PLANNING OPTIMAL IRRIGATION DISTRIBUTION AND APPLICATION SYSTEMS: TETON FLOOD DAMAGED LANDS[a]

Errata II

(Corrections to computer programs)

In SPNKLER subroutine, page B-19:
replace lines 1560-1561 with the following lines:

```
C      COMPUTE APPLICATION RATE (IN/HR) AND FLOW RATE PER LATERAL (GPM)
C
       IF(KODE.EQ.5) GO TO 40
       AR = TRAMC(L) / ((TSET(KT) - TMOV / 60.) * OAEFF / 100.)
       GPML = AR / 12. * LLEN * LSPA * 7.48 / 60.
       GO TO 41
    40 AR = TRAMC(L) / (FREQC(L) * 24. * OAEFF / 100.)
       GPML = AR / 12. * TOTA * 43560. * 7.48 / 60.
    41 CONTINUE
```

In POWCST subroutine, page B-87:
insert between lines 907 and 908 the following lines:

```
C      CALCULATE MONTHLY DEMANDS USING RATIOS OF WRQ TO WRQ(PEAK).
C      LOWEST POSSIBLE PUMPING RATIO IS 0.4*(PEAK DESIGN).
C      DEMAND RATIO. (TURBINE OR CENTRIFUGAL) IS APPROXIMATED BY
C      (QRATIO)**.33.
C      NOTE:  ALL MONTHS ARE ASSUMED TO HAVE MAXIMUM DESIGN DEMANDS
C      EXCEPT FOR BEGINNING AND ENDING MONTHS OF SEASONS LONGER THAN
C      4-5 MONTHS IN LENGTH.
C
       TCDEM = 0.
       HPM = HPW
       DO 72 KZ = 1,NW
       XRD = 1.
       IF(NW.GT.3.AND.KZ.EQ.1) XRD=(WRQ(1)/RAT*0.6+0.4)**0.33
       IF(NW.GT.4.AND.KZ.EQ.NW)XRD=(WRQ(NW)/RAT*0.6+0.4)**0.33
       HPW = HPM * XRD
```

---

[a] Richard G. Allen, C.E.Brockway, and John R. Busch, University of Idaho (Res. Tech. Comp. Rep. 9-76/3-78)

In POWCST subroutine, page B-17:

```
   replace line 925 with
      GO TO 71
   replace line 932 with
      GO TO 71
   replace line 936 with
      GO TO 71

   replace line 939 with the following:
   71 TCDEM = TCDEM + CDEM
   72 CONTINUE
      CDEM = TCDEM
      HPW = HPM
      GO TO 14
```

TECHNICAL COMPLETION REPORT

PLANNING OPTIMAL IRRIGATION DISTRIBUTION AND APPLICATION SYSTEMS: TETON FLOOD DAMAGED LANDS

by

R. G. Allen, C. E. Brockway, J. R. Busch
College of Engineering
College of Agriculture

UNIVERSITY OF IDAHO

Submitted to

U. S. Department of Agriculture
Science and Education Administration
(formerly Agricultural Research Service)

Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho

June, 1978

ACKNOWLEDGMENTS

This study was funded by the United States Department of Agriculture, Agricultural Research Service (now Science and Education Administration, SEA). Information, cooperation, and services obtained from SEA personnel at the Snake River Conservation Research Center, Kimberly, Idaho, greatly assisted in the model and study development. Special thanks are due to Dr. Marvin E. Jensen, Director of the Center, for his advice and editing of the manuscript.

Refinement of many of the computer routines and computer analysis of model data would have been difficult without the assistance and consulting services of Mr. Garth Newton, Mr. Gerry Galinato, and other personnel of the Idaho Department of Water Resources, Boise, Idaho.

Acknowledgment is also given to Mr. Gary Steinbach of the Engineering and Surveys Branch, Planning Division, United States Bureau of Reclamation, Boise, Idaho, and to Mr. Reed Oldham, president of the Salem Irrigation Canal Company.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

Note: Table of contents for each appendix is the first page of the appendix.

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

Tables Page

LIST OF FIGURES

Figure Page

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

ABSTRACT

A model used for obtaining least cost irrigation system specifications was refined and applied. Irrigation systems consisted of application system and distribution system components and did not include reservoirs of any type.

Computer routines were used to estimate annual costs and system efficiencies, and a two-stage dynamic and linear-programming technique was used to select and arrange system components for a least cost irrigation system subjected to physical and environmental constraints.

The model was applied to the Salem Irrigation District, located on the flood-damaged Teton River flood plain in Fremont and Madison Counties in eastern Idaho, to determine least cost rehabilitation schemes for various constraining conditions. These conditions were minimum allowable project efficiency, cost of water entering the system, and charges for water lost to deep percolation and surface runoff. Application systems considered were subirrigation, unimproved gravity, improved gravity, and hand-move, side-roll, solid-set, and center pivot sprinkler systems. Distribution system components were unlined channels, lined channels, gravity pipe systems, and a high-pressure pipe system supplied by a large pumping station or a regional gravity-high pressure pipe system.

Specified allowable system efficiency ranged from 13 percent to 70 percent. Results obtained indicate that the least cost rehabilitation scheme necessary to achieve an overall system efficiency of 60 percent

would be to apply concrete lining to most of the present unlined channel distribution system and to convert on-farm systems to hand-move, side-roll, and center pivot sprinkler systems. An increase in the cost of irrigation water could justify an increase in the overall system efficiency and the total cost of operating the system. Use of the present subirrigation system is the most economical method of water application when no charge for incoming water is assessed, and results in low losses of surface runoff and leaching of soil nutrients. Project irrigation efficiency for subirrigation is low (13 percent).

The results obtained indicate that the analytical model used in this study is a valid and useful tool for determining rapid, least cost irrigation system specifications.

CONCLUSIONS AND RECOMMENDATIONS

An irrigation systems evaluation and optimization model was refined and updated during this study to facilitate the selection of alternative irrigation systems for private or federal irrigation projects. The model was developed so that multiple combinations of various system components are generated with dynamic and linear optimization routines to rapidly evaluate alternative systems for constructing or rehabilitating district irrigation projects.

The methodology used in the model was formulated by J. R. Busch (1974) and includes costs estimating routines obtained from the United States Bureau of Reclamation (Galinato, 1977). Computer routines in the model determine the capacity and cost of irrigation distribution system and pumping plant components, and evaluate costs and efficiencies of on-farm systems.

On-farm systems evaluated include furrow and border surface systems and hand-move, side-roll (wheel-line), solid-set, and center pivot sprinkler systems. Water application and distribution efficiencies of surface systems are estimated for specific soil types, field lengths and slopes, and crops grown by modelling the surface hydraulics of these systems (Strelkoff, 1977; Vaziri, 1973). The number of laterals and operating schedules required for sprinkler irrigation of farms on various soil types are also computed.

Possible distribution systems evaluated by this model include lined and unlined canals and gravity and high pressure pipe. All earthwork quantities and costs and sizes of required system structures are itemized in the computer output. Combinations of lined and unlined canal and gravity pipe systems are formulated by a dynamic programming routine to determine efficient and optimal conveyance system configurations.

Subroutines in the model estimate the cost of wells, pumping plants, and electrical power if water is to be lifted to the project from underground or surface supplies or pressurized for sprinkler system operation.

Annual costs, water requirements, and irrigation efficiencies of the alternative system components evaluated can be input to a linear-programming routine to optimize combinations of distribution and application systems at least cost when subjected to physical and environmental constraints. These constraints can range from limited water or energy supplies and rates tospecified limits or charges for deep percolation, seepage, or surface runoff losses within the project.

The model used in this study can be useful in predicting changes in system configurations necessary for least cost operation at varying costs for water, construction materials, labor, and power. Costs and sizes of system components and quantities of earthwork and construction materials estimated for the various systems can provide valuable information for design phases of a project.

The model and methodology of this study have been designed for use in rehabilitation of existing systems or for use in planning of new irrigation systems in presently nonirrigated areas. Cost indices are input to the model for estimating many system components to compensate for differences in construction or operating costs of systems in various geographical regions, or to increase the cost estimates due to inflationary trends. However, careful planning and accurate data are required in the economic and physical modelling of an irrigation system if realistic and useful results are to be obtained. If all data requirements are met, the output generated by this model will provide valid and factual information to be used for planning purposes.

Alternative irrigation systems have been optimized which could be used in rehabilitation of irrigated areas flooded by the collapse of the Teton Dam. Subirrigation and unlined canal systems presently used in the area were evaluated, and combinations of surface and sprinkler systems supplied by lined canals, gravity pipe or high pressure pipe systems were identified as alternatives which could be used to irrigate the area more efficiently at least cost.

The specific irrigation district analyzed during this study was the Salem Irrigation District near Sugar City, Idaho. The unlined canal and subirrigation system used in this district now operates at an estimated overall irrigation efficiency of 13 percent and at an annual cost of $30 per acre. By lining much of the present canal system and converting to hand-move or side-roll sprinkler systems, the district could operate at an efficiency of 60 percent. Annual cost of this upgraded system was estimated to be $70 per acre at 1977 prices. Specification of a district irrigation efficiency of 70 percent would require the use of a gravity pipe-lined channel system combination to supply water to sprinkler systems at an annual cost of $84 per acre. These costs include costs of constructing, operating, and maintaining the total system and the cost of electrical power estimated over the life of the pumping system.

Optimal alternative systems were also determined at various charges for water supplied to the Salem District using parametric programming options in the linear-programming routine. Subirrigation systems supplied by unlined channel are the least cost system when no charge is assessed for water. However, if the price charged for water is allowed to approach $15 per acre-foot, the least cost system configuration would require lining of 50 percent of the distribution system and the conversion of application systems to sprinkler and graded border. The total annual cost per acre including the charge for water would be $115, and the system could be operated at an efficiency of 58 percent.

One effective method of increasing the irrigation efficiency of the study area, in terms of efficiency increase per dollar spent, would be to constrain the rate at which water is allowed to enter the system. Charging irrigators for water used in order to achieve an increase in the system efficiency would be more costly to the user. Although the water assessment could result in a net flow of money from the farm, this charge could be used for improved management and upgrading of the present distribution system.

The annual operation and construction costs and water-use efficiencies of the various systems evaluated for the Salem Irrigation District were felt to be representative of the costs and efficiencies of most of the irrigated areas along the lower Teton River and Henry's Fork of the Snake River in eastern Idaho. This area uses low cost, but inefficient systems and would require a major rehabilitation, including consolidation of canals and districts, if larger portions of the area's river flow were to be allocated for beneficial uses other than irrigation.

Recommendations

Several refinements and additions to this systems optimization model could increase the accuracy and range of the model application. The recommendations presented are from observations made in applying the model to the Teton study area.

On-farm application systems were optimized during this study for specific soil-crop combinations. Formulating the linear-programming matrix described in Chapter VI to specify similar systems for all crops on a major soil type would model a district more realistically by avoiding, for example, specification of graded-border and sprinkler system combinations for farms utilizing annual crop rotation patterns. This refinement is discussed in Chapter VII.

The APSYS subroutines BORDER and FURROW which evaluate efficiencies of surface systems for soil-crop combinations should be edited to more accurately define specific soil intake characteristics. These subroutines presently utilize Soil Conservation Service intake family classifications, which tend to cover very broad ranges of soil types (USDA-SCS, 1974).

Detailed cost data concerning construction, operation, and maintenance of large pumping stations could be helpful in calibrating the Bureau of Reclamation (USBR) subroutines used in the PUMP routine, so that accurate pumping costs for small, nonfederal projects could be estimated.

The methodology used in this model currently optimizes the costs of owning and operating irrigation systems. The inclusion of crop growth functions in the linear-programming matrix to describe crop responses to improved application systems and management practices would be valuable in evaluating cost/benefit ratios of various system configuations. Research is needed to evaluate the interactions of various crop-application system combinations and to accumulate existing data.

The authors recommend the consideration and possible use of this model for planning rehabilitation of inefficient irrigation districts in the western United States and for consolidation of small irrigation districts to improve system efficiencies and to decrease operation, management, and maintenance costs and problems. This model can be used to quantify optimal changes in system configurations in areas of increasing competition for water supplies or changes in regional water use plans.

The inclusion of energy requirements and constraints into the optimization section of this model can provide systems planning on the basis of energy supplies and demands. All input and output of the computer routines are currently dimensioned in English units. Conversion to System International (SI) dimensional units will be useful to future model applications.

CHAPTER I

INTRODUCTION

Although early irrigation systems in the western United States were individually planned at the time of construction, little or no consideration was given to the overall planning of the resultant complex of systems. The result has often been two or more canals serving essentially the same area, running parallel, or even crossing each other. Although such systems were constructed years ago, many are still in use and often contribute to inefficiency of land and water usage (Busch, 1974).

Preliminary development of irrigation systems in Idaho began in the 1870's in the Upper Snake River Region on land areas covered with dense sagebrush and native grass associations. Irrigated area has increased to more than 2,500,000 acres in this region which reaches generally east and north upstream from Bliss, Idaho, and includes irrigated areas along the Teton River and Henry's Fork of the Snake River. The gently sloping lands and fertile valleys of this region comprise one of the richest irrigated agricultural areas in the United States.

The early irrigators in the eastern portion of this region were organized primarily into small independent ditch companies, and because of the large labor requirements needed to bring river water onto each acre of land, the majority of the early irrigation systems were not large; generally less than 10,000 acres (Claiborn, 1975).

Since the early days of development, most irrigation systems in Idaho have undergone many evolutionary changes. Most rock and timber diversion dams have been replaced with concrete structures. Steel and concrete diversion headgates have been added to improve water regulation. However, major over-all project renovation such as consolidation of parallel canals, combination of smaller individual systems into larger operation entities, and channel alignment have not been implemented to any significant degree. Some smaller systems have been combined, but many exist essentially as they did 90 years ago.

The Teton flood plain in southeastern Idaho consists of many small, older irrigation districts, some of which are in need of systems updating and rehabilitation. The Salem Irrigation District located on the Teton flood plain has been selected as a study area for model testing and application.

Purpose of Study

The failure of the Teton Dam in June 1976 and the need for rapid rehabilitation of irrigation systems amplified the need for improved methods to rapidly determine cost estimates and efficiencies of irrigation systems for use in water resources systems planning. The methods used in this estimation and evaluation process need to be simple to use, general in application, yet must provide accurate answers related to specific system designs and imposed constraints.

A computerized planning model and methodology has been developed at the University of Idaho in 1973 (Busch, 1974) and updated by the addition of USBR planning routines (Galinato, 1977). This procedure enables systems planners to evaluate many irrigation systems alternatives and combinations for use in initial design or rehabilitation planning of federal or private irrigation districts. Linear and dynamic optimization procedures and routines in the model provide the ability to evaluate annual operation costs, alternative component interactions, and water use efficiencies over a wide range of combinations of application and distribution systems.

The major purpose of this study was to update, refine, and simplify computer routines and procedures developed during previous studies and to incorporate recently derived methods of evaluating on-farm application system efficiencies.

These improved routines were applied to a study area on the Teton River flood plain to verify their accuracy and reliability, determine the best methods of application of the routines, and to evaluate costs and efficiencies of various systems designs suitable for the Teton area.

A linear programming model was used with the output of the computer routines to optimize alternative components of irrigation application and distribution systems subject to minimum cost and physical, environmental, and social constraints.

This report is intended as a guide for using the irrigation design and optimization techniques. Examples of necessary input and output of the routines have been included in the text and appendices.

CHAPTER II

NEED FOR SYSTEMS PLANNING PROCEDURES

Thorough and well defined planning procedures are essential to the design, allocation, and consumption of renewable natural resources. Many water resources systems in use today operate well below efficiencies which could be attained by use of current or new technology. As new irrigation systems are planned, or as older systems are rehabilitated or modernized to reduce operational water losses or to improve the manageability of the system, modern technical concepts should be considered. These concepts can include automation of water control devices, use of underground pipe systems or impermeable barriers to reduce seepage losses and improve safety conditions, use of water pressure supplied by gravity rather than by electrical or thermal power, and use of technological advances in sprinkler design to decrease the pressure required for efficient operation. It is imperative that the systems planner employ in this planning procedure those technically and economically feasible design forms and methods which will contribute to more efficient use of energy, minerals, and water, and which will result in minimal degradation of environmental quality.

Irrigation presently uses a significant share of agriculture's energy requirement and most of this energy is used on the 25 percent of the irrigated land that is watered with sprinkler systems (Kruse et al 1977). As supplies of petroleum fuels diminish and competing demands increase, irrigation systems requiring such energy must operate at peak efficiencies.

Environmental implications of resources systems must be considered in systems planning. Inefficient irrigation systems lose water through surface runoff, evaporation, deep percolation, or seepage from the farm distribution systems. Surface runoff often carries large amounts of sediment which may restrict the uses that can be made of water in receiving streams. Deep percolation and seepage from farm ditches can raise water tables, sometimes removing land from agricultural production, although deep percolation in some fields irrigated with surface water may be beneficial as an important source of recharge to groundwater (U. S. Department of Interior, 1977).

Proper management of a water resources system is important if it is to function at efficient levels. For surface irrigation systems, increases in labor can frequently increase water use application efficiency by a substantial degree. Although application efficiencies of simple surface irrigation systems may range from 10 to 70 percent, Soil Conservation Service (SCS) irrigation guides indicate that application efficiencies of 55 to 75 percent can be obtained with furrows, and that graded-border systems can normally be operated at application efficiencies between 60 and 75 percent (USDA-SCS, 1960).

Although surface irrigation systems normally operate at lower water-use efficiencies than sprinkler systems, this lower water-use efficiency can in many cases be justified by lower energy requirements. The availability and total supply of energy forms and water in the geographical area of use will often dictate the choice between the use of surface irrigation systems and sprinkler irrigation systems.

