity of that node is thereby established by the summation of the minimums by the upper and lower bounds of the input and exhaust arc groups for each node. Care must be exercised in the establishment of the network so that it is representative of the existing network.

The data requirements for the source and sink nodes with their connecting links will have now been satisfied. The next step is the assignment of the upper and lower bounds for the flow in each link. The bounds can be set anywhere from zero to 9999 million gallons per day (MGD). If zero is used, the solution will be equal to or greater than zero. When establishing a fixed cost or when it is desired that a plant be used at least to its debt

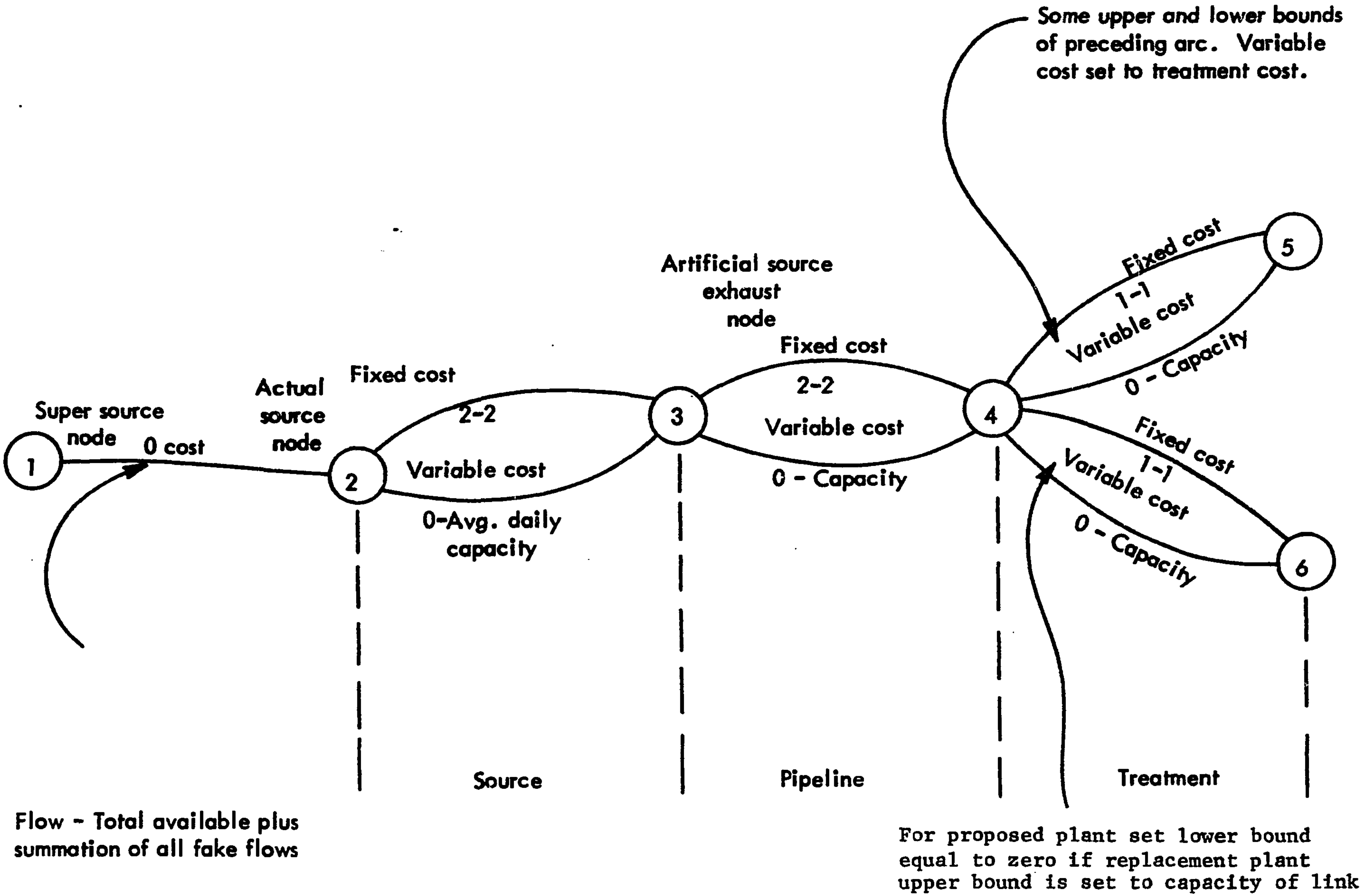


Figure 5-3. Example Flow Net.

limit, a minimum flow can be set. If a specific flow is desired, then the upper and lower bounds are both set equal to that flow.

Since there are no limits to the number of links entering or departing a node, although each node must have at least one link entering and one link departing, a full range of possibilities are available for each of the facilities. The fixed cost is set by assigning 1 MGD to both the upper and lower bounds of one of the links. This MGD is then added to all the fixed source links that feed it so that it does not affect the actual flow. This network is referred to as "fake flows". The variable flows can be assigned a cost \$/MGD, and the minimum and upper bounds assigned from 0 to 9999 MGD. The only constraint is that the upper limit must be greater than or equal to the lower bounds. Zero cost arcs can be added to provide continuity and/or a certain disaggregation of arcs.

After the capacities have been assigned, the remaining data requirements are added to each of the links. This is the cost of that link in dollars per million gallons per day (\$/MGD). This cost data should be the actual cost data in all cases possible. If the actual cost data is not available, then it should be estimated using standardized procedures. If the variable cost is a linear function that depends on the size of the facility, as in treatment plants, then an estimate has to be made initially as to the size needed. A family of curves is developed based on the cost per flow (see Figure 5-4). The upper and lower limits are set to the capacity range of the estimated plant size. The slope of that particular curve is entered as the cost for that link. After the run, the link results are examined. If the results show that the plant is being used to full capacity, then the link is desirable and a larger facility curve is used. If it is not being used, then a smaller

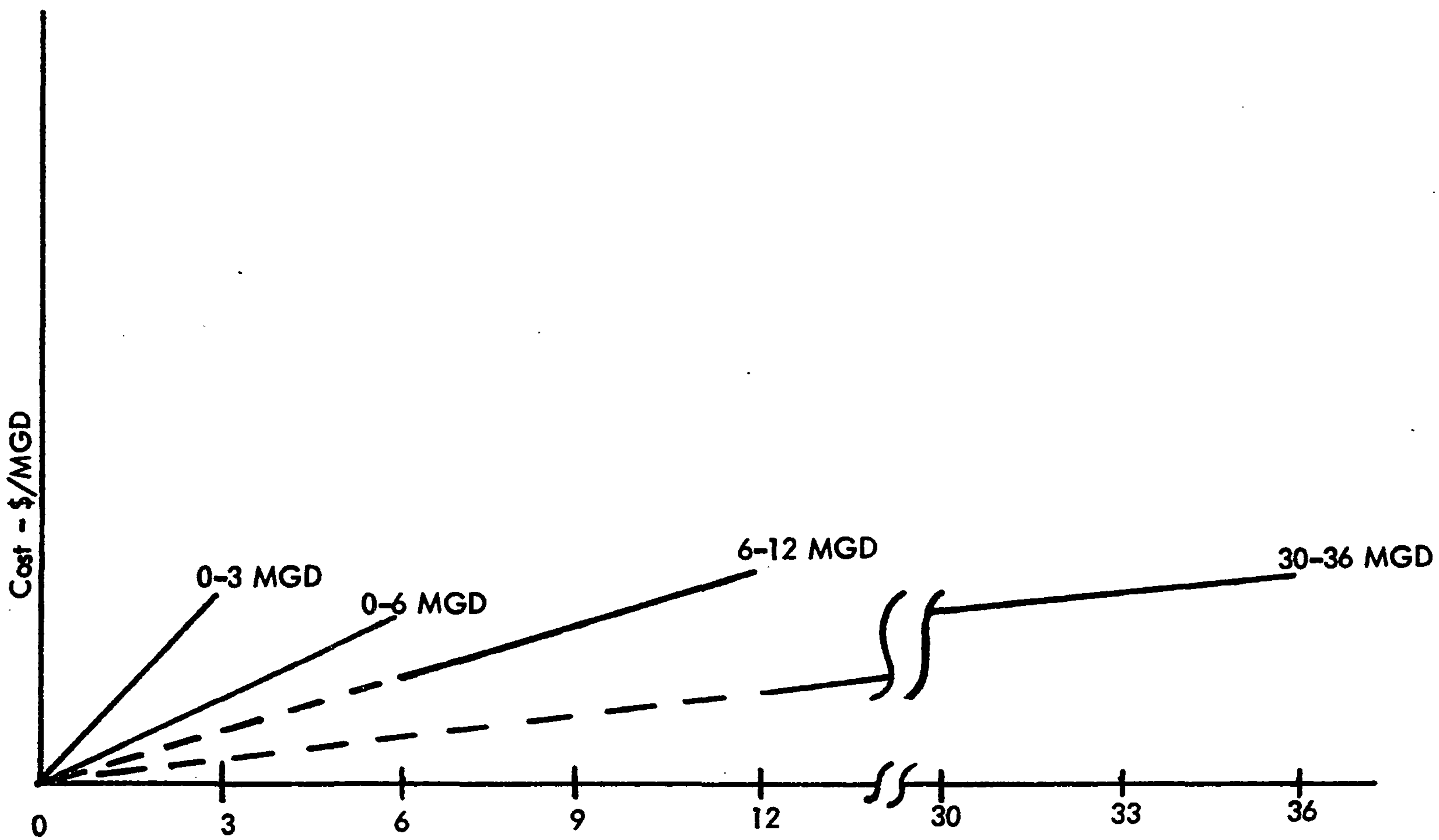


Figure 5-4. Linear Cost Functions.

facility curve can be tried.

One approach that has proven effective is to take the largest facility curve and minimum cost and set the lower bounds equal to zero. After the first run, set the link cost equal to the facility curve slope that the results dictate. Then run the model again to verify the results.

Future cost data can be acquired applying the Engineering News-Record Building Cost Index to the actual and derived cost data (24). There are other methods used for deriving and projecting cost data. No attempt will be made to suggest that one method is better than another in this report. The methods best understood and used by the using agency should be applied. The method used here is the one currently being used by the author.

5.5 Data Arrangement

The data are arranged in groups of links or arcs for each pair of nodes. One card is used for each arc using the following format:

Col. 1 - 6	Blank
Col. 7 -12	Name of source node i. All different combinations of characters including blanks for each name.
Col. 13-18	Name of sink node j. Same character availability as source node i.
Col. 19-20	Blank
Col. 21-30	Unit cost of sending flow from source i to sink j along this link, $/MGD.
Col. 31-40	Upper bounds of flow for this link, MGD.
Col. 41-50	Lower bounds of flow for this link, MGD.
Col. 51-60	Input flow for this link, usually set to zero. It is used only if a single input to the node has been established.