Sprinkler irrigation efficiencies vary nearly as much as those of surface systems. Batty et al. (1975) reported sprinkler application efficiencies ranging from 60 to 90 percent with an average of 70 percent. Highest efficiencies are obtainable with relatively large applications of water per irrigation under conditions of low wind on soils with high intake rates.

The efficiencies of most irrigation systems can be improved measurably by using physical systems capable of applying water uniformly when needed and without waste, and by using methods of determining the timing and optimum amount of irrigation water to be applied (Jensen et al. 1970). These parameters can be determined if an irrigator knows the water-holding capacity of the soil, the allowable water depletion, and the soil water content at all times during the irrigation season.

The cost of water often influences management practices. In many irrigated areas in the western United States, the only cost assessed water users is for the maintenance of the storage and delivery systems. This situation provides little incentive for improving efficiency, as the irrigator cannot justify investments in additional management or physical improvements in the system to save water.

Water rights laws may also affect efficiencies. An irrigation water right entitles the user to divert a fixed volume or flow of water. This diversion is based on beneficial use for the type of irrigation used and can include transmission losses. If the irrigator could sell the water saved by reducing transmission losses or improving the application system, there would be an economic incentive to invest in system improvement or increased labor. However, most western water laws do not allow the sale of this excess water (Hammond, 1978).

There are irrigation systems in which gravity flow provides adequate water, and surface and subsurface return flow is of good quality. In these cases uses of water over an entire project or river basin is a more important consideration than irrigation efficiencies on individual farms.

Although any planning procedure encompassing the broad spectrum of irrigation systems design and operation is invaluable in allocating the use of water and energy resources, a planning procedure utilizing a systems optimization approach can give additional freedom in comparing numerous system designs and plans with one another. If properly formulated, an optimization procedure can identify those components of multiple system plans which prove to be most beneficial in meeting physical, legal, environmental, and economic constraints. Use of these planning techniques with high speed digital computers can provide rapid and accurate cost estimations and system evaluations for hundreds of system designs.

When properly used with accurate economic and physical systems data, the systems optimization planning procedure can be a very useful tool in providing systems planners, owners, and operators with guidelines for use in the decision making process regarding resource allocation and use.

CHAPTER III

IRRIGATION SYSTEMS AND PLANNING PARAMETERS

Water resources systems planning is a prerequisite to the actual design and construction phases of a project. It is in the planning phase that alternative systems are reviewed and evaluated for potential use. System costs and initial designs are necessary for proper systems evaluation, although intricate and detailed designs are not normally required in selection of alternative systems.

Design of new irrigation systems or rehabilitation planning of existing systems requires the consideration of many facets not considered when older systems were designed. In addition to the environmental impacts of a proposed project, the safety, esthetics, and projected future growth patterns of urban areas must be considered. Any system which meets these requirements should also have a favorable benefit-cost ratio. To evaluate a proposed system economically it is necessary to estimate the annual costs of the system, including construction and repayment costs, water charges, energy costs, operation and maintenance (O & M) costs, and other social costs.

Irrigation Systems Description

Most irrigation systems are normally divided into two distinct subsystems concerning ownership and management. Distribution (conveyance) systems are often owned and operated by groups of individuals, whereas application (on-farm) systems are normally privately owned by a single investor. Distribution systems are used for conveyance and delivery of water to farms from reservoirs or rivers in amounts sufficient for optimum crop growth. They can be of many types, sizes, and shapes.

Irrigation distribution systems

The most widely used irrigation conveyance system uses unlined open channels. Water is transported from the source and distributed through the irrigation project by a network of unlined canals and laterals. The water passes from the canals and laterals to farm lands through turnout gates. Unlined systems can be improved by lining canals and laterals with concrete, shotcrete, clay membranes, or other means to reduce seepage.

Another type of distribution system is the closed conduit system. A low pressure gravity pipe system delivers water through a network of pipes due to the force of gravity, at pressure less than 20 feet of head.

In a fully pressurized pipe system, water is delivered at pressures necessary for the operation of sprinklers. Pressure is usually provided by pumps, although some locations may have a topographic feature that will provide sufficient pressure by gravity.

It is possible to have a mixture of open channel and closed conduit or pipe systems existing together within a particular irrigation district. Often the large canals are open channels while the laterals are pipe, although open channel systems may have closed conduit sections for purposes of efficiency or safety, or due to topographical constraints.

Each particular type of distribution system may have several advantages and disadvantages. The open channel unlined system is usually the least expensive type to construct, although the disadvantages of this system include seepage losses, high weed control costs, and evaporation losses. Canals and laterals require large rights-of-way and usually run on the contour, often cutting fields into irregular shapes.

Lined canal systems are more costly to construct than the unlined systems, but they do provide some advantages. Seepage is minimized, canal size is reduced, and there are fewer weed control problems on the lined systems than on the unlined systems. Lined canals still require rights-of-way and evaporation is decreased very little. Frost heave may be a problem with lined canals in colder climates when placed in inadequately drained soils.

Low pressure gravity systems are usually more costly to construct than lined open channels. Some of the advantages of the gravity pipe system are nearly complete elimination of seepage, evaporation losses, and weed control problems. Rights-of-way may be farmed, and the safety and general appearance of the project are improved. The total system length is often greatly reduced by using more direct routes.

The high pressure pipe system provides all the advantages of the low pressure pipe system and also provides sprinkler pressure at the farm turnout. As sprinkler systems are normally more efficient than surface methods, the total amount of water required and the system capacity are reduced.

Irrigation application systems

On-farm application systems are normally grouped into gravity and pressurized systems. Gravity systems encompass surface and subirrigation systems and include conventional methods of furrow and border irrigation, gated pipe, and buried lateral sets. Water is delivered to the farm turnouts via nonpressurized conveyance systems, and remains nonpressurized during the irrigation process. Gravity systems normally have lower irrigation efficiencies than most properly designed and operated sprinkler systems, although some well designed border systems may achieve application efficiencies of over 80 percent (SCS, 1974; Jensen and Howe, 1965).

Pressurized application systems include all sprinkler system designs and also pressurized trickle or spray nozzles. Water may be delivered to the farm under pressure, or may be pressurized from a gravity conveyance system or groundwater well through the use of an on-farm pumping station. In some types of low pressure trickle systems, elevation differentials on the farm are sufficient for proper operation.

Modeling Procedures

Four major cost routines are used in the optimization procedure to determine capacities of conveyance and application systems, evaluate system efficiencies, and estimate the annual cost of owning, operating, and maintaining each system evaluated. These routines provide system statistics for lined and unlined canals, pressurized and gravity pipe, on-farm application systems, and pumping plants and power costs. Annual system costs are used so that valid comparisons among alternative system components can be made regardless of individual service life expectancies. Costs are adjusted to a common point in time to compensate for inflationary trends.

Irrigation efficiencies

Application, distribution, and conveyance efficiencies are used in this modelling procedure to describe the adequacy of system components in the utilization of irrigation water. An irrigation systems's efficiency is a measure of the effectiveness of the system in supplying the water requirements of irrigated crops. Israelsen and Hansen (1962) have described water-related efficiencies that are useful for irrigation systems planning. These efficiencies listed in equation form are:

1. Water-conveyance efficiency, E_c

$$E_c = 100 \frac{W_o}{W_i} \tag{3.1}$$

where W_o = water delivered by a distribution system,

and W_i = water input to a distribution system.

2. Water-application efficiency, E_a

$$E_a = 100 \frac{W_s}{W_o} \tag{3.2}$$

where W_s = water stored in the root zone during irrigation,

and W_o = water delivered to the farm.

3. Water-distribution efficiency, E_d

$$E_d = 100 \{1 - \frac{y}{d}\} \qquad (3.3)$$

where y = average numerical deviation in depth of water stored from average depth stored during irrigation, and

d = average depth of water stored during irrigation.

It may be noted that the value for E_d in Equation 3.3 is the same as the uniformity coefficient developed by Christiansen (1942).

The ability of a distribution system to deliver a certain proportion of the water that enters the system is described by Equation 3.1. Once the water is delivered to the farm, the water-application efficiency is used to describe the quantity of delivered water which ends up in the root zone of the crop being irrigated. While a high precentage of the water delivered may reside in the crop root zone, enabling a high E_a value, the distribution of water within the area of a field may be very poor, resulting in a low-water-distribution efficiency. Variations in application and distribution-efficiencies are illustrated in Figure 1. It is most often desirable that irrigation systems be designed so that high values of both E_a and E_d are attained thus assuring uniform application with minimal waste, although in some instances, leaching requirements or groundwater recharge are considered as beneficial uses of water even though this water is not used consumptively by plants.

The "project irrigation efficiency" of a system is defined in this study as the amount of water consumptively used by irrigated crops divided by the amount of water diverted into the system. This term is set equal to $(E_c \times E_a)/100$.

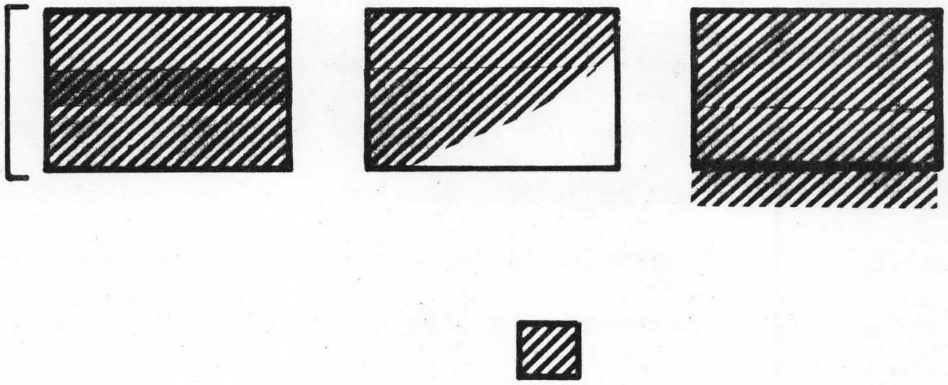


Figure 1. Illustrations of water-application and distribution efficiencies.

System configuration

To more readily and accurately design irrigation systems within a predefined study area, it is advantageous to divide the area of study into small land areas depicting system conveyance service areas. Service area selection should be based on geographic location, farm and field sizes, and cropping practices. The conveyance system serving the entire study area should be subsectioned to account for the dendritic nature of the conveyance system and also to enable the planner greater freedom in applying alternative design techniques to those subsections encompassing varying terrain, difficult soil types or rock outcroppings, or passing near population centers.

In the optimization procedure, service areas and conveyance sections are normally chosen and sized so that each component section or reach of the conveyance system will supply irrigation water to one service area and to any adjacent downstream conveyance section(s). Figure 2 is a schematic diagram of an irrigation system in which conveyance system sections and service areas are shown. Water is supplied to each area from the conveyance section having the same number.

Because each conveyance section is designed independent of other sections, the estimated cost range of a section is unique and accurate for that section only. Lengths of planning sections should be chosen so that a reduction in channel or pipe size along the section due to diminishing flow is unnecessary.

The sizes and shapes of service areas are determined primarily by the length and number of conveyance system sections and by the overall system size. In a gravity system, farm land constituting a service area must lie at a lower elevation than the conveyance section supplying irrigation water and should lie adjacent to the conveyance section. If a service area is separated from the main conveyance system by other land areas, an additional conveyance section should be added to the system planning configuration to supply the service area. As most irrigation distribution systems are dendritic in nature, lateral sections which branch from the main conveyance route are often required to model accurately the overall system design (Figure 2).

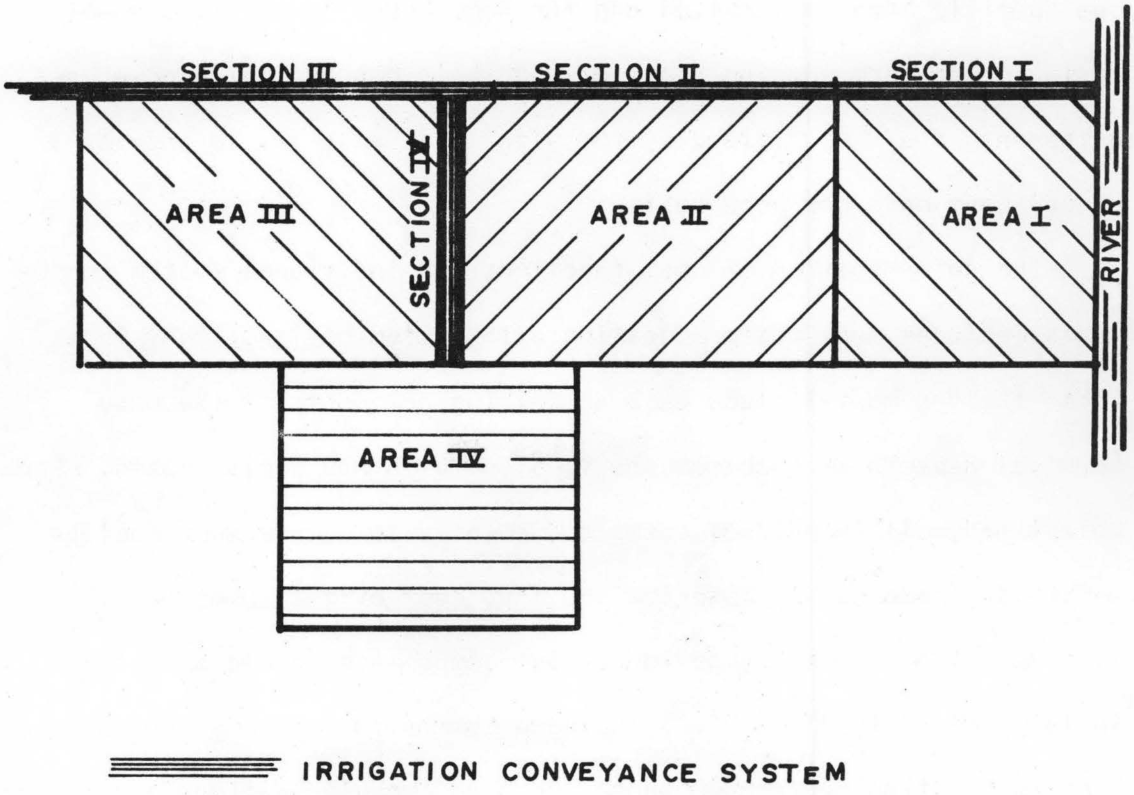


Figure 2. Schematic of an irrigation conveyance system including selected service areas.

Cost functions

Annual ownership costs of systems are calculated using attainable interest rates, component life expectancies, and initial costs at a common point in time. Annual costs for on-farm systems are computed on a per acre basis for selected farm sizes, soil types, and cropping patterns. Pumping plants are sized and plant and power costs are estimated for the specific area(s) serviced and for required flow rates. Annual costs for on-farm pumping stations and their corresponding power requirements are then divided by the size of area served to provide an annual cost on a per acre basis.

The determination of cost functions for individual system components includes many factors dealing with system costs of many types. These factors must include data describing net costs of the many physical aspects of each component, along with any social costs. Once determined, all individual costs for each system component must be combined to adequately describe the true cost of that component.

Annual costs of irrigation system components should be defined in terms of system parameters that are common to all component parts. For distribution system components such as conduit sections and structures, the system parameter of greatest importance is the flow rate of water that the component can convey or control. System components must have equal capacity at all points where water is transmitted from one component to another. Thus, the necessary size and cost of each control or conveyance structure can often be expressed as a function of the maximum design flow rate of the conveyance section.

There is often a minimum specified cost associated with distribution system components. This cost may result from fixed operation and maintenance cost or from minimum construction costs. Allowing for fixed costs regardless of the component size, the cost function for a conveyance or pumping system component in equation form may be expressed as:

$$\text{Annual cost} = a + b\,Q \qquad (3.4)$$

Where:

a = annual fixed cost
b = annual cost per unit flow rate, and
Q = maximum flow rate

The annual cost for an application system is best expressed on a per acre basis due to factors other than system capacity that affect the cost of applying water. Some of the factors include variations in crops irrigated, soil types, hours of operation per day, and other cultural practices. If the annual cost per acre, c, is known for an application system supplying water to N acres, then

$$\text{Annual cost} = cN \qquad (3.5)$$

Costs associated with irrigation systems must have common characteristics so that various alternative components can be compared. For a given interest rate, future sums of money can be expressed in an equivalent series of uniform payments by using the proper uniform-series sinking-fund factor, and a present amount of money can likewise be expressed as a similar uniform series by using the proper capital-recovery factor. The two factors mentioned allow capital investment costs associated with systems to be expressed on the basis of equivalent annual costs, and these equivalent annual costs can therefore be added directly to the various other annual costs associated with the system.

System labor and energy demands such as irrigator wages and pumping plant electrical charges are normally purchased within a specific time of actual use within the system, and are thus continuously paid throughout a system's service life. To enable system planners or owners to estimate overall system annual costs, labor and energy costs should be escalated to a value representing an equivalent annualized cost of the purchased services over the system life. The equivalent annualizing cost factor is based upon current interest rates, the current or projected escalation rate of the particular service, and total system life (Pearson, 1974; Keller, 1976).

If each analytical component cost function in an irrigation system can be expressed as a linear equation, then the individual linear cost functions can be added to form a composite linear cost function for the entire system. Simple linear functions are used to describe total annual system costs of conveyance sections and application systems in this model for systems optimization. Since technical relationships of systems are defined by a set of linear constraint equations, linear programming is used to determine the minimum cost of the complete system. Linear programming, in essence, is a mathematical routine used to solve simultaneous equations of the first degree, where the number of unknown variables exceeds the number of equations. Solution of the system variables is complete subject to minimization of some objective function (cost equation) describing the costs associated with system variables. It is normally necessary to use a non-sequential decision process such as linear programming to optimize an irrigation system design for minimum cost because of the numerous interactions of all possible components and the possible recycling of surface runoff and deep percolation within the system.

Data requirements

To successfully model any irrigation or water resources system, a planner must have physical and economic data representative of the planning area available to him. Available data must include descriptions and characteristics of area soil types including profiles, geographic locations, and water interaction characteristics. Topographical features of the area are necessary for conveyance system routing, service area selection, and application system design and evaluation. Local energy availability and rate schedules as well as labor supplies and costs must be known to select feasible and reasonable system alternatives for the specific area. Political boundaries depicting land ownership and field and farm sizes are useful in sprinkler system and pumping plant design and selection, and may serve as aids in determining feasible surface system run lengths. Also necessary in systems planning are the magnitude and type of water rights pertaining to the planning area, and knowledge of the availability and dependability of the water source.

The systems planner must have access to fairly detailed geological and hydrologic information concerning the planning region to estimate quantities of rock excavation, suitability of soils for embankment and foundation design, groundwater elevations and soil drainage characteristics, and flood information to be used in design of structures.

Materials and construction costs should be available for the local area of study to evaluate regional cost differences due to variable transportation costs of labor, machinery, and materials.

Data collection

The quantity and quality of data required for accurate systems modeling and planning are rarely available to a systems planner from one source. Data are normally assimilated from multiple local and regional sources and many times require some type of manipulative procedure to transform them into a format useable by the planner.

County soil maps and soils descriptions published by the United States Department of Agriculture-Soil Conservation Service (SCS) and state universities can serve as good sources of soil type locations and areas, and often contain needed information on soil profiles and water retention and conveyance characteristics. The SCS maps also give notice as to existing canal routes and locations, as well as field sizes and shapes. Additional soils and political information can be made available from county atlases and plat books published by county soil and water conservation districts and also from aerial photographs produced by private or governmental agencies. Crop survey and potential yield information can also be obtained from university and SCS sources.

Topographical features and land slopes are available from topographical maps furnished by the U. S. Geological Survey, or, in some areas, by the U. S. Bureau of Reclamation. Local surveys may be valuable in checking topographical maps or for supplying missing details.

Accurate information on irrigation application system efficiencies and runoff and deep percolation rates is often difficult to obtain, necessitating the use of field efficiency tests and soil sampling. Flow rate measurements on local canals or sampling of bed substrate and groundwater table elevations often can give information on channel seepage rates and operational losses. Knowledge of consumptive water use requirements of local crops and historical district water diversion records can be used to estimate present system operation efficiencies.

The quality of the irrigation water supply can be obtained through consultation with local users and by sampling of the water source. Data on well depths and drilling costs are normally available from local drillers or from well logs maintained by state agencies.

Information on water rights and dependability of the water source can be obtained from the state agency in charge of water rights registration and administration and by consultation with local area users.

Unit costs and local availability of required system components should be verified by area supply companies and dealers, and construction costs can be found by contacting area construction companies and from bid abstracts for similar system designs. Prices obtained from past bid abstracts should be updated to compensate for inflation or differences in location, topography, and quality of materials by consulting with area companies or by using construction cost indices published by the United States Bureau of Reclamation and Engineering News Record (see reference).

Required accuracy of planning data

All data used in the planning procedure must be valid and accurate. Accurate topographical characteristics of the planning area are essential in determining feasible canal and pipeline routes, as well as in measuring field slopes. Existing systems, soils, and cropping patterns should be accurately inventoried to provide the planner with a good data base.

Total accuracy of data concerning soil boundaries and properties is rarely achieved by a planner due to limitations on time and finances. In many planning situations, small areas of varying soil types and mixtures must be grouped into larger families of soils having similar characteristics, profiles, and locations. Soil infiltration rates, profile depths, water holding characteristics, and field slopes are generalized for similar soils having slight variations in properties caused by farming practices, crop rotations, and varying terrain. The resultant properties associated with these generalized soil families should, however, describe each individual soil type such that the systems planner can produce accurate application system designs and evaluations.

Knowledge of current construction and materials costs is important in the estimation of the total field cost of the irrigation system. Total system costs must be conservative to insure adequate funding of the system if it should be constructed, and yet must be accurate enough to provide the owner(s) with realistic costs of alternative systems, including construction and operation costs.

CHAPTER IV

STUDY AREA DESCRIPTION

The lower Teton River flood plain begins at the confluence of the Henry's Fork of the Snake River with the North and South Forks of the Teton River and extends 16 miles northeast, upstream to the mouth of the Teton River Canyon 5 miles northeast of Teton (Figure 3). The Teton flood plain averages 4 miles in width and was first brought under irrigation in the early 1880's. Roughly 25,000 acres of the Teton flood plain are irrigated with water from the Teton River. The northern areas along the flood plain receive water via canals from the Henry's Fork of the Snake River. As of 1974, water rights appropriated from the lower Teton River totaled 2038 cfs.

The topography of the Teton flood plain is markedly flat, with an average slope of .002 ft/ft. The soils are mostly thin layers of well developed sand and silt loams overlying coarse sand and gravel. Major crops raised in the region are potatoes, grain, alfalfa hay, and pasture for forage and grazing.

Present Regional Irrigation System

Currently all major water distribution in the Teton area is accomplished through the use of unlined canals, most of which were constructed before the turn of the century. Early water control and diversion structures along the canals were constructed of timber.

More recent improvements of the canal systems in the Teton flood plain area have resulted in concrete and steel structures replacing

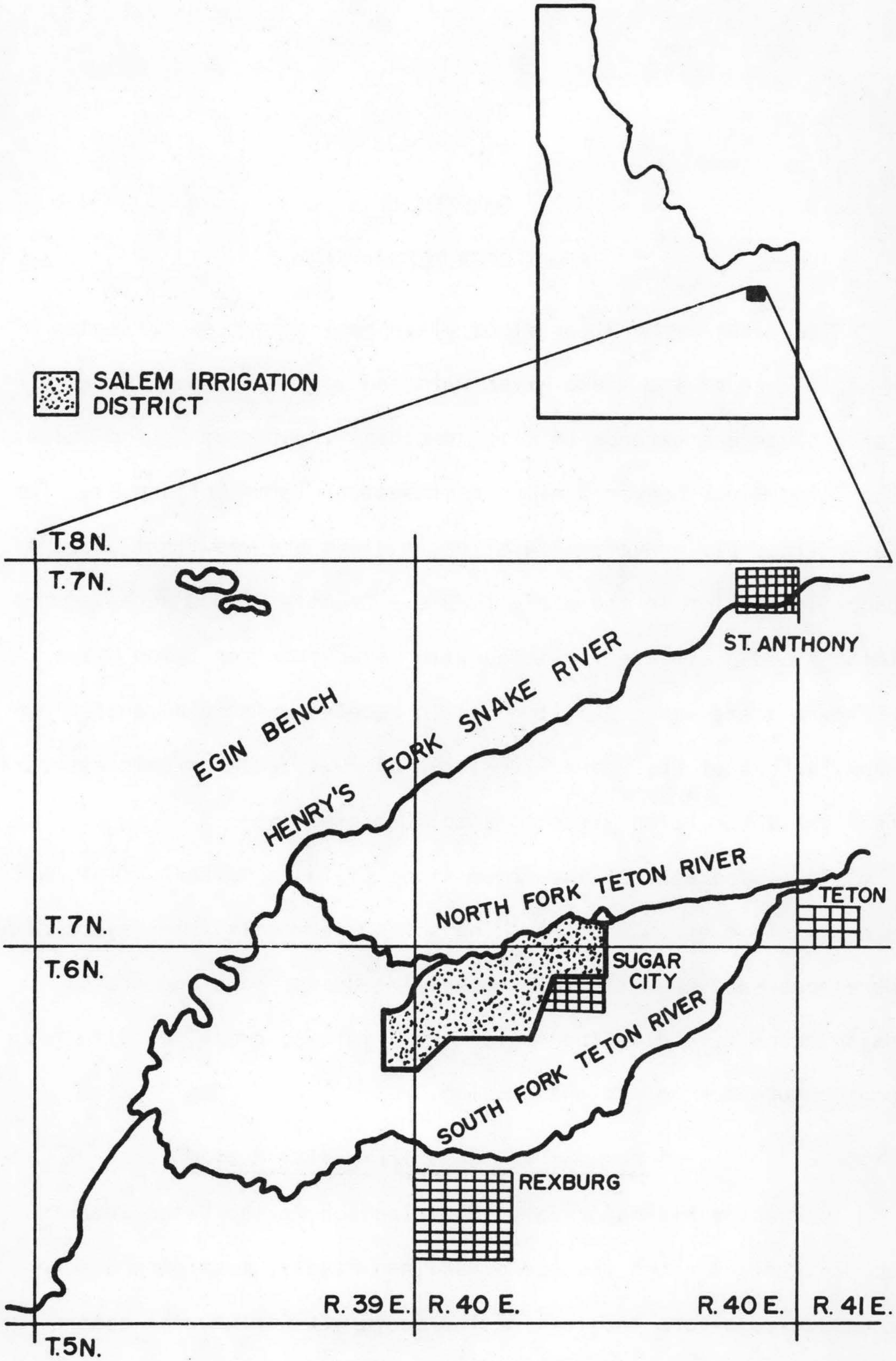


Figure 3. Location map of Teton River flood plain and study area.

many major timber structures. However, a large percentage of wooden water control structures and diversion turnouts remain in service today.

Traditionally, about 20,000 acres of farmland lying in the western half of the Teton flood plain have been irrigated by subirrigation, where the perched groundwater in the area is elevated toward the bottom of the crop root zone by artificial groundwater recharge. (U. S. Department of Interior, 1977).

Although this method of irrigation may annually require over 12 acre feet of water per acre to maintain the groundwater level at optimal levels for crop use, it generally works well in areas of even, gently-sloping terrain having naturally-occurring perched water bodies within 10-40 feet of the ground surface. Land areas lying in the eastern, higher portion of the Teton flood plain have traditionally been irrigated with surface systems or high pressure sprinkler systems.

Effects of the Teton Dam flood

In 1972 construction began on the Teton Dam located in the Teton River Canyon 5 miles upstream from the lower Teton flood plain. The resulting reservoir was planned mainly for the purpose of irrigation water supply with additional benefits of flood control, power generation and recreation.

On June 5, 1976, the collapse of the newly constructed Teton Dam resulted in a major, catastrophic flood of the Teton flood plain, the lower portion of the Henry's Fork of the Snake River flood plain, and low lying areas along the upper Snake River above the American Falls

Reservoir. Livestock, crops, machinery, and real estate losses were great, and much of the area's farmland was critically disturbed or destroyed by the flooding water. Canals were either deeply scoured or completely filled in by deposited sand and gravel and other debris. Damage to, and dislocation of, irrigation flow control and diversion structures along the canals was severe.

Restoration of the damaged canal systems and structures was immediately undertaken by the United States Bureau of Reclamation to renew the distribution of irrigation water to areas of the valley which had escaped extensive crop destruction. The restoration policy of the Bureau was to reshape the canals to their original dimensions and to rebuild or replace all canal structures with structures of size and type similar to those existing before the flood. This particular policy did succeed in restoring the irrigation distribution systems of the Teton flood area to their preflood status, thus insuring adequate functioning of all canal systems. The restoration resulted in little improvement, however, in canal routes, duplication of canal service areas, or types of flow control structures. Most preflood timber structures were replaced with timber, often costing as much or more than concrete or metal equivalents having a much longer or more dependable service life.

Many of the previously subirrigated fields in the Teton flood area received extensive soil displacement due to the flood, and in some areas large quantities of topsoil were eroded from the soil profile.

This unevenness of the ground surface has inhibited continued subirrigation on some fields, due to drowning out of crops lying in the low areas. Thus, without extensive land leveling operations, these fields can be irrigated only with sprinkler systems.

Most sprinkler systems installed in the Teton flood area have been designed or reviewed by the USDA Soil Conservation Service, and partial funding of the systems has been appropriated through the USDA Agricultural Stabilization and Conservation Service. One major conflict realized between the continued use of subirrigation systems and the use of new sprinkler systems in the Teton area is that of inadequate groundwater recharge by the sprinkler systems in areas lying adjacent to subirrigated fields (U. S. Department of Interior, 1977). A lowered water table below sprinkler irrigated fields has resulted, in many instances, in a lowering of the elevated water table in adjacent subirrigated fields, due to an increased gradient along the water table surface. In some cases, subirrigators have been unable to offset the increased groundwater deficit below their fields with an increased water supply and, as a result, have realized partial or total crop failures. Due to the complexity involved in manipulating groundwater elevations beneath sprinkler irrigated fields, irrigated farms in the previously subirrigated areas may be forced either to switch entirely to a combination of surface systems and pressurized sprinkler irrigation systems, or the entire area previously subirrigated may have to revert to total subirrigation.

A thorough evaluation of existing irrigation structures and canal systems and alternative system designs and requirements by governmental agencies prior to the flood restoration activity could possibly have resulted in much more efficient and economical irrigation systems throughout the Teton flood area, and may have been able to resolve some of the postflood conflicts between the various on-farm application systems. An evaluation of this type was not possible, however, because of lack of adequate planning time and lack of a rapid and accurate method of planning for irrigation systems rehabilitation.

Salem Irrigation District

The irrigation district selected for evaluation and modeling is the land area served by the Salem Island Canal Company. This area is located in Madison County, Idaho, 3 miles north of the city of Rexburg and is approximately 1.5 miles wide and 3 miles long (Figure 4). A total of 3170 acres of the district is irrigated. The characteristics of the Salem Irrigation District are representative of the majority of irrigation districts located on the Teton flood plain.

Irrigation conveyance system

The Salem Canal, supplied with water from the Teton River by the Teton Island Feeder, conveys water at an average flow rate of 240 cfs to the study area during the peak irrigation season from June through September. The water right of 240 cfs owned by the Salem Island Canal Company is dated June 1, 1885. A schematic showing the location of the Salem Canal and Salem Irrigation District is listed in Figure 4.

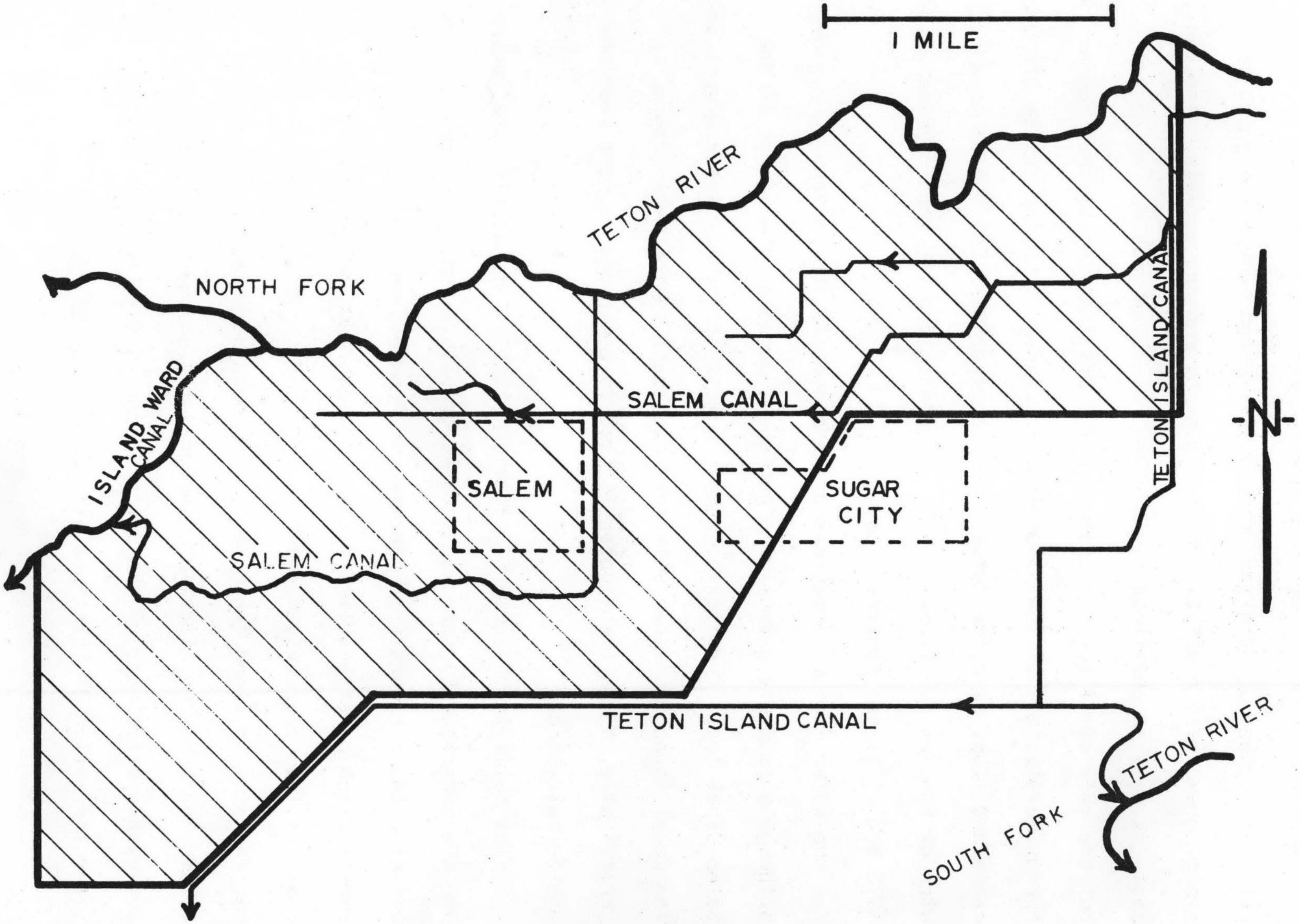


Figure 4. Salem Irrigation District, Sugar City, Idaho

The main distribution canal and laterals of the study area were originally constructed along property lines and natural contours to minimize excavation as all work was done by men and animals. Improvements as well as postflood restoration have been made on the system, but the main canal follows basically the original established route. Approximately half of the diversion structures along the system are concrete and steel circular gates with the other half being made of wood. Nine of the ten functional checks situated along the canal system as of 1978 are of timber construction.