All fields are right hand justified. A listing of the input used to verify the model for the Oklahoma City Political Jurisdiction is shown on the next page.

```
BEGIN
 OKC RUN 2
ARCS
           SS 1   AS 2              0          159          159
           AS 2   ATOKA3         3031            1            1
           AS 2   ATOKA3           45           50           50
           AS 2   DRAP 4         2000            1            1
           AS 2   DRAP 4           22            5            5
           AS 2   HUGO 8         5205            1            1
           AS 2   HUGO 8           27           30           30
           AS 2   FTSY10          142            1            1
           AS 2   FTSY10            2            9            9
           AS 2   CAN 12          407            1            1
           AS 2   CAN 12            2           16           16
           AS 2   OVH 13          608            1            1
           AS 2   OVH 13            4           20           20
           AS 2   NW  15          447            1            1
           AS 2   NW  15            7           22           22
           ATOKA3DRAP 4          1512            1            1
           ATOKA3DRAP 4             3           60            0
           ATOKA3ASSK20             0           60            0
           DRAP 4DRAP 5             1            2            2
           DRAP 4AN  22             1           30            0
           DRAP 4AN  22             0           60            0
           AN  22DRAP 5             0           90            0
           HUGO 8DLTPE 9         1472            1            1
           HUGO 8DLTPE 9            4           30            0
           FTSY10CAN 12             3            1            1
           FTSY10CAN 12             1            9            0
           FTSY10AS  11             0            9            0
           CAN 12OVH 13             2            1            1
```

```
         CAN  12UVH  13          1       25       0
         CAN  12AS   11          0       25       0
         UVH  13UTP  16          1        1       1
         UVH  13UTP  16          1       26       0
         UVH  13HEF  14          2        1       1
         UVH  13HEF  14          1       25      15
         UVH  13AS   11          0       45       0
         HEF  14HTP  18          1        1       1
         HEF  14HTP  18          1       42       0
         WH   15UTP  16        234        1       1
         WH   15UTP  16         11       22       0
         WH   15ASSK20           0       22       0
         DRAP  5DRAP  6        294        2       2
         DRAP  5DRAP  6          2       60       0
         DTPE  9DRAP  6        120        1       1
         DTPE  9DRAP  6          2       30       0
         AS   11ASSK20           0       69       0
         UTP  16OTP  17        270        2       2
         UTP  16OTP  17          2       30       0
         HTP  18HTP  19        212        1       1
         HTP  18HTP  19          3       42       0
         DRAP  6DKC   7        274        3       3
         DRAP  6DKC   7          1       90       0
         UTP  17DKC   7        289        2       2
         UTP  17DKC   7          1       30       0
         HTP  19DKC   7        307        1       1
         HTP  19DKC   7          1       30       0
         DKC   7ASSK20           0       94      94
         ASSK20SSK  21           0      159     159
         SSK  21SS  1            0      159     159
END

SOLVE
QUIT
READY
```

5.6 Model Format

The listing of the model is shown on the following pages.

EDI LIS NETWORK1

```
      OPTION LOAD
C        MAIN ROUTINE OF RS OKF3  OUT OF KILTER NETWORK ROUTINE
       FILENAME NN
      FILENAME KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(6),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      FILENAME KOR, KO
      INPUT, KOR
      INPUT, KO
C     MAXIMUM NODES-NODMAX- DIMENSION OF NN NP IJ NL-- +1 FOR IL JL
C      KQ(5) = 500
C    MAXIMUM ARCS-ARCMAX- DIMENSION OF JI KC KU KX JA IB LW
      KQ(4) = 1000
C  INFINITY
      IFIN =  2147483647
C  ERROR NUMBERS (IN LER)
C  1  TRIVIAL (TRANSPORTATION PROBLEM)
C  2  CARD PUNCHING ERROR WHICH MAY BE RECOVERABLE
C  3  ERROR NOT RECOVERABLE, BUT CARD READING MAY CONTINUE
C  4  CATASTROPHIC ERROR- RUN MUST BE SKIPPED
C -1 (AFTER SOLVE) PROBLEM INFEASABLE
C -2  KICKED OFF BY TIME LIMITATION
C -3  OVERFLOW IN NODE PRICES
      KQ(6)=0
      KQ(9)=0
      KAT=0
  100 L=1
  101 CALL PRELIM(KS,L)
      IF (KS.NE.0)  GO TO 1
  200 CALL ARCRD(L)
      IF (LER.GE.4) GO TO 88
      IF (L.EQ.0)  GO TO 1
    3 CALL NODERD
    1 IF (KAT.EQ.0.OR.N.EQ.0)  GO TO 87
      CALL POSTRD
      CALL SOLVE(KE)
      IF (LER.GT.0) GO TO 88
  199 CALL OUTPUT (KE)
      GO TO 100
   87 WRITE(KO,59)
      LER=4
   88 KAT=0
      WRITE(KO,58)      LER
   89 L = LOOKUP(KA(1,1))
      IF(L.EQ.1.OR.L.EQ.4.OR.L.EQ.6.OR.L.EQ.7.OR.L.EQ.15) GO TO 101
      READ (KOR,51)KA(1,1)
      GO TO 89
   51 FORMAT(A6)
   58 FORMAT( 5HOTYPE,I6,24H ERROR, SKIP TO NEXT RUN)
   59 FORMAT(30H ****NO ARC DATA IN THIS RUN   )
       END

READY
```

EDI LIS PRELIM

```
      SUBROUTINE PRELIM(KS,L)
C READ PRELIMINARY CONTROL CARDS
      FILENAME NN
      FILENAME KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LL(1000),
     & LC(6),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      FILENAME KOR, KU
      LER=0
      KS=0
      KQ3=KQ(3)
      WRITE(KO,96)
      CALL CUTOFF(LL)
      IF(LL.NE.1) GO TO 20
   11 WRITE (KO,97)
C     -        END JOB
  180 IF (KQ(6).EQ.0) GO TO 182
  181 K2=KQ(2)
      WRITE (KO,98)
      GO TO 183
  182 WRITE (KO,99)
  183 STOP
C  READ A CONTROL CARD
   21 READ (KOR,90)(KA(I,1),I=1,12)
      WRITE (KO,91)(KA(I,1),I=1,12)
      L=LOOKUP(KA(1,1))
   20 IF(L.EQ.15) GO TO 180
      IF (L.EQ.17) GO TO 21
      IF (L.GT.7) GO TO 110
      GO TO (21,50,110,6,110,6,60),L
C        TITLE
  110 DO 112 I=1,12
  112   KA(I,2)=KA(I,1)
      GO TO 21
C          SAVE
   50 KS=1
      RETURN
C        ARCS
   60 KAT=1
      RETURN
C     SKIP
    6 IF (KQ(9).NE.0) GO TO 7
    2 KQ(9)=1
    7 IF (L.NE.4) GO TO 13
      GO TO 21
C     SKIP
   13 READ (KQ3,92)KA(1,1)
      IF (LOOKUP(KA(1,1)).NE.16) GO TO 13
      GO TO 21
   90 FORMAT(12A6)
   91 FORMAT(12A6)
   92 FORMAT(A6)
   96 FORMAT(//////////)
   97 FORMAT(24H TIME LIMIT EXCEEDED     )
   98 FORMAT(31H0RESERVED TAPE HAS BEEN WRITTEN///1H0)
   99 FORMAT(34H0NO RESERVED TAPE HAS BEEN WRITTEN)
       END
```

READY

EDI LIS ARCRD1

```
      SUBROUTINE ARCRD(LL)
 ARC READ,  READ ARC DATA CARDS
      FILENAME KOR,  KU
      FILENAME NN
      FILENAME KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KO(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      MM=0
      M = 0
      N=0
      LL=0
    6 READ (KOR,90) (KA(I,1),I=1,3),(IX(I),I=1,4)
      K = LOOKUP(KA(1,1))
      IF (K.EQ.16) GO TO 1
      IF (K.EQ.8)  GO TO 2
      IF (K.EQ.17) GO TO 3
      GO TO 4
   END OF DATA
    2 LL=2
    1 DO 99 I=MM,M
        IF (I.GT.MM)WRITE(KO,94) NN(I)
        IL(I+1) = N+1
   99 CONTINUE
      IF(M.GT.KO(5)) GO TO 23
      IF (MM.NE.M) LER=MAXO(LER,1)
   CLEAR NODE PRICES
      DO 100 I=1,M
        NP(I)=0
  100 CONTINUE
      RETURN
   STORE ARC DATA
    3 N=N+1
      IF (N.GT.KO(4)) GO TO 20
      NM=N
    7 KC(N)=IX(1)
      KU(N)=IX(2)
      LW(N)=IX(3)
      KX(N)=IX(4)
      K=NODENO(KA(2,1))
      IF (K.EQ.MM) GO TO 9
      IF(K.LT.MM) GO TO 10
   EXCHANGE NODES
      MM=MM+1
      NN(K)=NN(MM)
      NN(MM)=KA(2,1)
      IF(K.GT.M) M= M+1
      DO 30 J=1,N
        IF (JA(J).EQ.K) GO TO 29
        IF (JA(J).EQ.MM) JA(J)=K
        GO TO 30
   29   JA(J)=MM
   30 CONTINUE
```

```
      IL(MM)=N
    9 K=NODENO (KA(3,1))
      IF (K.GT.M) M=M+1
      NN(K)=KA(3,1)
      JA(NN) = K
      GO TO 06
C   ARCS OUT OF ORDER, SLIDE THEM DOWN
   10 WRITE (KO,91) KA(2,1),KA(3,1)
      LER = MAX0(LER,2)
      KK=K+1
      DO 101 I=KK,NM
        IL(I)=IL(I)+1
  101 CONTINUE
      KK= IL(K+1)
      DO 102 JJ=KK,N
        J = N-JJ+KK
        KC(J)=KC(J-1)
        KX(J)=KX(J-1)
        KU(J)=KU(J-1)
        LW(J)=LW(J-1)
        JA(J)=JA(J-1)
  102 CONTINUE
      NM=KK-1
      KC(NN)=IX(1)
      KU(NN)=IX(2)
      LW(NN)=IX(3)
      KX(NN)=IX(4)
      GO TO 9
C    ERROR MESSAGES
    4 NN=N+1
      WRITE (KO,92)NN
      WRITE (KO,93) (KA(I,1),I=1,3),(IX(I),I=1,4)
      LER = MAX0(LER,3)
      IF (K.NE.20) RETURN
      GO TO 6
   20 WRITE (KO,89)
   25 LER= 4
      RETURN
   23 WRITE (KO,88) N,KQ(5)
        GO TO 25
    88 FORMAT(5H ****,I6,30H NODES IN THIS RUN  MAXIMUM IS,I6)
    89 FORMAT(30HOTOO MANY ARCS IN THIS RUN****)
    90 FORMAT(3A6,2X,4I10)
    91 FORMAT(36H **SOURCE NODES NOT ADJACENT IN ARC A6,1X,A6)
    92 FORMAT(29H ***FIELD ERROR IN ARC NUMBER,I6)
    93 FORMAT( 1X,3A6,2X,4I10/1X)
    94 FORMAT(24H *NO ARC BEGINS AT NODE A6)
        END

READY
```

EDI LIS NODERD1

```
      SUBROUTINE NODERD
C  NODE READ.  READ NODE DATA CARDS
      FILENAME KOR, KO
      FILENAME NN,KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      I = 0
   03 I = I+1
      READ (KOR,90) KA(1,1),KA(2,1),IX(1)
      KEYM=LOOKUP(KA(1,1))
      IF( KEYM.EQ.16) RETURN
      IF(KEYM.NE.17) GO TO 2
      K=NODENO(KA(2,1))
      IF (K.GT.M) GO TO 6
    5 NP(K)=IX(1)
      GO TO 03
    6 WRITE (KO,91) KA(2,1)
   10 LER= MAX0(LER,1)
      GO TO 03
    2 WRITE (KO,92)I,KA(1,1),KA(2,1),IX(1)
      LER = MAX0(LER,2)
      IF (KEYM.NE.20) GO TO 99
      GO TO 10
   99 RETURN
   90 FORMAT(2A6,8X,I10)
   91 FORMAT(7H *NODE , A6,12H NOT IN ARCS )
   92 FORMAT(34H **FIELD ERROR IN NODE CARD NUMBER,I6/1H 2A6,8X,I10)
      END
```