No water measuring devices are employed in the conveyance system, although a concrete diversion structure located at the source of the Salem Canal could function as a weir. Most of the maintenance work on the canal is accomplished with farm equipment by the water users. Periodically, a small bulldozer is used to clean and reshape sections of the main canal.

The soils in the Salem Irrigation District are usually shallow, and are underlain by sands and coarse gravels. Low conveyance efficiencies for canals in the area are common, as the bottoms of the canals often penetrate into highly pervious soil profiles. If the sediment load of conveyed water is light, deposition of a semipervious barrier of silt along the canal bottom does not occur, and substantial volumes of water may seep into the gravelly and sandy subsoils. Conveyance efficiency of the unlined canal system operated in the Salem Irrigation District was estimated to be 83 percent.

Canal seepage in some areas may be beneficial if subirrigation adjacent to the canal is practiced. However, seepage can cause water logging of soils and flooding in low lying areas. Canal seepage constitutues an economic loss if the conveyed water has been pumped from lower elevations, or if the total volume of the water supply to an area is necessary to fulfill crop consumptive use requirements.

Soil types

The major soil types of the study area are Annis silty clay loam, Withers clay loam, Blackfoot and Bannock loams, Labenzo silt loam, Hayeston Variant coarse sandy loam, and Haplaquolls miscellaneous. The Blackfoot and Bannock soils have been studied as one soil type and the Labenzo, Hayeston, and Haplaquolls soils have also been combined for study purposes. A general soils map depicting the location of these soil types is shown in Figure 5. Descriptions of these soil types are listed in Appendix A.

Most of the soils of the study area are medium to coarse textured with relatively high water intake rates. Surface irrigation of some of these soils can result in extremely low distribution and application efficiencies when run lengths are long. Galinato (1974) has reported field efficiencies in the 20-50 percent range for furrow and border systems operated on some soils of the upper Snake Region.

Farm characteristics

Crops presently grown in the study area are potatoes, grain, alfalfa for hay, and pasture. The irrigation system used to apply

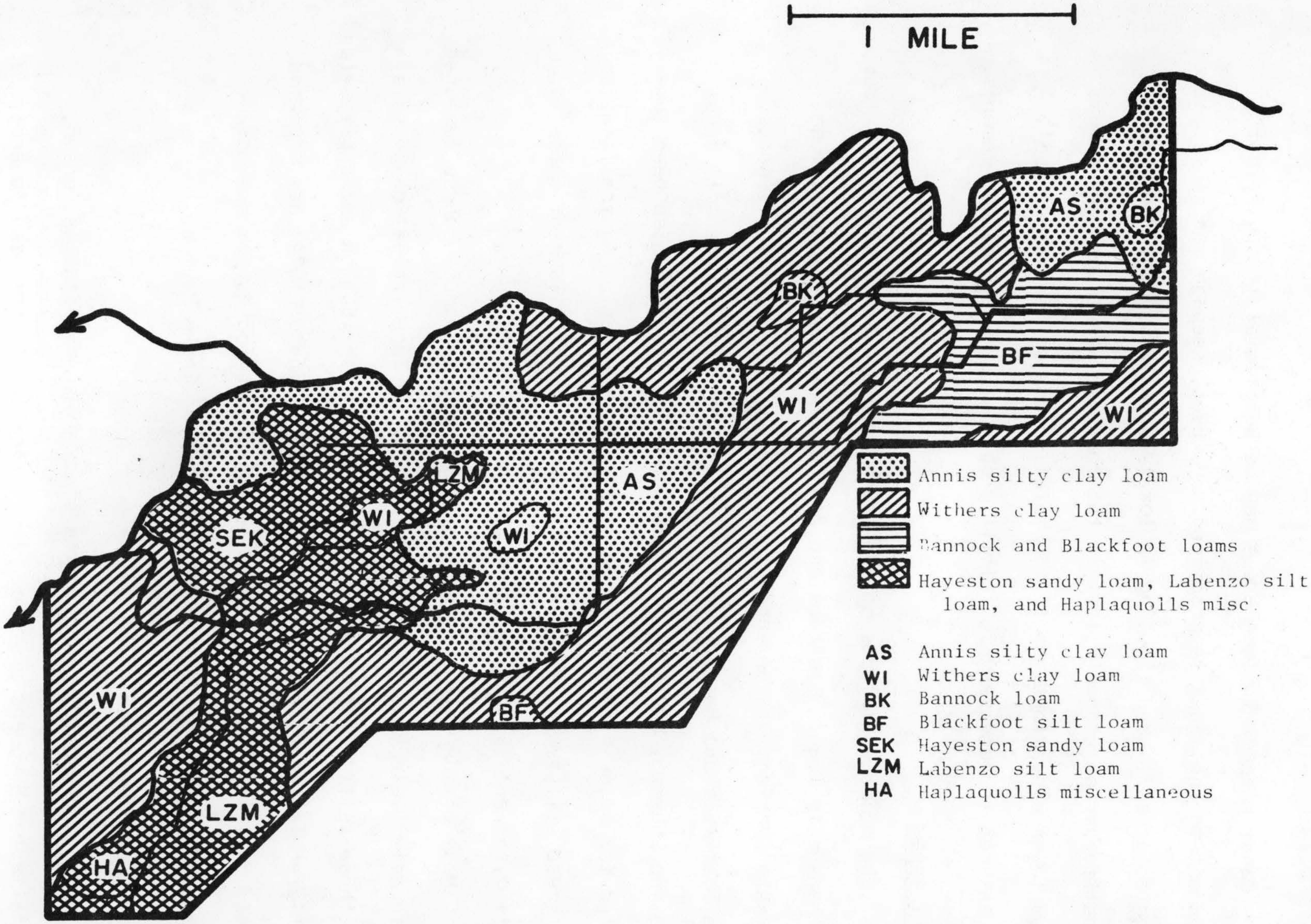


Figure 5. General soils map showing selected soil type groups for application systems design, Salem Irrigation District.

water to these crops historically has been subirrigation, although hand-move and sideroll sprinkler systems have been introduced recently on some farms.

Field shapes and dimensions and cropping patterns for the study area have been obtained from reconnaissance observations and from large scale aerial photographs of the Salem and Sugar City areas.

Field lengths and farm sizes are variable in the Salem Irrigation District. Many small acreages exist in the Salem area and small tracts of land owned by absentee owners are common. Field lengths range from 240 feet to 2640 feet with a mean length of 900 feet. The number of land owners in the study area, aside from owners of small acreages (less than 10 acres), is 30. Irrigable fields total 140 in number.

The topography of the study area is uniform, with an average slope of 0.002 ft/ft, although direction of the slope is variable.

Selection of System Planning Parameters

The soils of the study area were grouped into four major types, as shown in Figure 5, for ease of study and planning. Land areas in each soil type have similar average farm and field sizes, infiltration and water retention characteristics, cropping patterns, and geographical locations. A summary of farm and field sizes and infiltration rates of the soil types is given in Table 1. Crop acreages in each soil type and evapotranspiration rates (ET') at the peak period of consumptive use are listed in Table 2. ET requirements of crops in the study area were selected from data in University of Idaho Agricultural Experiment

Station Bulletin 516 (Sutter and Corey, 1970) and SCS Irrigation Guide for Southern and Southeastern Idaho (1970). Maximum ET rates of the alfalfa and grain crops may be greater than those shown in Table 2 Pair et al., 1973).

The farm and field areas in Table 1 represent average ownership conditions of each soil type. Design field dimensions were chosen so that system costs and efficiencies evaluated for these dimensions can be used to represent all fields of the particular soil type in a sufficiently accurate manner. Small acreages and tracts used for lawn or garden purposes were not included in the process of field dimension selection and system evaluation, as irrigation costs and efficiencies related to these areas are highly variable and are dependent upon management practices of the tract owner.

Conveyance system parameter selection

The water conveyance system route used for planning and evaluation of gravity systems is shown in Figure 6. The canal route shown is that of the present unlined Salem Canal and is considered as a possible system alternative. Since this route follows property lines and roads for much of its length and has fairly straight and uniformly sloped sections, it was chosen to represent the proposed routes of lined channel and gravity pipe systems, also. The lined channel alternative would entail reshaping and lining of the existing system and updating of water control and diversion structures. Pipe would be lain along or below the present unlined channel bottom for the gravity pipe alternative,

Table 1. Average farm and field sizes and infiltration rates of major soil types within the Salem Irrigation District.

	Annis[1]	Withers[2]	Blackfoot[3]	Hayeston[4]
Average farm size				
(acres)	80	120	100	160
(hectares)	32	48	40	64
Average field size				
(acres)	23	30	23	28
(hectares)	9	12	9	11
Planned field lengths				
(feet)	1100	1200	1400	1100
(meters)	335	365	425	335
Planned field widths				
(feet)	900	1100	700	1100
(meters)	275	335	215	335
Average infiltration rate				
(in/hr)	0.6-1.5	0.6-1.5	0.6-1.0	2.0
(mm/hr)	15. -40.	15. -40.	12. -25.	50.

[1] Annis silty clay loam

[2] Withers clay loam

[3] Bannock loam and Blackfoot loam

[4] Hayeston Variant coarse sandy loam, Labenzo silt loam and Haplaquolls miscellaneous

Table 2. A summary of crop percentages on each soil and maximum ET rates within the Salem Irrigation District

	Potatoes		Grain		Alfalfa		Pasture	
	Acres	%	Acres	%	Acres	%	Acres	%
Annis	262	30	306	35	175	20	131	15
Withers	413	30	482	35	276	20	207	15
Bannock and Blackfoot	85	30	141	50	56	20		
Hayeston, Labenzo, and Haplaquolls	126	20	252	40	126	20	126	20
Maximum ET (in/day)	.28		.20		.23		.19	

and the channel would be backfilled and leveled to the elevation of the surrounding terrain. The unlined channel sections 5, 6, and 7, as shown in Figure 6, follow topographical contours rather than land boundaries. The lined channel and gravity pipe alternative sections follow this same route, although these alternative systems could be constructed with more direct and straight sections at little or no extra cost.

As can be seen in Figure 6, junctions of the various gravity pipe and channel sections lie at essentially the same points. By thus choosing the locations of section junctions, the possibility exists for joining dissimilar but compatible components at various points within the system.

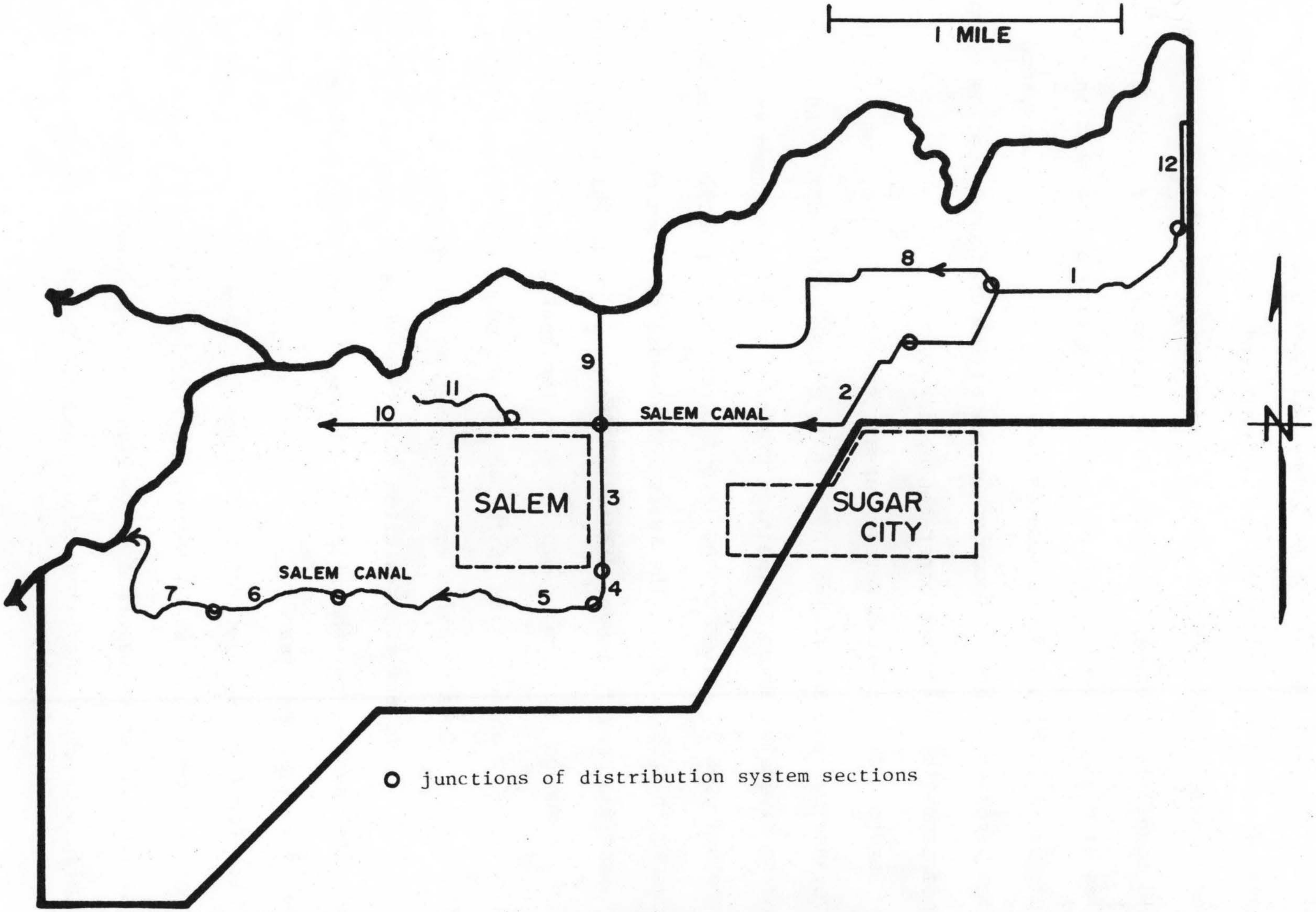


Figure 6. Gravity distribution system, Salem Irrigation District.

The pressure pipeline route shown in Figure 7 was chosen for minimum length of both the main system and laterals and to supply high pressure water to necessary locations. The high pressure route follows roads and field boundaries whenever feasible, to keep disturbance of productive fields at minimal levels. The fact that the pressure pipe section points shown in Figure 7 are located away from the gravity conveyance system junction points is inconsequential as the pressure pipeline system is not compatible with the other conveyance systems.

Section lengths and diversion areas (service areas) of the gravity conveyance systems are listed in Table 3, and section lengths and corresponding diversion areas of the high pressure system are shown in Table 4. The method used in selection and layout of conveyance sections has been discussed in Chapter III. The twelve conveyance sections chosen to represent the gravity conveyance system in the Salem Irrigation District are short enough that the assumption that the entire length of each section is of a uniform size in the design procedure will result in minimal error. Consideration was also given to selecting sections having fairly constant cross-section characteristics so that earth work costs involved in rehabilitation of the unlined canal sections could be defined more readily.

Section I for each alternative system, as shown in Figure 6 and 7, is that section through which the entire flow is conveyed to the rest of the system. Water is supplied to section I at the present point of diversion located on the Teton Island Feeder. Section 12 of the gravity

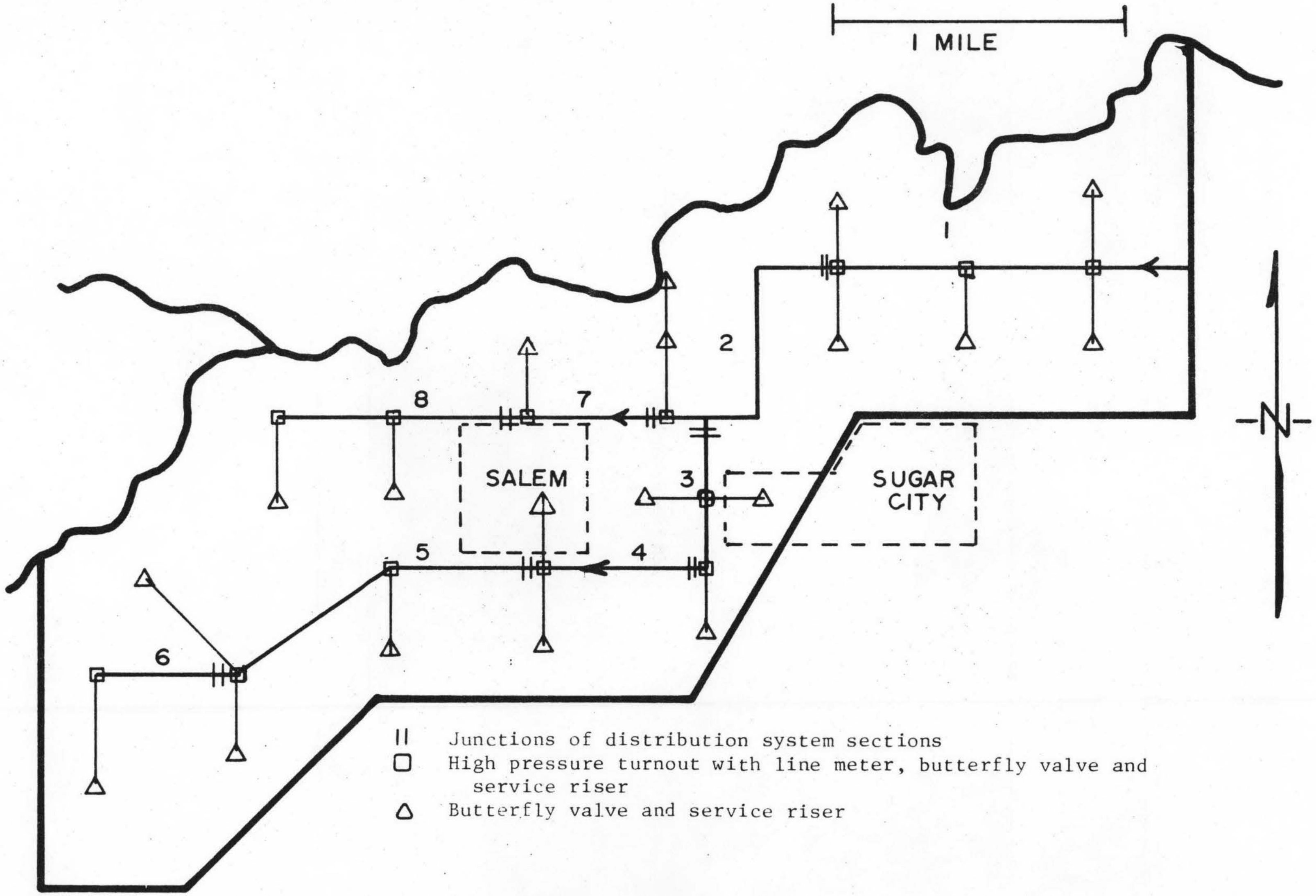


Figure 7. Route of proposed high pressure pipe system, Salem Irrigation District.

Table 3. Gravity conveyance system planning section lengths and diversion areas in the Salem Irrigation District.

Section	Length (feet)	Service area (acres)	Other sections served	Minimum design flow (cfs)	Maximum design flow (cfs)
1	6750	377	2,8	40	120
2	6490	400	3,9,10	30	90
3	2700	241	4	15	45
4	1040	135	5	9	36
5	5700	316	6	9	30
6	2800	102	7	4	16
7	2600	265		4	12
8	6750	402		5	17
9	2300	141		2	6
10	5500	319	11	6	20
11	3100	148		2	7
12		320	1		
Total	45730	3166			

Table 4. High pressure conveyance system planning section lengths and diversion areas in the Salem Irrigation District.

Section	Length (feet)	Service area (acres)	Other sections served	Minimum design flow (cfs)	Maximum design flow (cfs)
1	5060	666	2	27	60
2	8300	538	3,7	21	48
3	2725	343	4	10	24
4	2850	311	5	8	18
5	7150	504	6	5	12
6	2465	137		2	7
7	2725	205	8	6	12
8	5200	462		4	10
Total	36475	3166			

conveyance system was selected to represent a section of the Teton Island Feeder, as three turnouts on this section supply water to a small area of the Salem Irrigation District.

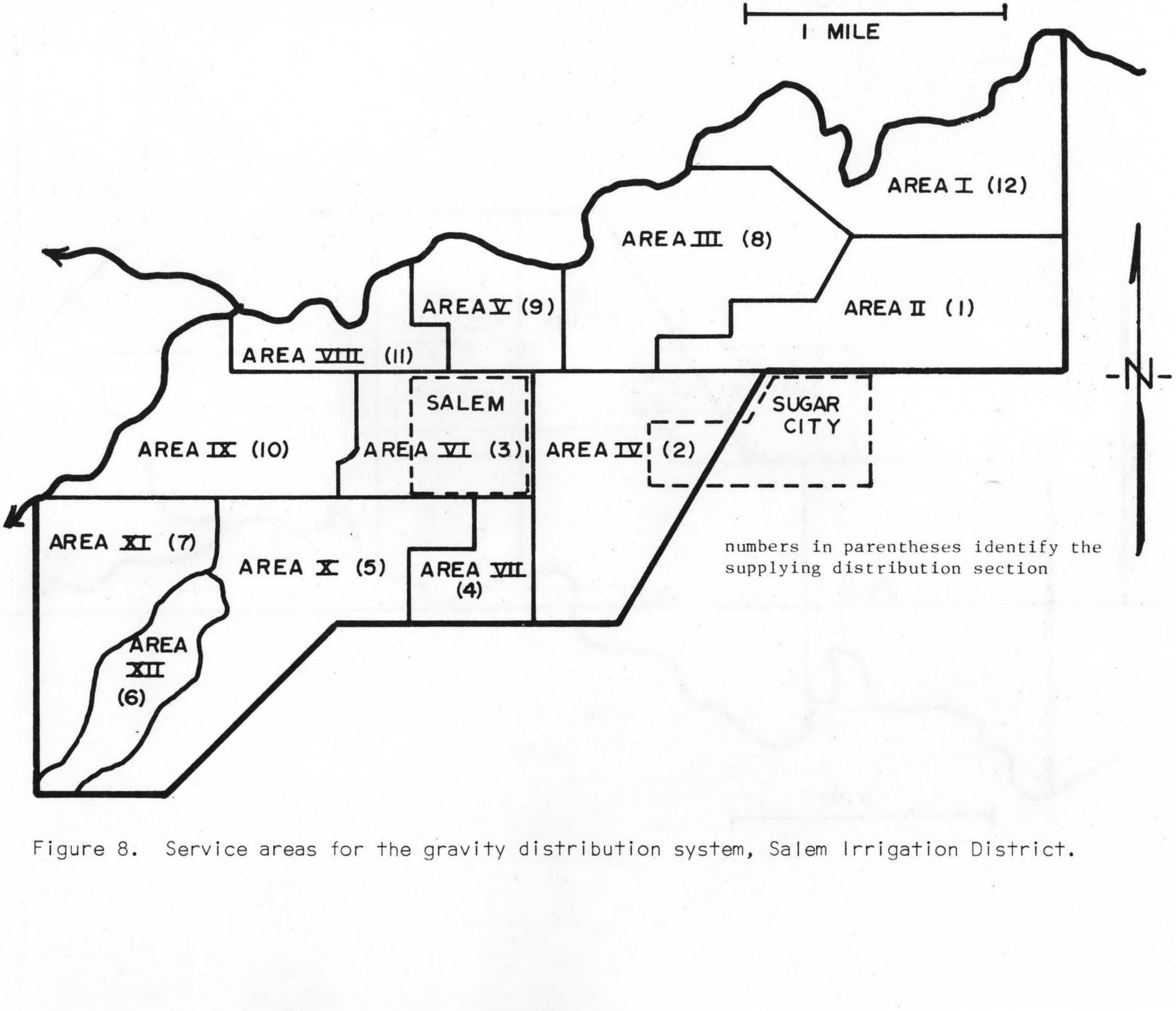
Service area selection

Each selected conveyance system section in the study area supplies water to a defined land area as well as to any conveyance sections located directly downstream. The land areas served by the gravity conveyance system can be seen in Figure 8, and the high pressure service areas are shown in Figure 9. Each service area in the gravity conveyance system is supplied through turnouts located along the supplying section. One requirement of a gravity service area is that all fields must lie at elevations below that of the supplying conveyance section. Small head ditches and laterals in a service area convey and distribute irrigation water to individual fields.

Service areas can be chosen independently of soil types and land uses. Their main purpose is to define the flow rates required in the conveyance system sections so that water can be adequately distributed throughout the irrigation system.

To accurately model the actual peak crop consumptive use and flow rate requirements of each service area, the relative areas of each soil type in a service area must be determined. Listed in Tables 5 and 6 is the areal distribution of each soil type in the service areas of the gravity conveyance system and high pressure pipe system. Percentages of each soil type lying in a particular service area are also listed.

Utilization of the aforementioned method of service area layout and soil type distribution technique will allow for application system planning on the basis of soil and farming characteristics, and will permit planning of distribution systems on the basis of topography, geology, and relative areal locations.



numbers in parentheses identify the supplying distribution section

Figure 8. Service areas for the gravity distribution system, Salem Irrigation District.

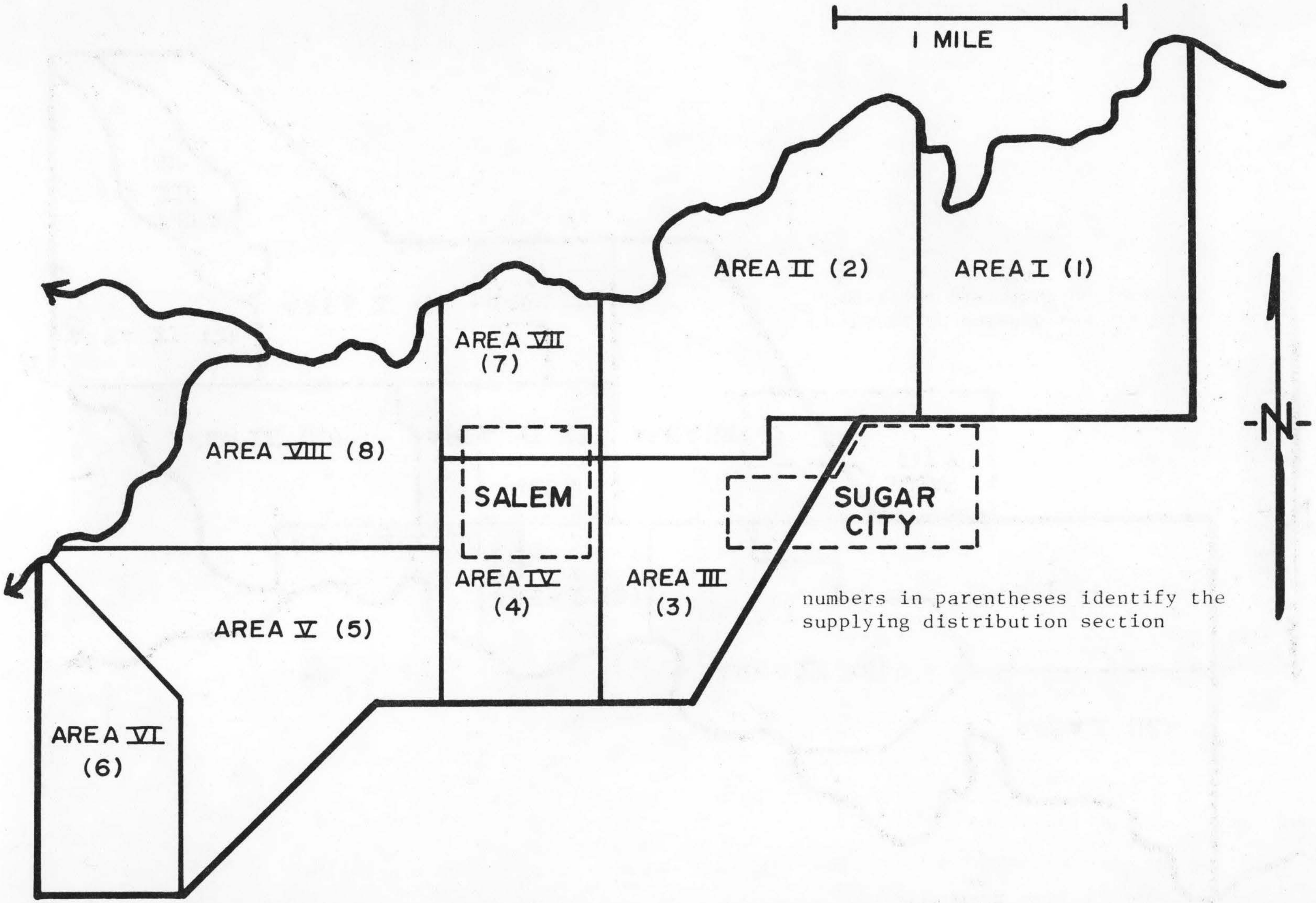


Figure 9. Service areas for the proposed high pressure pipe system, Salem Irrigation District.

Table 5. Soil type distribution in service areas supplied by gravity conveyance systems.

Service Area	Total Area (acres)	Annis[1] Acres	%	Withers[2] Acres	%	Blackfoot[3] Acres	%	Hayeston[4] Acres	%
I	320	124	14.2[5]	144	10.5	52	18.4	[6]	
II	377			147	10.7	230	81.6		
III	402	62	7.1	340	24.7				
IV	400	110	12.6	290	21.0				
V	141	66	7.5	75	5.4				
VI	241	208	23.7					33	5.2
VII	135	55	6.3	80	5.8				
VIII	148	148	16.9						
IX	319	53	6.0					266	42.2
X	316	50	5.7	62	4.5			204	32.4
XI	265			240	17.4			25	4.0
XII	102							102	16.2
Total	3166	876	100.0	1378	100.0	282	100.0	630	100.0

[1] Annis silty clay loam

[2] Withers clay loam

[3] Bannock loam and Blackfoot loam

[4] Hayeston Variant coarse sandy loam, Labenzo silt loam and Haplaquolls miscellaneous

[5] Percentage of soil type in unit = (acreage of soil type in unit/total acreage of soil type in Salem Irrigation District)

[6] A blank indicates the absence of a soil type in a service area

Table 6. Soil type distribution in service areas supplied by high pressure types.

Service Area	Total Area (acres)	Annis[1]		Withers[2]		Blackfoot[3]		Hayeston[4]	
		Acres	%	Acres	%	Acres	%	Acres	%
I	666[5]	184	21.0[5]	200	14.6	282	100.0		
II	538	87	09.9	451	32.8				
III	343	86	09.8	257	18.7				
IV	311	210	23.9	101	07.4				
V	504			226	16.5			278	43.8
VI	137			70	5.1			67	10.6
VII	205	137	15.6	68	05.0				
VIII	462	173	19.7					289	45.6
Total	3166	877	100.0	1373	100.0	282	100.0	634	100.0

[1] Annis sitly clay loam

[2] Withers clay loam

[3] Bannock loam and Blackfoot loam

[4] Hayeston Variant coarse sandy loam, Labenzo silt loam and Haplaquolls miscellaneous

[5] Percentage of soil type in unit = (acreage of soil type in unit/total acreage of soil type in Salem Irrigation District)

CHAPTER V

SYSTEMS COST ESTIMATION AND EVALUATION ROUTINES

The representation of physical and economic features and values in numerical terms can provide systems planners the capability of using various systems optimization techniques. These techniques can be used to fulfill all system requirements subject to any system constraints. In evaluation and comparison of alternative irrigation system plans, annual system costs and overall and individual component water-use efficiencies are normally used to rate each planning scheme. Although these two terms appear in this particular model in simple numercial form, there are many factors that must be included in their formulation.

Computer Programming Routines

Since many data forms and calculations are required to determine annual costs and efficiencies for most system components, four digital computer routines written in FORTRAN IV computer language are used in this modelling procedure. These routines, called APSYS, CANAL, PIPE, and PUMP, are used for the evaluation of application, open channel, pipe, and pumping systems, respectively. Each of these routines employs subroutines designed to compute costs and efficiencies for different types of system components. A synopsis of these routines is included in Table 7. All data, program calculations, and program solutions are currently expressed in English units of measurement.

All numerical data are input to the four cost routines with a FORTRAN subroutine entitled INPUT. This subroutine allows for free formatting of all data and also enables the programmer to document the input data listings with alphanumeric characters. Data need only be separated by blank spaces or commas, and all alphanumeric comments or labels are ignored. Continuation of data on multiple cards or card images is facilitated by ending a continued card with a comma. Data are passed from INPUT to the calling program via a one-dimensional array. A documented listing of subroutine INPUT is included in Appendix B.

Each of the systems cost estimation routines can be used with a time-share computer terminal. Prompting or conversational statements describing the type(s) of information and data to be entered for each 'input' statement can be directed to the operator when more data is required. If input data are to be read from cards or magnetic storage devices, the output unit (09) onto which the conversational statements are directed can be supressed. These format statements also serve as a good documentation of variable names used in the computer routines.

Determination of Application System Annual Costs and Efficiencies

The computer routine APSYS is used to calculate the annual costs and efficiencies of various types of irrigation application systems. The APSYS subroutines and their respective relationships to one another can be seen in Figure 10. Dashed lines within the figure depict input and output flows of data, whereas solid lines represent the order and flow paths of calculations and data within the routine. The subroutine SPNKLR is used to calculate annual costs for side-roll, hand-line,

Table 7. Synopsis of the computerized planning and cost estimation routines used to determine annual costs of irrigation systems.

APSYS	This routine determines the annual costs of owning and operating irrigation application systems including land forming costs. Water application and distribution efficiencies are evaluated for each system design and on-farm management practice. Specific application methods evaluated are furrow and border surface systems and hand-line, side-roll, solid-set, and center pivot sprinkler systems.
CANAL	Annual ownership costs and conveyance efficiencies of open channel conveyance systems are estimated in this routine. The planned system may be lined or unlined and construction costs may be estimated for new or rehabilitated systems. Procedures used in this routine estimate costs of earthwork, canel lining and shaping, lateral turn-outs, and flow control structures.
PIPE	This computer routine estimates costs of constructing a gravity or high pressure pipeline system through undisturbed terrain or along an unlined channel route for a rehabilitation project. Pipe costs can be estimated for concrete, steel, or PVC pipe, and turnout costs can be estimated for high or low pressure operation.
PUMP	Annual ownership, operation, and electrical power costs of large pumping plants and small on-farm pumping units are estimated in this computerized procedure. Provision has been made to estimate escalation of power costs over the system life. On-farm units can be of centrifugal or turbine type, and costs of deep or shallow wells can also be estimated. USBR planning specifications and procedures are used in the estimation of annual costs for large pumping systems.