READY

EDI LIS NODENO1

```
      FUNCTION NODENO(II)
C   FIND NODE NUMBER  OF NODE GIVEN
      REAL II
      FILENAME NN, KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOB,KTER,MINE,IFIN,KI,KO,K
      LOGICAL EQUAL
      IF  (M.EQ.0)  GO TO 3
      DO 1 I=1,M
        IF (EQUAL(NN(I),II))  GO TO 2
    1 CONTINUE
    3 NODENO=M+1
      RETURN
    2 NODENO=I
      RETURN
      END
```

READY

EDI LIS POSTRD1

```
      SUBROUTINE POSTRD
C  READ POST-DATA CONTROL CARDS
      FILENAME NN,KA
      FILENAME KOR, KU
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KUR,KTER,MINE,IFIN,KI,KO,K
C  OUTPUT FLAGS
      DO 19 I=1,8
        LC(I)=0
   19 CONTINUE
      KQ(7)=1
      KQ(8)=0
   20 READ (KOR,95)(KA(I,1),I=1,3),(IX(I),I=1,5)
      L = LOOKUP(KA(1,1))
      IF (L.EQ.18.OR.L.EQ.17) GO TO 140
      WRITE (KO,88)KA(1,1),KA(2,1),KA(3,1)
      IF (L.EQ.9) GO TO 121
      IF (L.EQ.14.OR.L.EQ.5.OR.L.EQ.13) GO TO 111
      IF (L.EQ.3) GO TO 300
      GO TO 200
C             COMPUTE
  111 WRITE (KO,93)N,M
      IF (L.EQ.14) KQ(8)=1
      IF (L.EQ.13) KQ(8)=2
  999 RETURN
C             SET OUTPUT CONTROL
  121 L = LOOKUP(KA(2,1)) -9
      IF (L.EQ.10) GO TO 82
      IF (L.LE.0.OR.L.GT.3) GO TO 200
   81 LC(L) = 1
      GO TO 20
   82 KQ(7) =0
      GO TO 20
C                   ALTER
  140 IF (IX(1).LT.1) IX(1)=1
  142 WRITE (KO,91)(KA(I,1),I=1,3),(IX(I),I=1,5)
      N1=NODENO(KA(2,1))
      N2=NODENO(KA(3,1))
      IF (N1.LE.M .AND. N2.LE.M)  GO TO 145
  144 WRITE (KO,92)
      LER=MAX0(LER,3)
```

```
      GO TO 20
  145 L1 = IL(N1)
      L2 = IL(N1+1) -1
      IF (L2.LT.L1)GO TO 144
  146 DO 147 LL=L1,L2
      IF (J(LL).NE.N2) GO TO 147
        IX(1)=IX(1)-1
        IF (IX(1).EQ.0) GO TO 149
  147 CONTINUE
      GO TO 144
  149 KC(LL)=IX(2)
      KU(LL)=IX(3)
      LW(LL)=IX(4)
      KX(LL)=KX(LL)+IX(5)
      GO TO 20
C REFNOD
  300 L=NODENO(KA(2,1))
      IF (L.GT.M) GO TO 301
      KAT=L
      GO TO 20
  301 WRITE(KO,94)    KA(2,1)
      LER= MAXO(LER,1)
      GO TO 20
C CARD PUNCHING ERROR
  200 LER=MAXO(LER,3)
      WRITE (KO,87)KA(1,1),KA(2,1),KA(3,1)
      IF (L.NE.20) RETURN
      GO TO 20
   87 FORMAT(18H ***ILLEGAL CARD =3A6)
   88 FORMAT(1X,3A6)
   91 FORMAT( 1X,3A6,I2,5I10)
   92 FORMAT(42H ***ARC ON ABOVE ALTER CARD NOT DEFINED    )
   93 FORMAT(12H NO OF ARCS=I5,  13H NO OF NODES=I5)
   94 FORMAT(9H ** NODE A6,12H NOT IN ARCS )
   95 FORMAT(3A6,I2,5I10)
      END

READY
```

EDI LIS SOLVE1

```
      SUBROUTINE SOLVE (KE)
C   SET UP ARRAYS AND CALL THE NETWORK SOLVING ROUTINES
      FILENAME KOR, KO
      FILENAME NN,KA
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
C                 FORM JL LIST
      DO 8 I=1,M
        NL(I)=0
    8 CONTINUE
      DO 10 J=1,N
        I = JA(J)
        NL(I)=NL(I)+1
   10 CONTINUE
      JL(1) = 1
      DO 20 I=1,M
        IF (NL(I).NE.0) GO TO 23
        WRITE (KO,91)NN(I)
        LER = MAX0(LER,1)
   23   JL(I+1) = JL(I) + NL(I)
        IJ(I)=JL(I)
        NL(I)=0
   20 CONTINUE
      I=1
      DO 2 J=1,N
        IF (J.GE.IL(I+1))I=I+1
        K=JA(J)
C   CALCULATE CIRCULATION AND CBAR
        NL(I)=NL(I)-KX(J)
        NL(K)=NL(K)+KX(J)
        KC(J)=KC(J)+NP(I)-NP(K)
C   TEST FOR LOWER BOUND GREATER THAN UPPER
        IF (LW(J).LE.KU(J)) GO TO 50
        WRITE(KO,51) NN(I),NN(K)
        LER=MAX0(LER,2)
        IX(9)=KU(J)
        KU(J)=LW(J)
        LW(J)=IX(9)
C   SUBTRACT LOWER BOUND FROM UPPER AND FROM X.
   50   KU(J)=IABS(KU(J)-LW(J))
        KX(J)=KX(J)-LW(J)
C   SETUP JI AND IB LISTS
        L=IJ(K)
        JI(L)=I
        IB(L)=J
        IJ(K)=IJ(K)+1
        IF (I.LE.K)  GO TO 2
        KX(J) = 0
        IF (KC(J).LT.0) KX(J)=KU(J)
```

```
    2 CONTINUE
C  MESSAGE FOR NON ZERO CIRCULATION
      DO 5 I=1,M
        IF (NL(I).NE.0) WRITE(KO,90) NN(I) ,NL(I)
        IF (NL(I).NE.0) LER=MAX0(LER,1)
    5 CONTINUE
      KE=0
      IF  (LER.GT.KQ(8)) RETURN
      KLE=0
      I=1
C  TRY TO BRING ALL ARCS INTO KILTER
      DO 26 K=1,N
        IF (K.GE.IL(I+1))  I=I+1
        CALL CUTOFF(KFX)
        IF (KFX.EQ.1) GO TO 16
        CALL KILTER (I)
        IF (LER.EQ.(-3)) GO TO 24
        IF(LER.NE.0) KE=KE+1
        IF (KE.NE.1) GO TO 26
        IX(8)=K
        IX(9)=I
   26 CONTINUE
C COMPLETED CHECKING ALL ARCS
      LER=-MIN0(1,KE)
   99 IF (KE.EQ.0) GO TO 100
      K=IX(8)
      CALL KILTER(IX(9))
C  RESTORE KC, KX, KU
  100 IF (KLE.NE.0) LER = -2
      I=1
      DO 101 J=1,N
        IF (J.GE.IL(I+1))  I=I+1
        K=JA(J)
        KU(J)=KU(J)+LW(J)
        KX(J)=KX(J)+LW(J)
        KC(J)=KC(J)-NP(I)+NP(K)
  101 CONTINUE
      RETURN
   16 KLE=1
      L=JA(K)
       WRITE (KO,53) NN(I),NN(L)
       GO TO 99
   24 L=JA(K)
       WRITE (KO,54)  NN(I),NN(L)
       GO TO 100
   51 FORMAT(7H **ARC A6,1X,A6,36H HAS LOWER BOUND GREATER THAN UPPER )
   53 FORMAT(33H0JOB CUTOFF BY TIME LIMIT ON ARC A6,1X,A6)
   54 FORMAT(33H0OVERFLOW IN NODE PRICES  ON ARC A6,1X,A6)
   90 FORMAT(7H *NODE A6,28H NON-CONSERVATIVE, NET FLOW=I12)
   91 FORMAT(22H *NO ARC ENDS AT NODE ,A6)
       END
```

REALY

EDI LIS KILTER1

```
      SUBROUTINE KILTER (I)
C   BRING ARC K INTO KILTER
      FILENAME NN,KA
      FILENAME KOR, KO
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
    1 IF (IJ(I).EQ.0) GO TO 70
      IJ(I) = 0
    2 DO 69 J=1,M
   69 NL(J)=0
   70 LER=0
    5 IF (KC(K)) 10,20,30
   10 IF(KX(K)-KU(K)) 50,40,60
   30 IF(KX(K)) 50,40,60
   20 IF(KX(K).LT.0) GO TO 50
      IF (KX(K).GT.KU(K)) GO TO 60
   40 RETURN
   50 KI = JA(K)
      KTER=I
      NL(KI)=+K
      GO TO 65
   60 KI=I
      KTER = JA(K)
      NL(KI)=-K
   65 CALL LABEL (KBR)
      IF (KBR.EQ.0) GO TO 68
   67 CALL BREAKT
      GO TO 5
   68 CALL RAISE
   39 IF (LER) 40,5,40
       END
```

READY

EDI LIS CUTOFF1

```
      SUBROUTINE CUTOFF(I)
C  DUMMY CUTOFF ROUTINE
C   SET  I = 1 TO CUTOFF, SET I TO ANY OTHER NUMBER TO NOT CUTOFF
      I=2
      RETURN
      END
```

READY

EDI LIS RAISET

```
      SUBROUTINE RAISE
C  RAISE NODE PRICES OF UNLABELED NODES RELATIVE TO LABELED
      FILENAME NN,KA
      FILENAME KOR,KO
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LN(1000),
     & LC(8),KA(12,2),KO(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      LC(6) = LC(6) + 1
      NDELTA = IFIN
      I=1
      DO 24 L =1,N
        IF (L.GE.IL(I+1))  I=I+1
        J = JA(L)
        IF (NL(I).EQ.0) GO TO 20
        IF (NL(J).NE.0) GO TO 24
        IF (KX(L).GE.KU(L)) GO TO 24
        GO TO 23
   20   IF (NL(J).EQ.0) GO TO 24
        IF (KX(L).LE.0) GO TO 24
   23   NDELTA = MINO(NDELTA,IABS(KC(L)))
   24 CONTINUE
      NDP = NDELTA
      IF (NDELTA.NE.IFIN) GO TO 31
      IF (KC(K).EQ.0.OR.ISIGN(1,NL(KI)).EQ.ISIGN(1,KC(K))) GO TO 51
      NDELTA = IABS(KC(K))
   31 I=1
      DO 47 L=1,N
        IF (L.GE.IL(I+1)) I=I+1
        J=JA(L)
        IF (NL(I).NE.0) GO TO 41
        IF (NL(J).NE.0) KC(L)=KC(L)+NDELTA
        GO TO 47
   41   IF (NL(J).EQ.0) KC(L)=KC(L)-NDELTA
   47 CONTINUE
      IF (NL(KAT).EQ.0) GO TO 50
C  REFERENCE NODE LABELED, ADD NDELTA TO UNLABELED NODES
      DO 49 I=1,M
        IF (NL(I).EQ.0) NP(I)=NP(I)+NDELTA
   49 CONTINUE
      GO TO 60
   50 DO 55 I=1,M
        IF (NL(I).NE.0) NP(I)=NP(I)-NDELTA
   55 CONTINUE
   60 CONTINUE
C  TEST FOR OVERFLOW OF NODE PRICES HERE WHEN POSSIBLE
C  SET  LER = -3  IF NODE PRICES OVERFLOW
      IF(NDP.EQ.NDELTA.OR.KX(K).EQ.0.OR.KX(K).EQ.KU(K)) RETURN
   51 LER = -1
      RETURN
      END
```