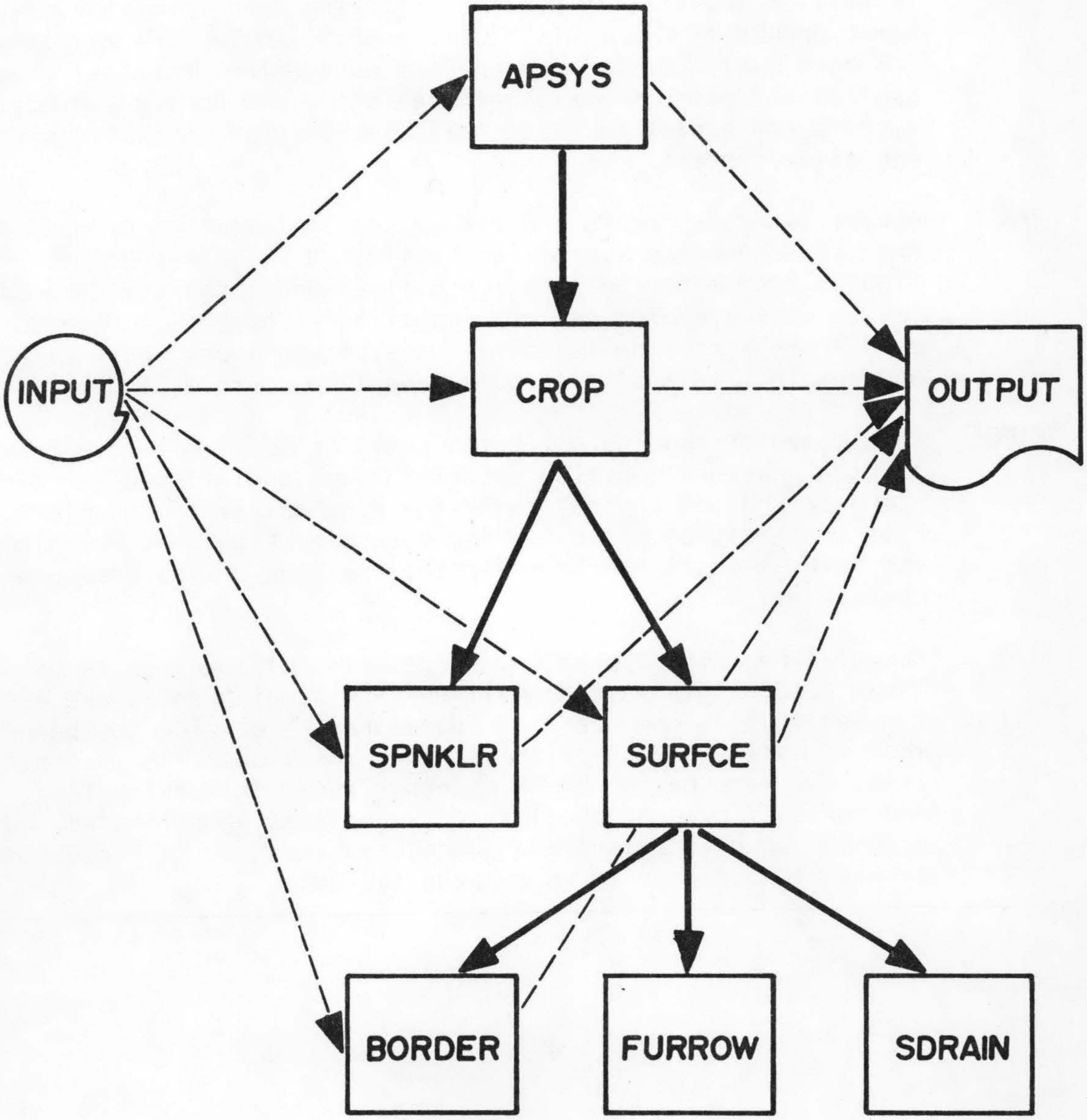


Figure 10. Flow chart of APSYS program used to calculate annual costs and efficiencies of irrigation application systems.

solid-set, and center pivot sprinkler systems, excluding pump and power requirements. Subroutine SURFACE is used to calculate annual costs and water application efficiencies for furrow and border surface systems. A documented lising of APSYS and associated subroutines is given in Appendix B.

The list of input parameters necessary for execution of APSYS is shown in Table 8. The main APSYS routine reads information for a specific soil type, and subroutine CROP inputs soil-plant-water data for each crop on that soil. Information concerning these parameters is then utilized by subroutines SPNKLR and SURFACE to calculate the desired information relating to sprinkler and surface systems.

Costs and efficiencies for sprinkler systems

Subroutine SPNKLR is designed to calculate the annual costs associated with a hand-line, side-roll, solid-set, or center pivot sprinkler system that may or may not be used in conjunction with a mainline supplying water to the laterals. Data for the laterals are entered separately from those pertaining to the mainline.

Lateral input parameters include a physical description of the system, related labor requirements, and costs associated with the sprinkler system. The physical description includes the lateral length and spacing, specified alternative set-length times, and the expected application efficiency of the system. This information is used to compute the area served by each lateral and the resulting schedule of operation. Knowledge of system labor requirements and average water rates over the system life

Table 8. Input parameters used to calculate annual costs and efficiencies of irrigation application systems.

Input Parameters for APSYS and CROP

- Soil type
- Farm size
- Field slope
- Intake family (SCS classification)
- Number of crops
- Soil water-holding capacity
- Root zone depth
- Percent of TAM usable as TRAM (total readily available moisture)
- Total annual ET
- Maximum ET rate incurred
- Crop Pattern Percentage

Input Parameters for Subroutine SPNKLR

- Lateral data:
  - Lateral length and spacing
  - Time required to move lateral
  - Alternative set-length times
  - Estimated system efficiency
  - Evaporation losses
  - Maximum allowable water intake rate
  - System cost (laterals, heads, nozzles, etc.)
  - System life
  - Interest rate
  - Salvage value, taxes, insurance, and maintenance costs
  - Contingency cost
  - Labor wage rate
  - Transport time between irrigations
  - Net value of water lost to deep percolation
- Mainline data:
  - Mainline pipe sizes
  - Mainline pipe lengths
  - Unit pipe costs, including mainline appurtenances
  - Earthwork costs
  - System life
  - Interest rate
  - Salvage value, taxes, insurance, and maintenance costs
  - Value of land lost to production

Table 8. Continued.

Input Parameters for Subroutine SURFCE

Manning's roughness coefficient for border-irrigated crops
Field lengths
Design flow rate
Furrow spacing or border width
Average set-length time
Labor requirements per irrigation
Additional labor requirements
Labor wage rate
Cost if Irrigation system equipment
Major land forming costs
System life expectancies
Salvage values
Interest rate
Annual land preparation costs
Value of land cost to production
Annual maintenance cost
Taxes, insurance, and maintenance costs
Net value of water lost to surface runoff
Net value of water lost to deep percolation
Subsurface drainage requirements
FURROW subroutine options:
    Fixed set-length time and flow rate
    Computed set-length time with fixed flow rate
BORDER subroutine options:
    Systems evaluated with available advance, recession, and intake data
    Fixed set-length time and fixed flow rate
    Variable set-length time and fixed flow rate
    Computed flow rate and set time for optimal efficiency

is necessary for computing annual labor costs. The initial system cost, life, and salvage value of system components are used along with the interest rate in computing the annual cost of capital recovery for the lateral. Other expenses include taxes and insurance which are computed as a percentage of the average capital investment.

Mainline input parameters are similar to those for the sprinkler lateral. The area supplied by the mainline, set equal to the planned farm size, is neccesary for computing costs on a per-acre basis. Annual capital recovery costs for the mainline are also computed.

Two additional parameters are used in the computation of total annual costs for sprinkler systems. The first parameter is the net value of land lost to production through the use of a particular system configuration. The second is the net value of water lost to deep percolation, and may be positive or negative depending upon leaching requirements, fertilizer losses, water table buildup, etc., by the system. The value of deep percolation losses is normally set equal to zero in this routine if the program output is to be used in conjuction with a linear-programming model, where deep percolation changes or benefits can be applied with the parametric programming option.

The flexibility of subroutine SPNKLR permits computation of annual costs for many different lateral-mainline combinations and farm sizes. Center pivot systems should be planned only for farms with fields of sufficient shape and size for adequate coverage and operational convenience. Estimation of sprinkler system efficiencies should be based on the level of operations management of the area farmers, prevalent wind patterns and speeds, proposed lateral and nozzle sizes and spacings, and estimated system operating pressures. These efficiency values are supplied by the systems planner.

Costs and efficiencies for surface systems

Subroutine SURFCE utilizes soil-crop data passed to it from the APSYS crop subroutine, in conjunction with the data listed in Table 8, to compute efficiencies and annual costs for planned surface systems. System dimensions and labor and equipment costs are utilized in much the same manner as they are in the SPNKLR subroutine. Land-forming costs are also required. These costs include initial leveling operations and annual land-planing requirements. The amount of land lost to production due to system components and values of water lost to surface runoff and deep percolation are also used in computing the total surface system cost. Runoff and deep percolation values should be set equal to zero if output is to be used with parametric programming options in the linear programming model. Multiple run lengths can be input to subroutine SURFCE to determine the most feasible or efficient field length for the particular soil type and crop studied.

Costs of a drainage system for surface irrigated lands are estimated in the SURFCE procedure by subroutine SDRAIN. This subroutine utilizes tile drainage system estimation guidelines furnished by the United States Bureau of Reclamation to size and space lateral drains. Input data include drain depth, permissible water table heights, drain slopes, and soil permeability, along with unit costs of drain pipes, excavation quantities, and gravel envelopes.

Whereas the efficiency of a sprinkler can usually be adequately estimated using knowledge of the system design, operation management and local climatic conditions, the determination of system efficiencies for a surface system is often difficult to compute. This difficulty is due to the many variables that affect the hydraulics of surface irrigation along with the high variability of system management.

Hydraulic characteristics of surface irrigation as applied to essentially planar two-dimensional flow in a border or furrow are currently well understood and can, in most instances, be represented in equation form. Exponential equations and models describing infiltration of water, irrigation advance trajectories, and border recession rates can be used along with open channel hydraulic equations such as Manning's equation to evaluate surface irrigation system performances and efficiencies, and to also design feasible lengths of border and furrow irrigated fields under known management conditions.

Data passed to the subroutines BORDER and FURROW from subroutine SURFCE for system evaluation include the SCS intake family designation of the soil type, representative field lengths and furrow and border widths, the desire volume of applied water per irrigation, field slopes, Manning's roughness coefficient for the specified crop, planned border and furrow flow rates, and the number of irrigations per season. Set-time lengths are optional input into both subroutines and coefficients of advance, recession, and infiltration equations may be optionally input to subroutine BORDER.

Border evaluation

The main method of border irrigation system evaluation and design used in the APSYS routine by the subroutine BORDER was obtained from a recent report on border irrigation hydraulics by Strelkoff and Katopodes (1977).

Border irrigation advance has been modelled using equations and graphs which provide dimensionless advance solutions. The methodology used combines theories of zero inertia, open channel flow, continuity, and mementum (Katopodes and Strelkoff, 1977). Graphical forms of dimensionless advance trajectories of border irrigation for typical agricultural soils have been described in a regression-equation form for use in the BORDER subroutine.

Recession rates are calculated in subroutine BORDER by an algebraic method also described by Strelkoff (1977). Intake opportunity times of selected points along a border irrigated field are then estimated using advance and recession rates. These intake times are used with an equation describing infiltration of water into the particular soil to compute infiltration volumes, deep percolation losses, and field efficiencies.

Four options of system evaluation and design used by subroutine BORDER (table 8) provide a systems planner flexibility in system design and planning. Advance, recession, and intake data, if available, can be input to subroutine BORDER, and water distribution and application efficiencies are evaluated on the basis of these data. The method of dimensionless advance is not used in this option, and advance and recession data must be supplied for the specific flow rate used. Infiltration of water is calculated through use of the Kostiakov-Lewis equation (Wilke and Smerdon, 1968). If the set-length time is not input into the model, it will be computed by the program.

The last three BORDER options listed in Table 8 utilize the aforementioned methods of dimensionless advance and algebraic recession to estimate hydraulics of the irrigation water. Border systems can be evaluated for constant set-length times and system flow rates, or for times and flow rates calculated by the subroutine to provide optimal distribution and application efficiencies.

Furrow evaluation

Subroutine FURROW utilizes coefficients of the Kostiakov-Lewis infiltration equation in conjunction with infiltration equations described by Vaziri et al (1973) to compute the advance, infiltration, and efficiencies of furrow irrigated fields. As in the border evaluation subroutine, parameters describing the water infiltration coefficients are representative of standard SCS intake families (USDA-SCS, 1974). The furrow flow rate size is required input for subroutine FURROW. Set-time lengths can be calculated in the program if unknown.

APSYS output

A sample of APSYS program solutions for a side-roll sprinkler system is shown in Table 9, and a sample output for a border irrigation system is listed in Table 10. Program solutions include pertinent system parameters read into the computer routines along with computed annual costs, losses, and efficiencies. Pumping unit and annual power costs are not included in the application system annual cost figures. A sinking fund method of calculating depreciation and interest is used in the APSYS routine for determining annual system ownership and operation costs.

Program limitations

The APSYS routine requires data that are known or that can be readily obtained. Generalities in input and program computation are necessary in order that program solutions may be representative of an area larger than an individual farm. The routines used assume uniform land slopes and uniform soil types with infiltration rates similar to those of SCS classifications (USDA-SCS, 1974). Any non-uniform soil types or soils with variable slopes should be subsectioned for refined analyses.

One typical farm size is used to represent ownership conditions of each soil type. Wide variations in farm and field sizes and shapes may necessitate further division of a soil class.

This program does allow flexibility in selecting the type or level of farm and irrigation management to be practiced by farmers in an

Table 9. Sample APSYS computer routine output for a sprinkler irrigation system, Salem Irrigation District.

```
Annual Cost of Irrigation -- Side Roll Wheel Line
Soil Type Number -- I (Annis)

                          Grain
          Farm Data:

Lateral life, years                             15.
Field Length Ft.                              1300.
Farm size, acres                                80.
No. of irrigations                               3.
Frequency of irrigation, days                   21.
GPM/lateral                                    247.
Labor rate, $/hr.                                5.

Number of laterals/farm                          2.
Length of lateral, feet                       1300.
Lateral spacing, feet                           50.
Time to move lateral, min/set                   30.
Time of setting, hrs.                           12.
Transport time per rotation, hrs.                1.
Area covered by each lateral, acres             40.

Cost per lateral line, $                      5940.
Salvage Value                                  772.20
Allowable intake rate, in/hr.                    0.80
Total labor, hr/ac/yr                            1.

Deep percolation, af/acre                        0.256
Application efficiency, percent                 75.00

           Mainline Data:

Mainline life, years                            20.
Total area served by mainline, acres            80.
Total length of mainline, feet                1300.

     Diameter (in)    Length (ft)    Cost ($/ft)

          8.             600.           3.65
          6.             700.           2.30

Salvage value                                  376.20
Total cost of mainline, $                     4180.
Total investment ($/ac)                        201.
```

Table 9. Continued

Annual Cost: (9.5% interest)	$/ac
Depreciation (sinking fund)	
Laterals	4.38
Mainline	0.88
Interest on investment	
Laterals	14.11
Mainline	4.96
Labor cost	4.31
Maintenance cost (3.0% initial investment)	6.02
Taxes and insurance (0.5% initial investment)	1.10
Total	35.76

Note: Total Annual Cost Does Not Include Pump Unit and Reservoirs

Table 10. Sample APSYS computer routine output for a border irrigation system, Salem Irrigation District.

```
Annual Cost of Irrigation -- Gravity Irrigation System with Good
   Management -- Soil Type Number -- 1 (Annis)

                              Grain

          Farm Data:

Field length, ft.                                     1000.
Labor required, hr/ac/irr                                0.35
Additional labor, hr/ac/irr                              0.0
Labor rate, $/hr                                         5.00
Cost of const. farm ditch, $/ft                          0.40
Cost of irrigation structures $/ac                      20.00
Cost of farm ditch lining, $/ft                          2.50
Cost of misc, equip., $/ac                               0.0
Cost of leveling, grading, $/ac                        200.0
Cost of land preparation, $/ac                          10.00
Cost of land lost to production, $/ac                  250.00

Number of irrig./season                                  3.
Depleted RAM between irrigations, inches                 4.20
Frequency of irrigation at peak use, days               21.

Farm size, acres                                        80.
Field size for this crop, acres                         28.
System life, years                                      50.
Salvage value                                            0.0
Total investment, $/ac                                 346.

    Ownership cost ($/ac)

Depreciation (sinking fund)                              2.70
Interest on initial investment (9.5%)                   32.90

Operation and Maintenance cost ($/ac)
Labor cost                                               5.25
Maintenance and repair (including annual land prep)     10.73
Taxes and insurance (0.5% initial investment)            0.37

    Sub total .................................        51.95
Cost of land lost to production                          7.50
```

Table 10. Continued

Cost of water lost	0.0
Cost of sub-surface drain ($/ac)	0.0
Total annual cost ($/ac/yr)	59.45
Border Irrigation Efficiency Estimates Soil Type Number -- 1	
Length of irrigation run, ft	1000.
Depth of water applied at field head, in	4.20
Depth of water applied at field end, in	3.61
Unit stream size, cfs/ft	0.0516
Border width, ft	40
Field slope, ft/ft	0.0020
Time of application, min	162.
Application efficiency, percent	67.
Distribution efficiency, percent	90.
Volume of deep perc, ac-ft/ac/yr	0.0
Volume of runoff, ac-ft/ac/yr	0.50

irrigation district. The optimal efficiency options present in the surface subroutines should be used only if area farmers are financially and physically capable of maintaining high levels of operation and maintenance management. These options assume coordination with efficient irrigation scheduling.