READY

EDI LIS BREAKT1

```
      SUBROUTINE BREAKT
C   LABELS BROKE THROUGH, INCREMENT FLOW
      FILENAME NN,KA
      FILENAME KOR, KO
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      LC(5) = LC(5) +1
C   FIND FLOW INCREMENT,  SET UP CIRCLE LIST IN IJ
      MINE=IFIN
      KT = KTER
      DO 30 J =1,M
        KP = NL(KT)
        KK=IABS(KP)
        IF (KP.GT.0) GO TO 22
        KT=JA(KK)
        IF (KC(KK).GE.0) GO TO 19
        MINE = MINO(MINE,KX(KK)-KU(KK))
        GO TO 28
 19     MINE = MINO(MINE,KX(KK))
        GO TO 28
 22     KRP=JL(KT)
        DO 23 KR=KRP,N
          IF (IB(KR).EQ.KK) GO TO 24
 23     CONTINUE
 24     KT=JI(KR)
        IF (KC(KK).GT.0) GO TO 26
        MINE = MINO(MINE,KU(KK)-KX(KK))
        GO TO 28
 26     MINE = MINO(MINE,-KX(KK))
 28     IJ(J) = KP
        IF (KT.EQ.KTER) GO TO 40
 30   CONTINUE
 40   JJ=J
      LC(7) = LC(7) + JJ
C    INCREMENT CYCLE BY "MINE".
      DO 43  J = 1,JJ
        KK = IJ(J)
        IF (KK.GT.0) GO TO 42
        KK = IABS(KK)
        KX(KK) = KX(KK) - MINE
        GO TO 43
 42     KX(KK) = KX(KK) + MINE
 43   CONTINUE
      DO  45  J=1,N
        NL(J) = 0
 45   CONTINUE
      IJ(1) = 0
      RETURN
      END
```

READY

EDI LIS OUTPUT1

```
      SUBROUTINE OUTPUT (KZ)
C   PROBLEM OUTPUT
      FILENAME NN, KA
      FILENAME KOR, KO
      FILENAME K2, STORE
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
      REAL A1,A2,A3
      DATA MNQ1/4HK    /,MNQ2/4H    /,MNQ3/4HN   /,MNQ4/4HCUT /,
     & MNQ5/4HCUT*/,MNQ6/4H*   /
      MZ=MNQ1
      IF (LER.NE.0) MZ=MNQ2
      IF (KZ.NE.0) WRITE(KO,99) KZ
      CALL CUTOFF(KFX)
      IF(KFX.EQ.1.AND.LC(2).NE.0)  LC(1)=1
      INPUT, K2
      INPUT, STORE
      IF (LC(3).EQ.0) GO TO 12
      WRITE(STORE,90)(KA(I,2),I=1,12)
      WRITE (KO,89)
   12 IF (LC(1).EQ.0) GO TO 41
      IF (KQ(6).NE.0) GO TO 24
      KQ(6) =1
   24 WRITE (K2,90)(KA(I,2),I=1,12)
      WRITE (KO,88)
   41 A3=0.
      LINE=0
      I=1
      DO 3 J=1,N
        IF (J.GE.IL(I+1)) I=I+1
        K=JA(J)
        MX=MZ
        MY=MNQ2
        LLC=KC(J)+NP(I)-NP(K)
        IF(KX(J).LT.LW(J).OR.KX(J).GT.KU(J).OR.KX(J).LT.KU(J).AND.
     &    LLC.LT.0.OR.KX(J).GT.LW(J).AND.LLC.GT.0)  MX=MNQ3
        A1=KC(J)
        A2=KX(J)
        A3=A3+A1*A2
        IF (KZ.EQ.0) GO TO 16
        IF(NL(I).NE.0.AND.NL(K).EQ.0) MY=MNQ5
        IF(NL(I).EQ.0.AND.NL(K).NE.0) MY=MNQ4
   16 IF (LC(1).EQ.0) GO TO 51
      WRITE (K2,93)NN(I),NN(K),KC(J),KU(J),LW(J),KX(J)
```

```
   51 IF (KQ(7).EQ.0) GO TO 56
        IF (LINE.EQ.0) WRITE (KO,91)(KA(II,2),II=1,12)
        LINE=LINE+1
C   PRINT 50 LINES/PAGE
        IF (LINE.EQ.50) LINE=0
      WRITE (KO,94)NN(I),NN(K),KC(J),KU(J),LW(J),KX(J),LLC,MX,MY
   56 IF (LC(3).EQ.0) GO TO 3
      WRITE(STORE,93)NN(I),NN(K),KC(J),KU(J),LW(J),KX(J)
    3 CONTINUE
      IF (KQ(7).NE.0) WRITE(KO,196)
      IF (LC(1).NE.0) WRITE(K2,96)
      IF (LC(3).NE.0) WRITE(STORE,96)
      DO 200 I=1,M
        MY=NNQ2
        IF (KZ.NE.0.AND.NL(I).NE.0) MY=NNQ6
        IF (LC(1).NE.0) WRITE(K2,95) NN(I),NP(I)
        IF (KQ(7).NE.0) WRITE(KO,199) NN(I),NP(I),MY
        IF (LC(3).NE.0.AND.NP(I).NE.0) WRITE(STORE,95)NN(I),NP(I)
  200 CONTINUE
      IF(LC(1).NE.0) WRITE(K2,97)
      IF (KQ(7).NE.0) WRITE(KO,98)
      IF (LC(3).NE.0) WRITE(STORE,97)
      WRITE (KO,92) LC(5),LC(6),LC(7),LC(8)
      WRITE (KO,999) A3
      RETURN
   88 FORMAT(27H0THIS RUN OUTPUT TO FILE K2 )
   89 FORMAT(30H0THIS RUN OUTPUT TO FILE STORE)
   90 FORMAT(12A6/4HARCS22X,4HCOST5X,5HUPPER5X,5HLOWER6X,4HFLOW,12X)
   91 FORMAT(1H112A6/5H ARCS16X,4HCOST6X,5HUPPER6X,5HLOWER7X,4HFLOW7X,
     & 4HCBAR/1X)
   92 FORMAT(18H0NO OF BREAKTHRUS=I12,22H, NO OF NONBREAKTHRUS=I12,18H,
     &NO OF X CHANGES=I12,/42H NO OF NODES FROM WHICH LABELING WAS DONE=
     &I12)
   93 FORMAT(6X,2A6,2X,4I10)
   94 FORMAT(2(1X,A6),5I11,1X,2A4)
   95 FORMAT(6X,A6,6X,I12)
   96 FORMAT (6HNODES ,54X)
   97 FORMAT(3HEND,27X)
   98 FORMAT(4H0END)
  99 FORMAT(1H0I5,23H ARCS ARE OUT OF KILTER)
  193 FORMAT(12H1NODE PRICES/1X)
  199 FORMAT(1X,A6,I13,A4)
  999 FORMAT(16H0SUM OF PRODUCTS,1PD20.12)
       END
```

READY

EDI LIS LABEL1

```
      SUBROUTINE LABEL (KBR)
C  LABEL NODES
      FILENAME NN,KA
      FILENAME KOR, KO
      COMMON NN( 500),NP( 500),IL( 501),JL( 501),IJ( 500),NL( 500),
     & JI(1000),KC(1000),KU(1000),KX(1000),JA(1000),IB(1000),LW(1000),
     & LC(8),KA(12,2),KQ(9),IX(9),M,N,LER,KAT,KOR,KTER,MINE,IFIN,KI,KO,K
C JI FIRST NODE OF ARC IN SECOND NODE LIST
C KC COST
C KU UPPER BOUND
C KX FLOW
C JA SECOND NODE OF ARC IN NORMAL ORDER
C IB ARC NUMBER OF ARC IN SECOND NODE LIST
C LW LOWER BOND
C NN NODE NAME
C NP NODE PRICE
C IL FIRST ARC OF GIVEN NODE IN LIST OF ARCS ARRANGED NORMALLY
C JL FIRST ARC OF GIVEN NODE IN LIST OF ARCS ARRANGED IN SECOND NODE ORD
C IJ SCAN LIST (CIRCLE LIST IN "BREAKT")
C NL NODE LABEL,  SIGNED NUMBER OF ARC WHICH LABELED IT
C NUP CURRENT LENGTH OF SCAN LIST
C NU PRESENT LOCATION IN SCAN LIST OF NODE BEING SCANNED
      KBR = 0
      IF (IJ(1).EA.0) NUP=1
      IJ(1)=KI
      NU  = 1
   14 I=IJ(NU)
C SEARCH FORWARD ARCS
      L2 = IL(I+1)
      L  = IL(I)
   16 IF  (L2.LE.L) GO TO 28
      J = JA(L)
      IF (NL(J).NE.0) GO TO 27
      IF (KC(L).GT.0) GO TO 21
      IF (KX(L).GE.KU(L)) GO TO 27
      GO TO 22
```

```
      21 IF (KX(L).GE.0) GO TO 27
      22 NL(J) = L
         NUP = NUP + 1
         IJ(NUP) = J
      27 LF=(U+EQ.KTER) GO TO 47
         GO TO 16
C     SEARCH BACKWARD ARCS
      28 L2 = JL(I+1)
         L  = JL(I)
      31 IF (L2.LE.L) GO TO 43
         J = JI(L)
         IF (NL(J).NE.0) GO TO 42
         KR = IB(L)
         IF (KC(KR).GE.0) GO TO 36
         IF (KX(KR).LE.KU(KR)) GO TO 42
         GO TO 37
      36 IF (KX(KR).LE.0) GO TO 42
      37 NL(J) = -KR
         NUP = NUP + 1
         IJ(NUP) = J
         IF  (J.EQ.KTER) GO TO 47
      42 L = L+1
         GO TO 31
C     GO TO NEXT NODE IN SCAN LIST
      43 IF (NU.GE.NUP) GO TO 48
         NU = NU + 1
         GO TO 14
C      BREAK-THRU
      47 KBR = 1
      48 LC(6) = LC(6) +NU
         RETURN
         END

READY
```

```
EDI LIS LOOKUP1

      FUNCTION LOOKUP(K)
C   LOOK UP CONTROL NAME
      LOGICAL EQUAL
      REAL K
      FILENAME KEY
      DIMENSION KEY(19)
      DATA KEY(1)/6HBEGIN /,KEY(2)/6HSAVE  /,KEY(3)/6HREFNOD/,
     & KEY(4)/6HTAPE  /,KEY(5)/6HGO    /,KEY(6)/6HSKIP  /,
     & KEY(7)/6HARCS  /,KEY(8)/6HNODES /,KEY(9)/6HOUTPUT/,
     & KEY(10)/6H TAPE /,KEY(11)/6H IF CO/,KEY(12)/6H PUNCH/,
     & KEY(13)/6HSOLVE /,KEY(14)/6HGOGO  /,KEY(15)/6HQUIT  /,
     & KEY(16)/6HEND   /,KEY(17)/6H      /,KEY(18)/6HALTER /
      DATA KEY(19)/6H NO SY/
      LOOKUP = 20
      DO 1 I = 1,19
        IF(EQUAL(KEY(I),K))GO TO 2
    1 CONTINUE
      RETURN
    2 LOOKUP = I
      RETURN
      END

READY
```

```
EDI LIS EQUAL1

      LOGICAL FUNCTION EQUAL(J,K)
C   SYSTEM/GE ROUTINE
C   TRICK SYSTEM/GE INTO COMPARING 6 BYTE WORDS
      DIMENSION J(2),K(2)
      EQUAL=.FALSE.
      IF (J(1).NE.K(1)) RETURN
C        TRUNCATION ON GE VALID ONLY FOR POSITIVE NUMBERS
      JJ=J(2)/65536
      IF(65536*JJ.GT.J(2).AND.J(2).LT.0) JJ=JJ-1
      KK=K(2)/65536
      IF(65536*KK.GT.K(2).AND.K(2).LT.0) KK=KK-1
      IF (JJ.EQ.KK) EQUAL=.TRUE.
      RETURN
      END

READY
```

5.7 Model Validation

The model was validated against the existing Oklahoma City network (see Figure 5-5). The output for this run is shown on the next page. The runs for future networks are not shown because the data used to formulate them was not obtained from actual land use projections and was used only to validate the gaming capabilities.

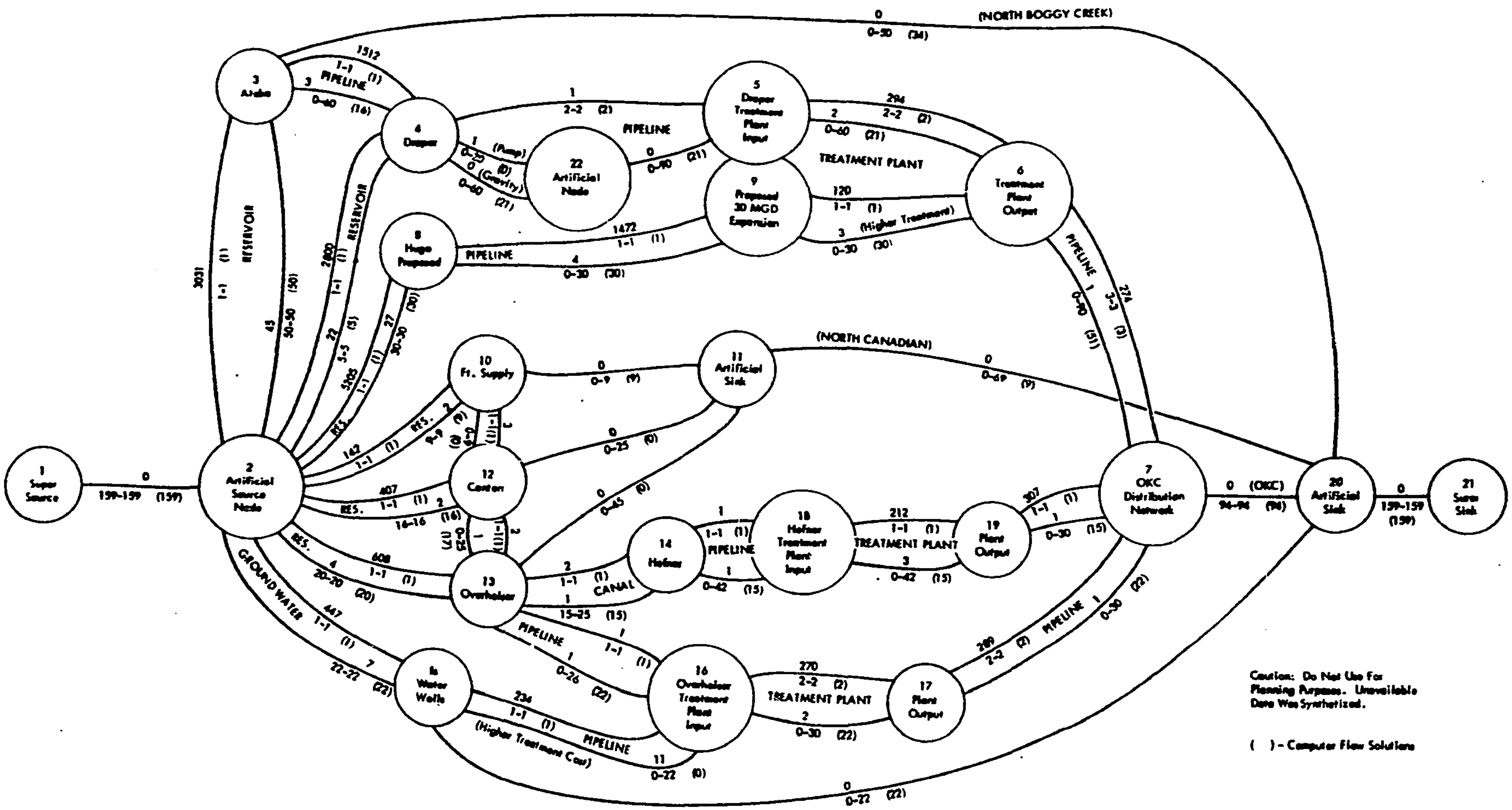


Figure 5-5. Average Daily Flow Net (1980)

BEGIN
OKC RUN 2
ARCS
SOLVE
NO OF ARCS= 58 NO OF NODES= 22
1 OKC RUN 2

ARCS		COST	UPPER	LOWER	FLOW	CBAR	
SS 1	AS 2	0	159	159	159	7	K
AS 2	ATOKA3	3031	1	1	1	3030	K
AS 2	ATOKA3	45	50	50	50	44	K
AS 2	DRAP 4	2800	1	1	1	2796	K
AS 2	DRAP 4	22	5	5	5	18	K
AS 2	HUGO 8	5205	1	1	1	5205	K
AS 2	HUGO 8	27	30	30	30	27	K
AS 2	FTSY10	142	1	1	1	141	K
AS 2	FTSY10	2	9	9	9	1	K
AS 2	CAN 12	407	1	1	1	405	K
AS 2	CAN 12	2	16	16	16	0	K
AS 2	OVH 13	608	1	1	1	605	K
AS 2	OVH 13	4	20	20	20	1	K
AS 2	WW 15	447	1	1	1	446	K
AS 2	WW 15	7	22	22	22	6	K
ATOKA3	DRAP 4	1512	1	1	1	1509	K
ATOKA3	DRAP 4	3	60	0	16	0	K
ATOKA3	ASSK20	0	60	0	34	0	K
DRAP 4	DRAP 5	1	2	2	2	1	K
DRAP 4	AN 22	1	30	0	0	1	K
DRAP 4	AN 22	0	60	0	21	0	K
AN 22	DRAP 5	0	90	0	21	0	K
HUGO 8	DTPE 9	1472	1	1	1	1468	K
HUGO 8	DTPE 9	4	30	0	30	0	K
FTSY10	CAN 12	3	1	1	1	2	K
FTSY10	CAN 12	1	9	0	0	0	K
FTSY10	AS 11	0	9	0	9	0	K
CAN 12	OVH 13	2	1	1	1	1	K
CAN 12	OVH 13	1	25	0	17	0	K
CAN 12	AS 11	0	25	0	0	1	K
OVH 13	OTP 16	1	1	1	1	0	K
OVH 13	OTP 16	1	26	0	22	0	K
OVH 13	HEF 14	2	1	1	1	3	K
OVH 13	HEF 14	1	25	15	15	2	K
OVH 13	AS 11	0	45	0	0	2	K
HEF 14	HTP 18	1	1	1	1	0	K
HEF 14	HTP 18	1	42	0	15	0	K
WW 15	OTP 16	234	1	1	1	231	K
WW 15	OTP 16	11	22	0	0	8	K
WW 15	ASSK20	0	22	0	22	0	K
DRAP 5	DRAP 6	294	2	2	2	292	K
DRAP 5	DRAP 6	2	60	0	21	0	K

DTPE 9 DRAP 6	120	1	1	1	118 K
DTPE 9 DRAP 6	2	30	0	30	0 K
AS 11 ASSK20	0	69	0	9	0 K
OTP 16 OTP 17	270	2	2	2	268 K
OTP 16 OTP 17	2	30	0	22	0 K
HTP 18 HTP 19	212	1	1	1	209 K
HTP 18 HTP 19	3	42	0	15	0 K
DRAP 6 OKC 7	274	3	3	3	273 K
DRAP 6 OKC 7	1	90	0	51	0 K
OTP 17 OKC 7	289	2	2	2	288 K
OTP 17 OKC 7	1	30	0	22	0 K
HTP 19 OKC 7	307	1	1	1	306 K
HTP 19 OKC 7	1	30	0	15	0 K
OKC 7 ASSK20	0	94	94	94	6 K
ASSK20 SSK 21	0	159	159	159	-6 K
SSK 21 SS 1	0	159	159	159	0 K

1NODE PRICES

SS 1	0
AS 2	-7
ATOKA3	-6
DRAP 4	-3
AN 22	-3
HUGO 8	-7
FTSY10	-6
CAN 12	-5
OVH 13	-4
HEF 14	-5
WN 15	-6
DRAP 5	-3
DTPE 9	-3
AS 11	-6
OTP 16	-3
HTP 18	-4
DRAP 6	-1
OTP 17	-1
HTP 19	-1
OKC 7	0
ASSK20	-6
SSK 21	0

0END

0NO OF BREAKTHRUS= 25, NO OF NONBREAKTHRUS= 12, NO OF X CHANGES= 162

NO OF NODES FROM WHICH LABELING WAS DONE= 395

0SUM OF PRODUCTS 2.300600000000D+04

READY

CHAPTER VI

SEWER NETWORK MODEL

6.1 Introduction

Since the same procedures and network models are used for both water and sewerage systems, the general discussion of the technical process was presented in Chapter V, Water Network Model. Consequently, one should review and refer to Chapter V prior to the reading of this chapter. This was done because the procedures were lengthy and would have been redundant if presented again. The only thing that will be discussed in this chapter is the philosophical and technical differences that the sewerage network creates in the application of the preceeding presentation.

The flow charts, data arrangement,and model listings are identical to those in Chapter V and will only be referenced in this chapter. The remainder of this chapter will be devoted to the explanation of the techniques used to operate the "model" as a sewerage network model.

As previously discussed, the first phase is the isolation of the feasible independent networks and the reduction of the problem to its simplest form. The first step is to reduce the network to the "real" network by identifying the unfeasible alternatives and eliminating them from the network. This is a course screening done by the best qualified people. The independent networks are then evaluated using engineering cost data analysis.

The interconnected networks or the alternate solutions that interconnect independent solutions are evaluated by loading the system onto the computer and evaluating them with the network model. The flexibility that was built into the model for the water network analysis is preserved for the evaluation of the sewer system.