In all methods of application systems design used in this model, a continuous supply of water is assumed during periods of peak consumptive use. Sprinkler systems are designed for continuous operation during this period, aside from required moving times. Surface irrigations would require continuous scheduling among water users to provide irrigated fields with the proper flow rate required for efficient irrigation.

The APSYS routines do not evaluate benefits achieved from increased crop growth uniformities or yields resulting from increased irrigation management or system design. Crop growth models coupled with a multidisciplinary approach to systems evaluation will be necessary for a complete understanding of an irrigation system's impact on crop production levels.

Application of APSYS routine to the Salem Irrigation District

Data obtained for the four crops considered for each of the four general soil series combinations shown in Figure 5 are listed in Table II. The application systems considered for each soil type along with their basic individual characteristics are listed in

Table 11. Design Parameters for on-farm application systems, Salem Irrigation District.

Crop	Water Holding Capacity (in/ft)	Rooting Depth (ft)	Readily Available Moisture (%)	Normal Irr. Requirement (in)	Daily Peak Use (ipd)	Crop Pattern (%)	Application depth (in)	Irr. Freq. (days)	Number of Irrigations
Annis Soil Class[1]									
Potatoes	2.4	2.5	40.	18.0	0.28	30.	2.4*	8*	8*
Grain	2.4	3.5	50.	12.3	0.20	35.	4.2	21	3
Alfalfa	2.4	4.0	60.	19.0	0.23	20.	5.8	25	4
Pasture	2.4	2.5	50.	17.0	0.19	15.	3.0	16	6
Withers Soil Class[2]									
Potatoes	2.2	2.5	40.	18.0	0.28	30.	2.2	8	9
Grain	1.9	3.0	50.	12.3	0.20	35.	2.9	14	7
Alfalfa	1.9	3.0	60.	19.0	0.23	20.	3.4	15	6
Pasture	2.2	2.5	50.	17.0	0.19	15.	2.8	14	7
Blackfoot Soil Class[3]									
Potatoes	2.2	2.5	40.	18.0	0.28	30.	2.2	8	9
Grain	2.2	3.5	50.	12.3	0.20	50.	3.9	19	4
Alfalfa	2.2	4.0	60.	19.0	0.23	20.	5.3	23	4
Hayeston Soil Class[4]									
Potatoes	1.6	2.5	40.	18.0	0.28	20.	1.6	6	12
Grain	1.4	3.0	50.	12.3	0.20	40.	2.1	10	6
Alfalfa	1.4	3.0	60	19.0	0.23	20.	2.5	11	8
Pasture	1.6	2.5	50.	17.0	0.19	20.	2.0	10	9

[1] Annis Silty Clay Loam

[2] Withers Clay Loam

[3] Blackfoot and Bannock Loam

[4] Hayeston Variant Coarse Sandy Loam, Labenzo Silt Loam, Haplaquolls Misc.

* Data obtained from output of APSYS routine

Tables 12 and 13. Appendix C contains a complete listing of the computer input used for application systems evaluation for the Salem Irrigation District.

Data setup. The following methodology was used to obtain the cost and efficiencies of specific application system types for each of the soils groups in Figure 5. Farm and field sizes and crop distribution for each soil group were obtained from large-scale aerial photos and the Madison County Atlas and Plat Book (1977), and by visual observation. Field slopes and slope directions were measured from topographical maps and by discrete field surveys. Soil intake classifications were selected from information gathered from local and regional SCS personnel, and crop patterns of the various soil types were estimated from area reconnaisance work and historical records. All application systems cost data used were collected from sources near Rexburg, Idaho. An interest rate of 9.5 percent was used for all on-farm systems planning.

The farm sizes for each crop and soil type were grouped into the size categories listed in Table 1. Multiple field lengths were analyzed for gravity systems, and selection of field lengths to be used in the linear programming optimization procedure was based on current field sizes, attainable irrigation efficiencies, and annual system costs. Improved and unimproved furrow systems were evaluated for potatoes on all soils and improved and unimproved border irrigation systems were evaluated for grain, alfalfa and pasture crops. Descriptions of these gravity systems are listed in Table 13.

Table 12. Sprinkler application systems considered for the Salem Irrigation District

System type	Mainline length (feet)	Area served by mainline (acres)	Lateral length (feet)	General description
Hand-line sprinkler	2600	160 (Hayeston)[*]	1300	The layout of this system consists of hand-carried laterals supplied by a semi-permanent mainline. Lateral spacing is 50 feet.
	2010	120 (Withers)	1300	
	1675	100 (Blackfoot)	1300	
	1300	80 (Annis)	1300	
Side-roll sprinkler	2600	160	1300	The layout of this system consists of mechanically moved laterals supplied by a semi-permenant mainline. Lateral spacing is 50 feet.
	2010	120	1300	
	1675	100	1300	
	1300	80	1300	
Solid-set sprinkler	2600	160	650	The layout of this system consists of a solid set of semi-permanent laterals on 50 feet spacings supplied by a semi-permanent mainline. This system is used on potatoes only.
	2010	120	650	
	1675	100	650	
	1300	80	650	
Center pivot sprinkler	1300	160	1298.5	This system consists of a mechanically moved lateral which rotates about a central pivot point. Water is supplied by a permanent buried mainline. The lateral includes an attached corner system.

[*] Soil types are defined in Table I and Appendix A.

Table 13. Surface application systems considered for the Salem Irrigation District.

System Type	Field length (feet)	Furrow width (feet)	Border (feet)	General Description
Unimproved gravity	1300 1000 800 600 400	3	40	This system consists of poorly maintained earthen ditches with earthern and wooden structures and portable canvas dams used for water control. Maximum allowable length of irrigation run is 1300 feet. Minimum allowable set time length is 240 minutes.
Improved gravity	1300 1000 800 600 400	3	40	This system consists of well maintained concrete ditches with concrete and metal structures used for water control. Maximum allowable length of irrigation run is 1300 feet. Extensive land leveling operations and irrigation scheduling management is required. Set time length is adjusted for maximum efficiencies.

For sprinkler systems, the representative farm size and layout on each soil type were used in conjunction with crop acreage data to determine the overall annual costs per acre. Hand-line and side-roll sprinkler laterals were assumed to be 1300 feet in length. Center pivot systems were evaluated for square fields 160 acres in area. Increased costs and irrigated areas created by the use of corner systems on the center pivots were included. Only one soil class (Hayeston) has field areas large enough to accomodate a large pivot sprinkler system. Thus, this system was not evaluated for the other three soil types.

Solid set systems were evaluated with 650-foot laterals and were planned for potatoes only. Pumping costs were added to all sprinkler system costs before inclusion in the linear-programming model for systems not receiving water from a high pressure distribution system.

Program output. The annual costs per acre and efficiencies for each type of application system considered are listed in Tables 14 through 17 for the four crops and soil series groups studied. The annual costs computed for application systems include the costs of applying water and conveying the water from a point of delivery to the point or points of application. Also included in the annual costs of the sprinkler systems are pumping and power costs computed by the PUMP program discussed towards the end of this chapter. The volume of energy demanded by the center pivot system (Table 17) is lower than solid-set or hand-move and side-roll systems because continuous operation of the center pivot system during peak water use is possible, facilitating

Table 14. Application system parameters for Annis silty clay loam -- Salem Irrigation District.

System symbol	System	Crop	Run or lateral length (feet)	Annual cost including pumping cost ($/acre)	Application efficiency (percent)	Maximum required (cfs/acre)	Energy Demand (kwh/acre)
SUBPI	sub-irrigation	Potatoes	1100	20.50	18.	0.0665	
SUBGI		Grain	1100	20.50	13.	0.0657	
SUBAI		Alfalfa	1100	20.50	19.	0.0522	
SUBBI		Pasture	1100	20.50	17.	0.0475	
UNGPI	Unimproved gravity	Potatoes	1000	59.00	41.	0.0287	
UNGGI		Grain	1000	37.50	39.	0.0215	
UNGAI		Alfalfa	1000	39.30	54.	0.0179	
UNGBI		Pasture	1000	42.80	26.	0.0307	
IMGPI	Improved gravity	Potatoes	1000	74.30	43.	0.0274	
IMGGI		Grain	1000	59.50	67.	0.0125	
IMGAI		Alfalfa	1000	61.20	58.	0.0166	
IMGBI		Pasture	1000	64.70	51.	0.0157	
HMPPI	Hand-line sprinkler	Potatoes	1300	76.90	70.	0.0168	846
HMPGI		Grain	1300	65.50	70.	0.0120	
HMPAI		Alfalfa	1300	71.50	70.	0.0138	
HMPBI		Pasture	1300	71.40	70.	0.0114	
SRPPI	Side-roll sprinkler	Potatoes	1300	78.90	70.	0.0168	790
SRPGI		Grain	1300	74.30	70.	0.0120	
SRPAI		Alfalfa	1300	76.70	70.	0.0138	
SRPBI		Pasture	1300	76.70	70.	0.0114	
SSPPI	Solid-set sprinkler	Potatoes	650	230.50	75.	0.0157	636

Table 15. Application system parameters for Withers clay loam -- Salem Irrigation System.

System symbol	System	Crop	Run of lateral length (feet)	Annual cost including pumping cost ($/acre)	Application efficiency (percent)	Maximum required (cfs/acre)	Energy Demand (kwh/acre)
SUBP2	sub-irrigation	Potatoes	1200	20.60	18.	0.0665	
SUBG2		Grain	1200	20.60	13.	0.0657	
SUBA2		Alfalfa	1200	20.60	19.	0.0522	
SUBB2		Pasture	1200	20.60	17.	0.0475	
UNGP2	Unimproved gravity	Potatoes	1300	46.60	44.	0.0268	
UNGG2		Grain	1300	29.30	27.	0.0311	
UNGA2		Alfalfa	1300	30.60	34.	0.0284	
UNGB2		Pasture	1300	50.40	48.	0.0307	
IMPP2	Improved gravity	Potatoes	1300	58.30	46.	0.0256	
IMPG2		Grain	1300	47.70	58.	0.0145	
IMPA2		Alfalfa	1300	49.00	57.	0.0169	
IMPB2		Pasture	1300	50.40	48.	0.0166	
HMPP2	Hand-line sprinkler	Potatoes	1300	66.40	70.	0.0168	732
HMPG2		Grain	1300	58.50	70.	0.0120	
HMPA2		Alfalfa	1300	61.80	70.	0.0138	
HMPB2		Pasture	1300	63.20	70.	0.0114	
SRPP2	Side-roll sprinkler	Potatoes	1300	69.40	70.	0.0168	632
SRPG2		Grain	1300	59.10	70.	0.0120	
SRPA2		Alfalfa	1300	60.50	70.	0.0138	
SRPB2		Pasture	1300	61.10	70.	0.0114	
SSPP2	Solid-set sprinkler	Potatoes	650	223.20	75.	0.0157	486

Table 16. Application system parameters for Blackfoot and Bannock loams -- Salem Irrigation District.

System symbol	System	Crop	Run of lateral length (feet)	Annual cost including pumping cost ($/acre)	Application efficiency (percent)	Maximum required (cfs/acre)	Energy Demand (kwh/acre)
SUBP3	sub-	Potatoes	1400	20.60	18.	0.0665	
SUBG3	irrigation	Grain	1400	20.60	13.	0.0657	
SUBA3		Alfalfa	1400	20.60	19.	0.0522	
UNGP3	Unimproved	Potatoes	1300	46.60	34.	0.0346	
UNGG3	gravity	Grain	1300	27.90	50.	0.0168	
UNGA3		Alfalfa	1300	27.90	55.	0.0176	
IMGP3	Improved	Potatoes	1300	58.30	36.	0.0327	
IMGG3	gravity	Grain	1300	46.30	67.	0.0125	
IMGA3		Alfalfa	1300	46.30	54.	0.0169	
HMPP3	Hand-line	Potatoes	1300	63.10	70.	0.0168	622
HMPG3	sprinkler	Grain	1300	54.40	70.	0.0120	
HMPA3		Alfalfa	1300	56.40	70.	0.0138	
SRPP3	Side-roll	Potatoes	1300	72.30	70.	0.0168	580
SRPG3	sprinkler	Grain	1300	60.30	70.	0.0120	
SRPA3		Alfalfa	1300	61.10	70.	0.0138	
SSPP3	Solid-set Sprinkler	Potatoes	650	226.80	75.	0.0157	580

Table 17. Application system parameters for Hayeston Variant coarse sandy loam, Labenzo silt loam, and Haplaquolls misc. -- Salem Irrigation District.

System symbol	System	Crop	Run of lateral length (feet)	Annual cost including pumping cost ($/acre)	Application efficiency (percent)	Maximum required (cfs/acre)	Energy Demand (kwh/acre)
SUBP4	sub-irrigation	Potatoes	1200	20.80	18.	0.0665	
SUBG4		Grain	1200	20.80	13.	0.0657	
SUBA4		Alfalfa	1200	20.80	19.	0.0522	
SUBB4		Pasture	1200	20.80	17.	0.0475	
UNGP4	Unimproved gravity	Potatoes	1000	61.00	46.	0.0274	
UNGG4		Grain	1000	34.80	6.	0.1401	
UNGA4		Alfalfa	1000	38.30	8.	0.1208	
UNGB4		Pasture	1000	40.00	5.	0.1597	
IMGP4	Improved gravity	Potatoes	600	111.00	47.	0.0251	
IMGG4		Grain	600	79.00	68.	0.0124	
IMGA4		Alfalfa	600	85.00	70.	0.0138	
IMGB4		Pasture	600	88.00	36.	0.0222	
HMPP4	Hand-line sprinkler	Potatoes	1300	62.00	70.	0.0168	664
HMPG4		Grain	1300	54.00	70.	0.0120	
HMPA4		Alfalfa	1300	58.80	70.	0.0138	
HMPB4		Pasture	1300	59.30	70.	0.0114	
SRPP4	Side-roll sprinkler	Potatoes	1300	71.30	70.	0.0168	566
SRPG4		Grain	1300	57.30	70.	0.0120	
SRPG4		Alfalfa	1300	59.30	70.	0.0138	
SRPB4		Pasture	1300	59.30	70.	0.0114	
SSPP4	Solid-set sprinkler	Potatoes	650	222.30	75.	0.0157	469

Table 17. Continued.

System symbol	System	Crop	Run of lateral length (feet)	Annual cost including pumping cost ($/acre)	Application efficiency (percent)	Maximum required (cfs/acre)	Energy Demand (kwh/acre)
CPPP4	Center	Potatoes	1298.5	61.00	80.	0.0147	451
CPPG4	Pivot	Grain	1298.5	61.00	80.	0.0105	
CPPA4	sprinkler	Alfalfa	1298.5	61.00	80.	0.0121	
CPPB4		Pasture	1298.5	61.00	80.	0.0100	

a lower flow rate.

Listings of computer output from routine APSYS have been included in Appendix D for the Annis silty clay loam soil type. Sample output is shown in Tables 9 through 10.

Distribution System Annual Costs and Efficiencies

Distribution system costs are estimated for open channel and pipe system components by the FORTRAN IV computer routines entitled CANAL and PIPE. Many of the design procedures used in these routines were obtained from the United States Bureau of Reclamation. These procedures were incorporated into this irrigation alternative optimization model during a project support primarily by the USBR in 1977 (Galinato et al. 1977), and the XCANAL and XPIP routines written during that study coincide with the routines CANAL and PIPE presently used in this model.

The XCANAL and XPIP routines were rewritten during this project to provide for rehabilitation planning of existing unlined canal systems and to estimate construction costs of privately financed irrigation projects. The basic design procedures used in XCANAL and XPIP have been retained in the present computer routines, although most of the cost-estimating algorithms have been modified.