6.2 Network Formulation

The sewerage network varies from the water network in that it is primarily a gravity flow system. The use of pumps, pressurized lines and lift stations are normally avoided and are only implemented when absolutely necessary.

The sewerage network begins within each small basin with a collector system. These grid or block by block collector networks are sized by using the technique described in Appendix C (14), Water, Sewer, and Storm Drainage Micro Area Requirements. The sewage then flows from the collector systems into the sewer mains. These mains are also designed using the technique described in Appendix C (14). It is not the purpose of this study to design and plan for this portion of the sewerage network, although a procedure was given in Appendix C (14).

The design of the collector systems that serve these smaller basins is the responsibility of the political jurisdictions involved. The portion of the system that this study does deal with is the collection of the sewage from these smaller basins and political jurisdictions, its transportation to a system of treatment plants, and finally the discharge of the effluent into a receiving stream.

It is also not the purpose of this study to develop a stream recovery model that examines in detail the effect that the effluent will have on the receiving streams. The way that the network model does take this into consideration is by limiting the upper bounds of the arc that connects the outfall of a treatment plant to the receiving stream to a value of effluent that the stream can handle. This value is obtained by using methods Appendix D, Water Quality (14). By controlling the amount of effluent based on a specified level of treatment for the study area, in this case secondary, that can be discharged at different points, the quality of the receiving streams can be maintained. This can even be made seasonal by changing these values based in the seasonal flows and characteristics of each receiving stream.

The sewerage model examines all of these feasible alternatives for the region and optimizes them into a regional sewer network. It is also possible, if not probable, as in ACOG, that the region is made up of several major basins of different characteristics that are not connected within the study area (see Figure 6-1). These basins may be analyzed separately, or, as in the example for the study area, be analyzed by interconnecting two or more of the basins.

There is also the capability of the using agency to evaluate the alternatives of having one major treatment plant or any combination of smaller treatment plants. The portion of the study that was selected as an illustrative example combines all of the above possibilities. The example problem looks at the feasibility of connecting two major basins, the Deep Fork and the North Canadian Rivers, by a lift station to one metro-treatment plant or by serving each basin by a selection of smaller treatment plants. The problem is illustrated in sections 6.4, 6.5, and 6.6.

The procedure for formulating the sewer network is identical to that described in Section 5.2 of the preceding chapter. The first step is to established the current network from the inventory data. The procedures and firms used are the same as before. The only difference between this phase, which is for the sewer networks, and those for water is that the flow is

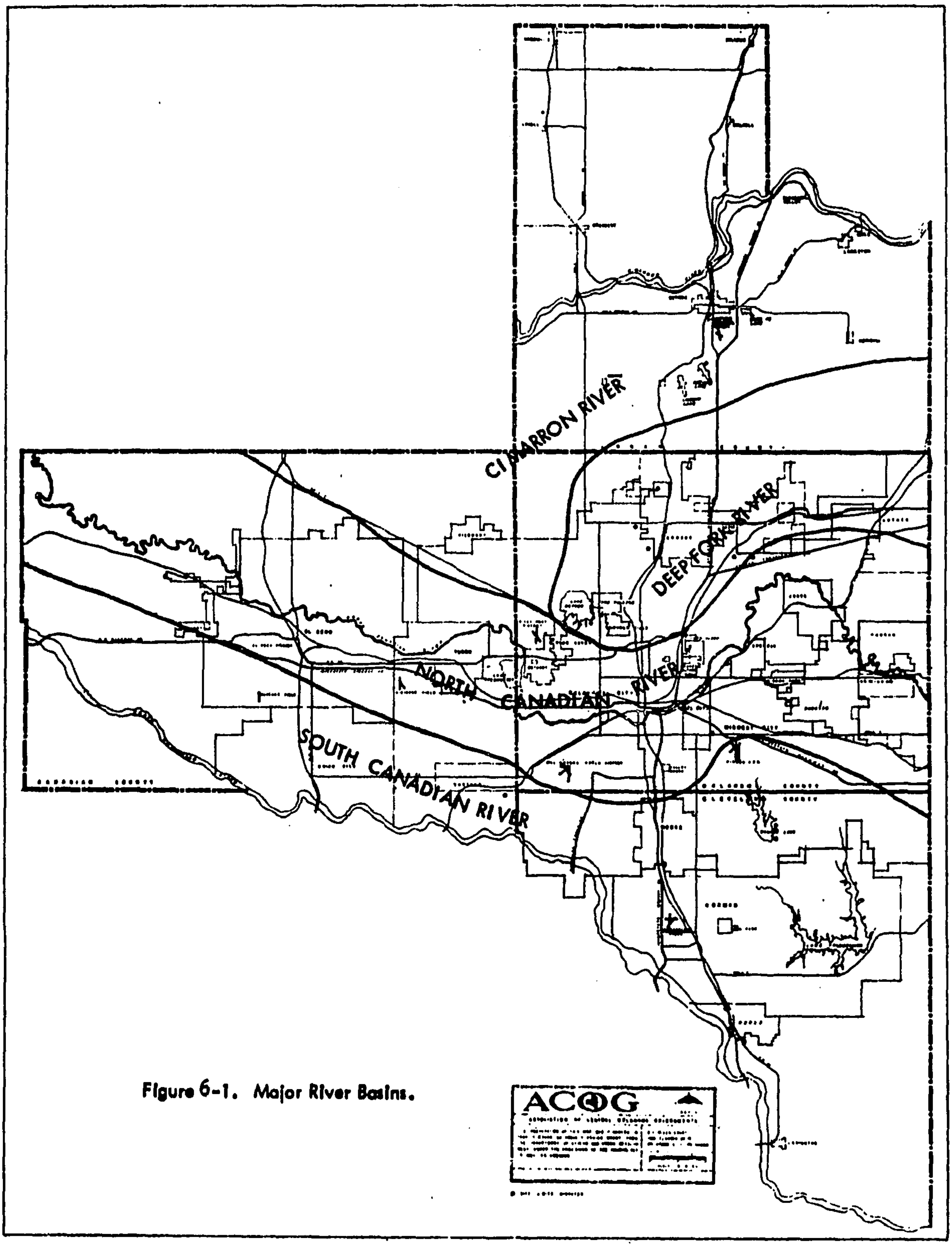


Figure 6-1. Major River Basins.

reversed. The use of special areas, mainly basins, within each political area is greatly increased. This allows the demand portion of the model to work within the framework of gravity flow across corporate boundaries.

The identification of the real network and its shortages and capabilities is handled in the same manner as water. It is also advanced into the "desirable" worlds and evaluated as to their incremental capabilities, deficiencies, and availabilities using those techniques described in Section 5.2.

At the conclusion of this procedure, the using agency will have a complete understanding of the sewer networks, their requirements, and feasible alternatives for the region under study. The problem will have again been reduced to its simplest form and be ready for presentation to the committee of concerned agencies for final selection of the alternatives that they may wish to analyze further. Each choice will then be modeled for the selection of the best alternatives which will then be incorporated into the final plan.

6.3 Model Description

The model again varies with the type of network under consideration. If it is a simple independent network, the use of derived cost functions are used, but if it is a complicated independent or interconnected network, then the computer model is employed.

When the computer model is run, it is used in the same manner as that of the water network. The same model is employed by both networks. The network is again made up of nodes and arcs. Each facility is represented by a node for the inlet and another node for outlet. If a fixed cost is encountered in this facility, it is represented by an arc with a fixed "fake flow", usually one MGD. If the conservation of flow changes this fake flow to another value, then the fixed cost is reduced proportionately. Another arc is used to represent that portion of the cost, above fixed cost, that which varies linearly with flow. A system of cost lines are developed for each type of facility as shown in Figure 5-3. These arcs and nodes with their derived cost functions can be used to depict accurately any type of facility (see page 178). The use of these dual nodes and multi-arcs is limited only by the users abilities to depict each facility by its proper combination of arcs.

If the network under consideration is a simple independent network, it can be handled using cost functions similar, in many cases identical, to those used in the water network. The equations for transmission, pipeline, and right-of-way costs are the same. The remainder of the costs for the system as acquired form the same sources as those for the computer model data requirements (see Section 6.4).

It can be seen that this modeling technique has a tremendous advantage in that it is not only highly flexible, but can be used for both water and sewer networks. This study group is also working with it in transportation and stream recovery modeling. Flow charts are shown in Section 5.3.

6.4 Data Requirements

The data requirements for this model are the same as those required for the water network. The only difference is in the cost curves and functions used to provide the actual costs. It is obvious that these cost data are available from many sources and those that are used here are not considered as absolute. The user agency should use those functions that it feels are most accurate. The functions that the author uses are obtained from those listed in the Bibliography (31, 32, 33, 34, and 35).

6.5 Data Arrangement

The data are arranged in groups of links or arcs for each pair of nodes. All links from each source node must be listed in groups. The format is the same as that shown in Section 5.5. A listing for the runs used to compare the utilization of a single metro-plant for two river basins, versus several treatment plants in each basin is shown in Section 6.7.

6.6 Model Format

The model listing is the same as that shown in Section 5.6.

6.7 Model Validation

There were many runs made of different arrangements for the network. The run selected is shown in Figure 6.2. The output, which follows, shows that the metro-plant is a more economical solution to the problem than the multi-plant alternative. This example is not a true representation of the problem due to the lack of accurate cost data for the actual system. This could be accurately determined under the conditions and funding of a full study of the region.

The true validation of this model has been accomplished, and its full usefulness is only limited by the skill of the using agency in depicting the system and alternatives in modeling nomenclature. Once a proper set of cost functions for their systems have been developed and projected (this study used the ENR cost index), the optimization of the network will be obtained.

```
BEGIN
 OKC SEWAGE

ARCS     SS 1   AN 2           0        66        0
          AN 2 NDFB24          0        26       26
          AN 2 IFPM 4          0        40       40
          AN 2 CNNC 3          0        40        0
        NDFB24PTP 25         212        26        0
        NDFB24PLS 27          40         1        1
        NDFB24PLS 27           9        25       25
        PTP 25PTPO26        2180         1        0
        PTP 25PTPO26          86        25        0
        PTPO26DFR 10           0        26        0
        DFR 10NCR  8           0        26        0
        PLS 27OFPM 5         380         1        0
        PLS 27OFPM 5          20        25        0
        IFPM 4OFPM 5         638         6        0
        IFPM 4OFPM 5         173        34        0
        OFPM 5PJMP 6           0         7        0
        OFPM 5PJMP 6           0        59        0
        PJMP 6PJPO 7         769         7        0
        PJMP 6PJPO 7          45        59        0
        PJPO 7DFR 10         247         1        0
        PJPO 7DFR 10           8        25        0
        PJPO 7NCR  8           0         6        0
        PJPO 7NCR  8           0        34        0
        CNNC 3JYOK11           0         5        0
        CNNC 3NMUS12           0         2        0
        CNNC 3NWOK13           0         2        0
        CNNC 3SSP 14           0        26        0
        CNNC 3SWOK15           0         2        0
        CNNC 3DELC16           0         3        0
        JYOK11 OF 17        2180         1        0
        JYOK11 OF 17         240         4        0
        NMUS12 OF 18         183         1        0
        NMUS12 OF 18         458         1        0
        NWOK13 OF 19         183         1        0
        NWOK13 OF 19         458         1        0
        SSP 14 OF 20        2180         1        0
        SSP 14 OF 20          86        25        0
        SWOK15 OF 21         183         1        0
        SWOK15 OF 21         458         1        0
        DELC16 OF 22        2180         1        0
        DELC16 OF 22         458         2        0
          OF 17 AN 23          0         5        0
          OF 18 AN 23          0         2        0
          OF 19 AN 23          0         2        0
          OF 20 AN 23          0        26        0
          OF 21 AN 23          0         2        0
          OF 22 AN 23          0         3        0
          AN 23NCR  8          0        40        0
        NCR  8 SSK 9           0        66        0
          SSK 9 SS 1           0        66       66

END.
SOLVE
QUIT

READY
```

```
BEGIN
 OKC SEWAGE
ARCS
          SS 1   AN 2              0            66            0
          AN 2  NDFB24             0            26           26
          AN 2  IFPM 4             0            40            0
          AN 2  CNNC 3             0            40           40
         NDFB24PTP 25            212            26           26
         NDFB24PLS 27             40             1            0
         NDFB24PLS 27              9            25            0
         PTP 25PTP026           2180             1            0
         PTP 25PTP026             86            25            0
         PTP026DFR 10              0            26            0
         DFR 10NCR  8              0            26            0
         PLS 27OFPM 5            380             1            0
         PLS 27OFPM 5             20            25            0
         IFPM 4OFPM 5            638             6            0
         IFPM 4OFPM 5            173            34            0
         OFPM 5PJMP 6              0             7            0
         OFPM 5PJMP 6              0            59            0
         PJMP 6PJPO 7            769             7            0
         PJMP 6PJPO 7             45            59            0
         PJPO 7DFR 10            247             1            0
         PJPO 7DFR 10              8            25            0
         PJPO 7NCR  8              0             6            0
         PJPO 7NCR  8              0            34            0
         CNNC 3JYOK11              0             5            0
         CNNC 3NMUS12              0             2            0
         CNNC 3NWOK13              0             2            0
         CNNC 3SSP 14              0            26            0
         CNNC 3SWOK15              0             2            0
         CNNC 3DELC16              0             3            0
         JYOK11 OF 17           2180             1            0
         JYOK11 OF 17            240             4            0
         NMUS12 OF 18            183             1            0
         NMUS12 OF 18            458             1            0
         NWOK13 OF 19            183             1            0
         NWOK13 OF 19            458             1            0
         SSP 14 OF 20           2180             1            0
         SSP 14 OF 20             86            25            0
         SWOK15 OF 21            183             1            0
         SWOK15 OF 21            458             1            0
         DELC16 OF 22           2180             1            0
         DELC16 OF 22            458             2            0
          OF 17 AN 23              0             5            0
          OF 18 AN 23              0             2            0
          OF 19 AN 23              0             2            0
          OF 20 AN 23              0            26            0
          OF 21 AN 23              0             2            0
          OF 22 AN 23              0             3            0
          AN 23NCR  8              0            40            0
         NCR  8 SSK 9              0            66            0
          SSK 9 SS 1               0            66           66
END
SOLVE
QUIT

READY
```

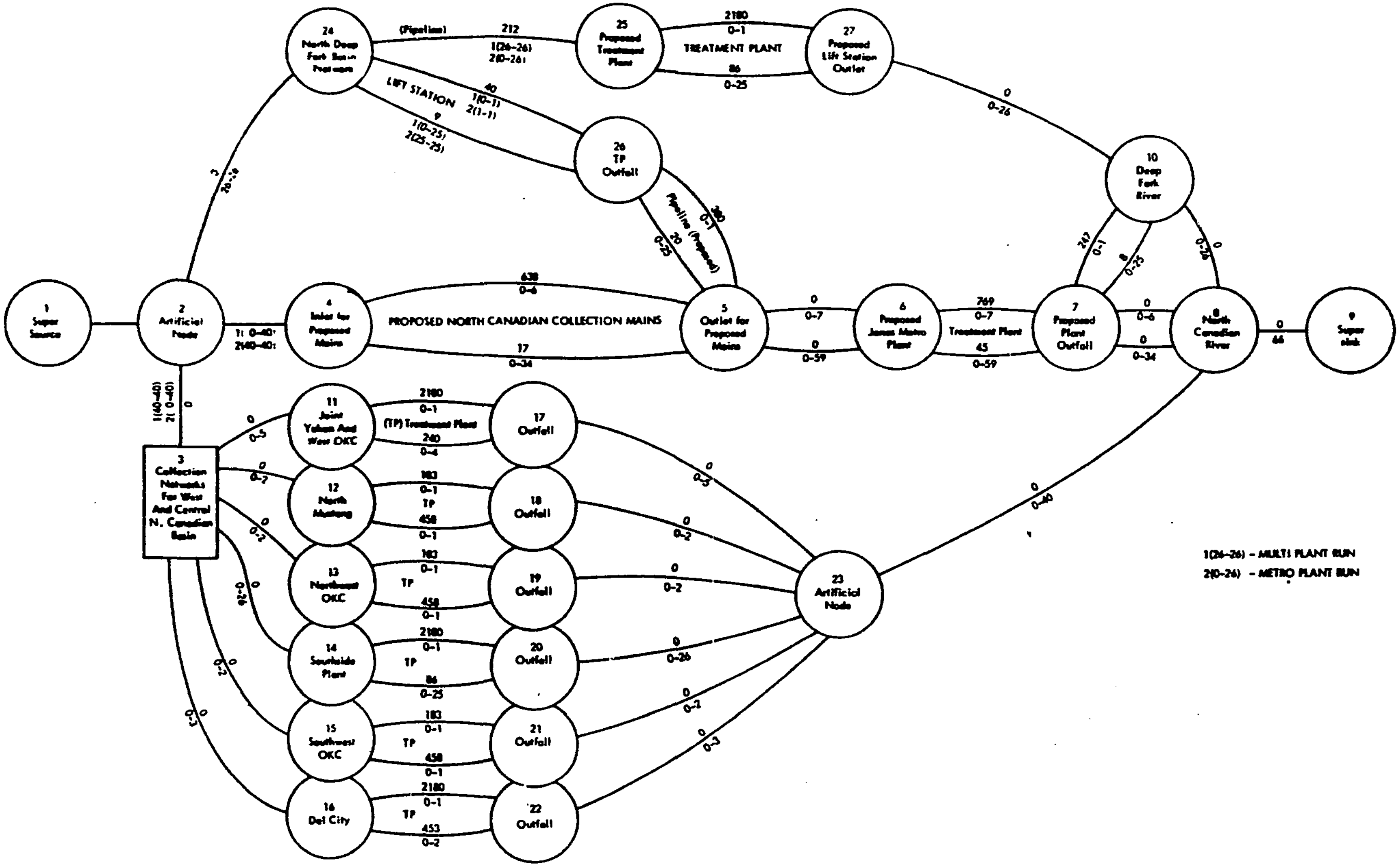


Figure 6.2. North Canadian River Basin (Plant Selection)

BEGIN
 CKC SEWAGE
ARCS
 SOLVE
 NO OF ARCS=   50 NO OF NODES=   27
1 CKC SEWAGE

ARCS		COST	UPPER	LOWER	FLOW	CBAR	
SS 1	AN 2	0	66	0	66	0	K
AN 2	NDFB24	0	26	26	26	86	K
AN 2	IFPM 4	0	40	0	0	0	K
AN 2	CNNC 3	0	40	40	40	2192	K
NDFB24	PTP 25	212	26	26	26	2318	K
NDFB24	PLS 27	40	1	0	0	31	K
NDFB24	PLS 27	9	25	0	0	0	K
PTP 25	PTPO26	2180	1	0	1	0	K
PTP 25	PTPO26	86	25	0	25	-2094	K
PTPO26	DFR 10	0	26	0	26	0	K
DFR 10	NCR 8	0	26	0	26	0	K
PLS 27	OFPM 5	380	1	0	0	360	K
PLS 27	OFPM 5	20	25	0	0	0	K
IFPM 4	OFPM 5	638	6	0	0	695	K
IFPM 4	OFPM 5	173	34	0	0	230	K
OFPM 5	PJMP 6	0	7	0	0	0	K
OFPM 5	PJMP 6	0	59	0	0	0	K
PJMP 6	PJPO 7	769	7	0	0	724	K
PJMP 6	PJPO 7	45	59	0	0	0	K
PJPO 7	DFR 10	247	1	0	0	247	K
PJPO 7	DFR 10	8	25	0	0	8	K
PJPO 7	NCR 8	0	6	0	0	0	K
PJPO 7	NCR 8	0	34	0	0	0	K
CNNC 3	JYOK11	0	5	0	5	0	K
CNNC 3	NMUS12	0	2	0	2	-1722	K
CNNC 3	NMOK13	0	2	0	2	-1722	K
CNNC 3	SSP 14	0	26	0	26	0	K
CNNC 3	SMOK15	0	2	0	2	-1722	K
CNNC 3	DELC16	0	3	0	3	0	K
JYOK11	DF 17	2180	1	0	1	0	K
JYOK11	DF 17	240	4	0	4	-1940	K
NMUS12	DF 18	183	1	0	1	-275	K
NMUS12	DF 18	458	1	0	1	0	K
NMOK13	DF 19	183	1	0	1	-275	K
NMOK13	DF 19	458	1	0	1	0	K
SSP 14	DF 20	2180	1	0	1	0	K
SSP 14	DF 20	86	25	0	25	-2094	K
SMOK15	DF 21	183	1	0	1	-275	K
SMOK15	DF 21	458	1	0	1	0	K

DELC16	OF 22	2180	1	0	1	0	K
DELC16	OF 22	458	2	0	2	-1722	K
OF 17	AN 23	0	5	0	5	0	K
OF 18	AN 23	0	2	0	2	0	K
OF 19	AN 23	0	2	0	2	0	K
OF 20	AN 23	0	26	0	26	0	K
OF 21	AN 23	0	2	0	2	0	K
OF 22	AN 23	0	3	0	3	0	K
AN 23	NCR 8	0	40	0	40	0	K
NCR 8	SSK 9	0	66	0	66	-12	K
SSK 9	SS 1	0	66	66	66	0	K

NODE PRICES

SS 1	0
AN 2	0
NDFB24	-86
PTP 25	-2192
PTPO26	-12
DFR 10	-12
PLS 27	-77
IFPN 4	0
LFPN 5	-57
PJNP 6	-57
PJPO 7	-12
CNNC 3	-2192
JYOK11	-2192
MNUS12	-470
MNOK13	-470
SSP 14	-2192
SNOK15	-470
DELC16	-2192
OF 17	-12
OF 18	-12
OF 19	-12
OF 20	-12
OF 21	-12
OF 22	-12
AN 23	-12
NCR 8	-12
SSK 9	0

OEND
ONO OF BREAKTHRUS= 20, NO OF NONBREAKTHRUS= 11, NO OF X CHANGES= 167
NO OF NODES FROM WHICH LABELING WAS DONE= 402
OSUM OF PRODUCTS 2.2331000000000D+04

READY

BEGIN
OKC SEWAGE
ARCS
SOLVE
NO OF ARCS= 50 NO OF NODES= 27
1 OKC SEWAGE

ARCS		COST	UPPER	LOWER	FLOW	CBAR	
SS 1	AN 2	0	66	0	66	0	K
AN 2	NDFB24	0	26	26	26	298	K
AN 2	IFPM 4	0	40	40	40	1654	K
AN 2	CNMC 3	0	40	0	0	0	K
NDFB24	PTP 25	212	26	0	0	0	K
NDFB24	PLS 27	40	1	1	1	1138	K
NDFB24	PLS 27	9	25	25	25	1107	K
PTP 25	PTPO26	2180	1	0	0	2094	K
PTP 25	PTPO26	86	25	0	0	0	K
PTPO26	DFR 10	0	26	0	0	0	K
DFR 10	NCR 8	0	26	0	26	0	K
PLS 27	OFPM 5	380	1	0	1	0	K
PLS 27	OFPM 5	20	25	0	25	-360	K
IFPM 4	OFPM 5	638	6	0	6	0	K
IFPM 4	OFPM 5	173	34	0	34	-465	K
OFPM 5	PJMP 6	0	7	0	7	0	K
OFPM 5	PJMP 6	0	59	0	59	0	K
PJMP 6	PJPO 7	769	7	0	7	0	K
PJMP 6	PJPO 7	45	59	0	59	-724	K
PJPO 7	DFR 10	247	1	0	1	0	K
PJPO 7	DFR 10	8	25	0	25	-239	K
PJPO 7	NCR 8	0	6	0	6	-247	K
PJPO 7	NCR 8	0	34	0	34	-247	K
CNMC 3	JYOK11	0	5	0	0	0	K
CNMC 3	NMUS12	0	2	0	0	0	K
CNMC 3	NMOK13	0	2	0	0	0	K
CNMC 3	SSP 14	0	26	0	0	0	K
CNMC 3	SMOK15	0	2	0	0	0	K
CNMC 3	DELC16	0	3	0	0	0	K
JYOK11	CF 17	2180	1	0	0	2180	K
JYOK11	CF 17	240	4	0	0	240	K
NMUS12	CF 18	183	1	0	0	183	K
NMUS12	CF 18	458	1	0	0	458	K
NMOK13	CF 19	183	1	0	0	183	K
NMOK13	CF 19	458	1	0	0	458	K
SSP 14	CF 20	2180	1	0	0	2180	K
SSP 14	CF 20	86	25	0	0	86	K
SMOK15	CF 21	183	1	0	0	183	K
SMOK15	CF 21	458	1	0	0	458	K
DELC16	CF 22	2180	1	0	0	2180	K
DELC16	CF 22	458	2	0	0	458	K

```
  OF 17  AN 23        0        5        0        0        0 K
  OF 18  AN 23        0        2        0        0        0 K
  OF 19  AN 23        0        2        0        0        0 K
  OF 20  AN 23        0       26        0        0        0 K
  OF 21  AN 23        0        2        0        0        0 K
  OF 22  AN 23        0        3        0        0        0 K
  AN 23 NCR  8        0       40        0        0        0 K
 NCR  8  SSK 9        0       66        0       66        0 K
  SSK 9  SS 1         0       66       66       66        0 K
1NODE PRICES

  SS 1           0
  AN 2           0
 NDFB24       -298
 PTP 25        -86
 PTPO26          0
 DFR 10          0
 PLS 27      -1396
 IFPM 4      -1654
 OFPM 5      -1016
 PJMP 6      -1016
 PJPO 7       -247
 CMNC 3          0
 JYOK11          0
 NMUS12          0
 NMOK13          0
 SSP 14          0
 SMOK15          0
 DELC16          0
  OF 17          0
  OF 18          0
  OF 19          0
  OF 20          0
  OF 21          0
  OF 22          0
  AN 23          0
 NCR  8          0
  SSK 9          0
OEND
0NO OF BREAKTHRUS=          9, NO OF NONBREAKTHRUS=          11, NO OF X CHANGES=          78
 NO OF NODES FROM WHICH LABELING WAS DONE=        108
0SUM OF PRODUCTS  1.934000000000D+04


READY
HEL
0073.44  CRU    0003.34  TCH    0121.85  KC

U#=
```

CHAPTER VII

DEVELOPMENT OF THE WATER AND SEWER PLAN

7.1 Introduction

It was the prime objective of this research project to provide the average planning group with a usable model for Regional water and sewerage planning networks. We feel this objective has been accomplished. The model we have developed fulfills all of the originally stated objectives.

All models developed are operational and are presented in their true configurations. Examples of the input and output for each stage have been presented for validation when being loaded on other hardware. It is the authors' opinion that any planning agency can use this system with very little effort and without the addition of new technical personnel.

The model starts with the required inventories and then lists the procedures for establishing this data into usable information systems. It then asks the planning group to intervene by establishing the growth parameters in the population model. This allows the using agency to tell the model for what goals the region would like to strive. The population model then provides the planner several population profile alternatives in five year increments for each of these alternatives (see Figure 7-1).

Again the planner is required to made additional input into the model by allocating the population profile for each alternative into an areal scheme. In other words, the planner develops a land use plan or plans for each set of goals and analytical alternatives under consideration.

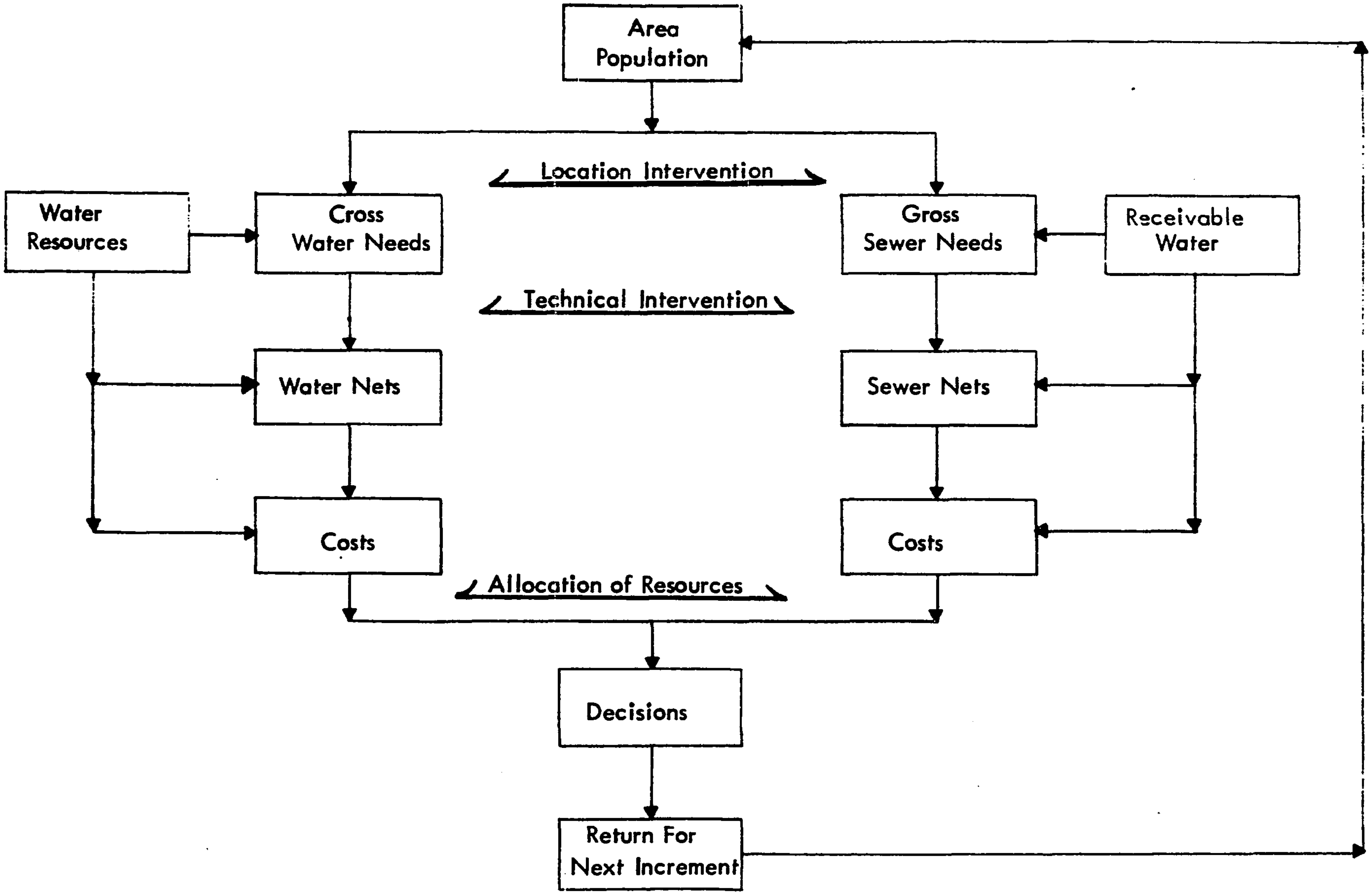


Figure 7 -1. Final Procedure Outline.

After the land use has been allocated to the SAU's the user group sets up and runs the demand model. This model takes the population and land use that were developed by the planner and computes the water requirements and sewage outputs for several adjustable configurations, such as political jurisdiction, basin, special area, etc.

The appropriate planning group is then asked to made another intervention. He is required to take the output from the demand model and the inventory of the existing and proposed facilities and create the networks for each time increment that is to be evaluated further. He is required, by a given procedure, to reduce this problem to its simplest form before evaluation by the network models.

The alternatives for both water and sewage which are to be run on the network model are then depicted by a link-node process. The alternatives are then loaded onto the network model and reevaluated. The result is the optimization of flow at the least cost.

At this point the model has completed all necessary information for the development of the final plan. There only remains to be done that portion which takes the cost of all the desirable alternatives and incrementally evaluates them against the financial structure of the region. The final step is to establish the priorities for the development of the alternatives that were selected for implementation.

7.2 Analysis of Alternatives

The process of financial analysis of these alternatives is a relatively simple procedure that follows the standard techniques used in economics. A profile of the financial structure including bond debt limits and future financial resources is developed. This analysis is done on an incremental basis using the same steps as the models. The cost of each of the alternatives is then evaluated against the financial profile, and priorities are set by the committee of concerned agencies. The net result is the capital investment profile of the region to obtain the selected goals.

The process, as described in this report leads to a comprehensive and continuing planning model. The output can be easily developed into a plan that will maximize the use of our natural resources, help protect our environment and preserve the quality of life that is desired.

7.3 Limitations and Future Research Needed

The primary limitation to this model, as well as most others, is the availability of data, particularly cost functions. It is possible to develop the simplest link-node configuration for each type of equipment or facility in the system. After the configuration is complete, then cost functions can be developed for each type and common manufacturer of the equipment. These packages can then be placed into the input-like building blocks. This would greatly facilitate the use of the network model for gaming alternatives.

The fact that research has shown that non-linear cost functions of any order can be represented, the full capabilities of this model have not been reached. This model can very easily be expanded to include solid waste, stream control, air pollution, or transportation, to name but a few. The full potential should be developed, because the use of a single technique for so many functions of urban planning is invaluable.

The only other limitation is, as always, the development of a usable and general land use model, one that would bridge the tedious step from the population model to the demand model. What is needed is a model that evaluates old neighborhoods on an incremental basis and allocates the proper portion of the population model to them. It should also take the difference and compute the new neighborhoods and industrial areas needed to support this growth. The planner would then only have to intervene by allocating the different types of neighborhoods to the land before proceeding to the demand model.

The development of these areas would then give the using agency a model that could be used to depict completely the urban development of the region using a minimum of computerized models---a most desirable goal.

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