The computer model written for the USBR is described in detail in a completion report published by the Water Resources Research Institute at the University of Idaho (Galinato, et al. 1977), and is currently supported on the USBR computer in Denver, Colorado. The Bureau model provides good cost estimates for planning of federal irrigation projects,

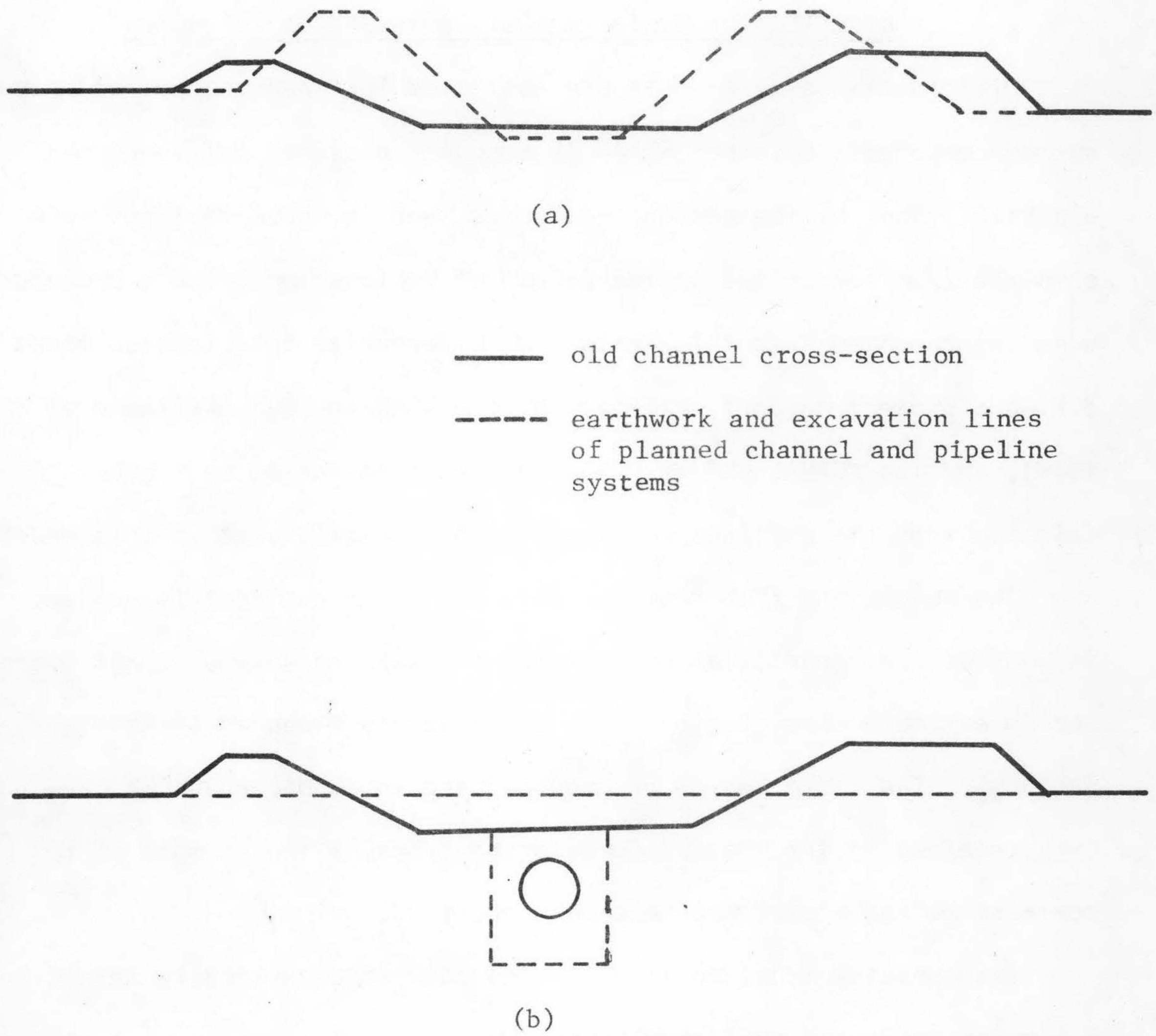


Figure 11. Cross-section showing channel modification (a) or installation of pipe during rehabilitation of an irrigation distribution system (b).

although these estimates may overestimate construction costs of smaller projects or private irrigation systems where the service life of system components may be shorter or the components may be designed for construction out of lighter or less expensive materials.

Systems rehabilitation procedures.

The routines CANAL and PIPE provide cost estimations for various types of irrigation conveyance systems and include subroutines which estimate earthwork costs associated with construction of these systems. Provision has been made in these subroutines to estimate various volumes of earthwork which would be required in modernizing or rehabilitating an existing unlined open channel system. Rehabilitation would be accomplished either by reshaping and lining the channel with an impervious membrane or by installing sections of high or low-head pipe along the channel bottom (Figure 11).

Rehabilitation of a conveyance system is normally undertaken to decrease high seepage losses and operational losses caused by poor water control facilities and mismatched sizes of system components, as well as to rectify incompatabilities between conveyance and on-farm systems. Utilization of an existing canal system in a rehabilitation project can considerably reduce earthwork costs and the need for new rights-of-way acquisitions required in new route selection. Often, however, a common purpose of systems rehabilitation is to straighten irrigation channels to reduce operation and maintenance costs as well as seepage losses from the conveyance system. In this case, an existing channel with many tortuous sections would most probably be abandoned and leveled.

Estimated volumes of required earth fill are assumed to be borrowed from land areas adjacent to the channel. In the pipe rehabilitation scheme, the existing channel is leveled after the pipe is installed to conform with the surrounding terrain.

Formulation of annual cost functions

Annual costs for conveyance systems are formulated in the CANAL and PIPE programs as functions of the range of flow rates each section can be expected to convey. The flow rate range of a section is dependent upon the consumptive water requirements of crops grown, the expected efficiencies of planned application systems, and the size of the land area served by the conveyance section including other downstream sections and their corresponding seepage losses. Each conveyance is sized in the linear-programming optimization procedure to obtain minimum cost combinations of application and distribution systems which satisfy all system constraints. Thus, depending upon efficiencies of application systems selected by the optimization procedure, a wide range of design flow rates for each section is possible.

Annual section costs need to be determined for the case where the least efficient application systems are operated in all service areas in conjunction with distribution system types with the highest conveyance losses. If annual costs are also computed for the case where the most efficienct application and conveyance systems are incorporated into the study area, then annual costs for the maximum and minimum possible design flow rates of each section will be known.

Annual costs should be determined for 8 to 10 flow rate increments between the minimum and maximum rates possible for each conveyance section. A least-squares linear regression analysis is then used in the distribution cost routines to determine the best fit linear relationship between annual cost and design flow rates. This relationship, in the form of Annual cost = a + bQ, is discussed in Chapter III. A linear relationship between annual cost and section flow rates is necessary for compatability with the linear programming model discussed in Chapter VI.

Although annual cost functions of distribution system components may not be linear, they can usually be described accurately by a linear function if only a short arc of the function is described. Figure 12 is a sketch of a function representing annual costs of a distribution section. The endpoints of the arc A-B correspond with the minimum and maximum design flow rates, Q_A and Q_B, for that section. A correlation coefficient, r, will indicate the accuracy of a linear function in estimating the annual cost of a section. A high correlation coefficient will normally be obtained if the minimum and maximum design flow rates, and thus, the length of arc A-B, are chosen to represent a limited range of flow rates.

Open channel conveyance systems

Calculations of sizes and costs of flow control structures and devices required for regulation and construction of most open channel trapezoidal systems have been included in the CANAL routine. All costs and conveyance losses in this routine are computed in relation to the flow rates conveyed. Figure 13 is a simple diagram of the subroutines called by the CANAL program. Dashed lines in the figure represent input and output flows of data, and solid lines depict the order and flow paths of calculations and data within the routine. A documented listing of the CANAL program is included in Appendix B.

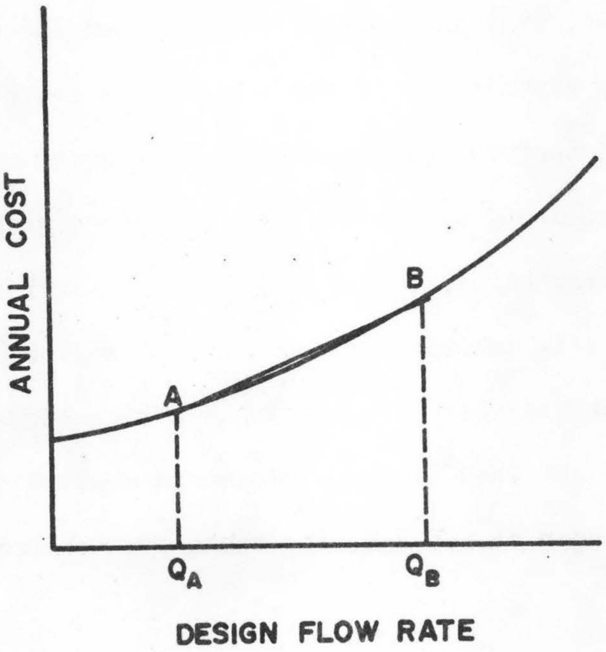


Figure 12. Linearization of an annual cost function.

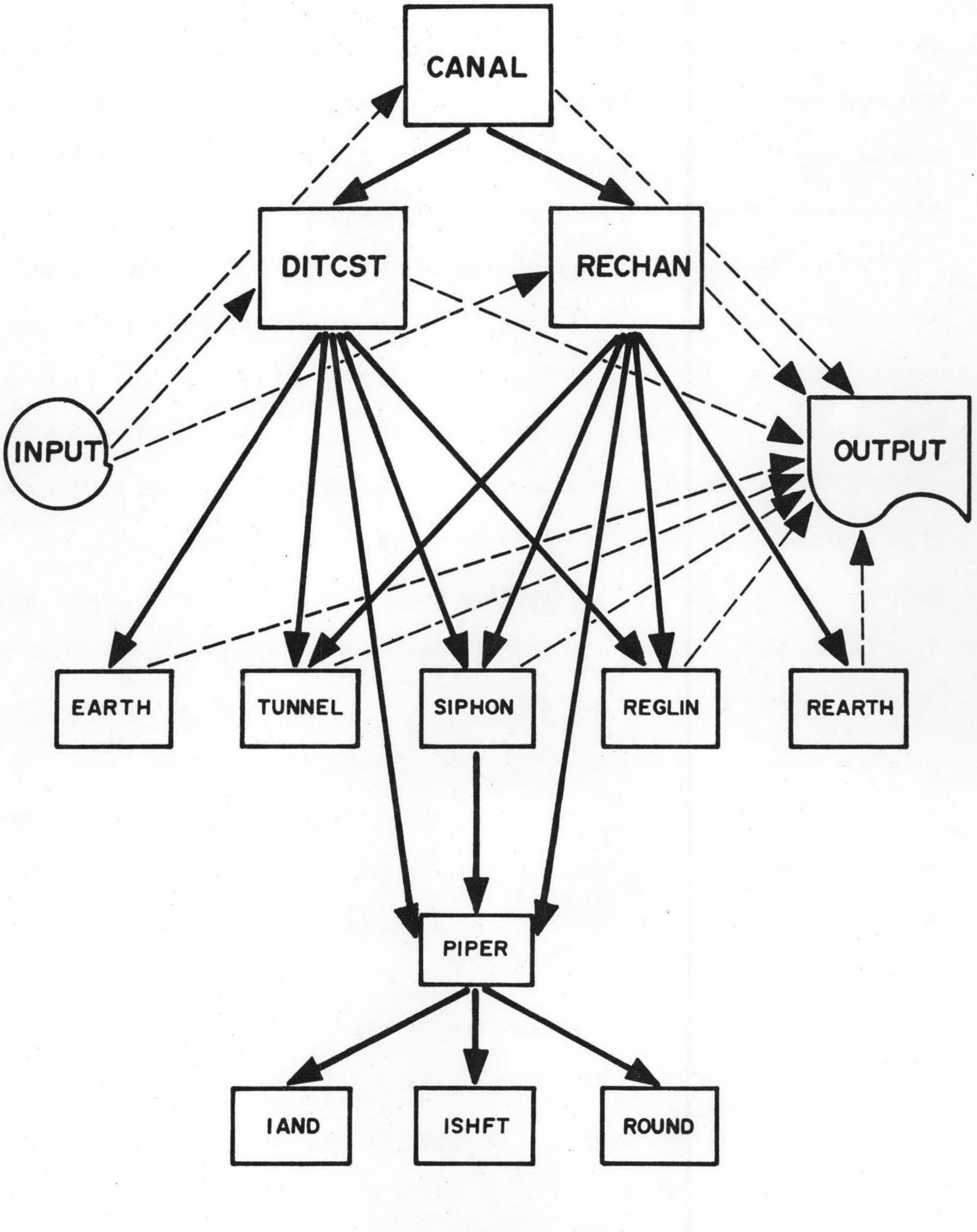


Figure 13. Flow chart of CANAL program used to calculate annual costs of open channel distribution systems.

Data input, design, and cost estimation. Most of the data utilized by CANAL is read with the free-form format subroutine INPUT, described at the beginning of this chapter. Some alphanumeric data required by the subroutines for labeling purposes require a specific format. Table 18 lists input parameters read into the CANAL routine.

Unit prices and cost indices for earthwork and canal structures are entered into the main routine CANAL along with an indicator concerning rehabilitation. The unit prices coincide with cost parameters used by the Bureau of Reclamation on most federal projects and can normally be obtained for the region of study. Cost indices can be computed for the base year noted by utilizing cost index curves (USDI-USBR, 1977; Engineering News Record, 1977) or by contacting area construction companies.

Data input to CANAL are transferred to either subroutine DITCST or RECHAN, depending upon the planning conditions. RECHAN is used if an existing canal is to be included in the rehabilitation plan, and DITCST is called if the planned conveyance system is to be constructed in undisturbed terrain. Both subroutines utilize essentially the same design procedures. The main difference is in the estimation procedure used for computing earthwork volumes.

Data are entered into subroutine DITCST or RECHAN concerning economic and hydraulic data common to all conveyance sections in the distribution system evaluated. The subroutine then reads data for each specific conveyance section including the minimum and maximum possible design flow rates.

For each Q (flow rate) considered, subroutine DITCST or RECHAN will compute a channel base-height ratio, freeboard, bank height, total channel depth, and height, thickness, and volume of the channel lining. Five options are considered for lining materials, namely: (1) no lining, (2) unreinforced Portland cement concrete, (3) reinforced Portland cement concrete, (4) asphaltic concrete, and (5) shotcrete. The canal seepage rate is estimated using the Moritz equation (Abbett, 1956), and the volume of water lost during an irrigation season is based on the number of days the canal would carry 75 percent of peak flow.

DITCST and RECHAN will also compute the cost of water control structures in each section, including rectangular inclined drops, concrete checks, modified Parshall flumes, county bridges, farm bridges, drainage crossings, and farm turnouts. Estimating curves are used to compute costs for the above structures with the exception of county and farm bridges and drainage crossings. These estimating curves are in the simple eponential from $C = aQ^b$ where C = the installed cost of the structure; Q = flow rate capacity of the structure; a = the intercept of the unit capacity of the cost curve; and b = the exponential slope of the cost curve.

If a siphon is present in the system, subroutine SIPHON is called to estimate construction costs. This routine is a modified version of the USBR program SIPHN. If a tunnel within a section is required, subroutine TUNNEL is called to estimate the cost of drilling or blasting the tunnel. Subroutine PIPER is utilized to estimate the cost per linear foot of concrete pipe for given diameters and head classes, if any siphons or drainage crossings are required in the channel sections.

Channel earthwork volumes are required rights-of-way are calculated by subroutine EARTH in the DITCST option and by subroutine REARTH in the RECHAN rehabilitation option. Subroutine EARTH is a modified version of the USBR program BR021, and requires prismatic and terrain data similar to USBR specifications. The types of parameters required by EARTH and REARTH are included in Table 18, and a schematic of a channel cross-section depicting the various prismatic and terrain parameters required by EARTH is shown in Figure 14. Parameters B, D, and HC in the figure are computed by subroutine DITCST. Prismatic parameters used to describe the shape of an existing channel to be rehabilitated are shown in Figure 15.

Subroutines DITCST and REHAB compute total construction and annual equivalent costs for each specified flow rate within the specified range. Subroutine REGLIN is then called to determine linear regression coefficients of annual cost vs. flow rate. This procedure is repeated for all canal sections to be evaluated by the program. The linear regression cost coefficients, conveyance efficiency, and canal seepage computed for each canal section are used as data for the optimization procedures.

CANAL output. A sample solution of the CANAL program for a rehabilitated open-channel section is shown in Table 19. Program output

Table 18. Input Parameters used to calculate annual costs and efficiencies of open channel distribution systems.

Input Parameters for CANAL

- Unit costs for excavation, backfill, and compaction:
  - Canals
  - Canal structures
  - Siphons
  - Pipe trenches
- Unit costs for concrete:
  - Canal lining
  - Canal structures
  - Siphons
- Unit costs for steel and cement
- Cost indices for estimation of pipeline construction (USBR parameters):
  - Hourly wage rates
  - Equipment index
  - Area factor
  - Haul distances
  - Steel index
  - Cement index
- Indicator for new or rehabilitation planning procedure

Input Parameters Common to DITCST and RECHAN

- Cost contingencies (percentages):
  - Canal and lateral structures
  - Earthwork
  - Rights of way
  - Canal lining
- Canal structures cost index
- Lining material code
- Channel hydraulics:
  - Side slope of trapezoidal channel
  - Manning's roughness coefficient
  - Maximum allowable velocity
  - Minimum channel depth
- County bridge data
- Project life
- Annual interest rate
- Salvage value (% of original cost)
- Value of water lost from canal

Table 18. Continued.

Number of days canal operates above 75% of capacity
Operational losses (% of flow)

Input Parameters for Each Specific Channel Section (DITCST and RECHAN)

- Seepage coefficient, Moritz equation
- Percent rock excavation
- Additional right of way and value
- Area and unit costs for severance payment
- Elevations of section inlet and outlet
- Number and sizes of turnouts
- Number and sizes of drainage crossings
- Number of canal structures:
  - Rectangular inclined drop < 3 feet
  - Rectangulat inclined drop > 3 feet
  - Concrete check w/o apron
  - Modified Parshall flume
  - County bridge
  - Farm bridge
  - Siphon
  - Tunnel
- Siphon data (USBR specifications):
  - Head loss and velocity
  - Lengths of upstream, downstream, and bottom slopes
  - Transition loss coefficient
  - Slopes of upstream, downstream, and botton sections
  - Width of right of way
- Tunnel data (USBR specifications):
  - Head loss and velocity
  - Elevation of job
  - Length
  - Number of headings
- New channel earthwork option (DITCST):
  - Prismatic data (USBR specifications):
    - Rock cut slope
    - Upper cut bank slope
    - Fill cut slope
    - Upper bank width
    - Lower bank width
    - Compacted embankment width
    - Compactment factor
    - Percent rock in fill
    - Depth of cut adjustment
    - Compacted embankment code

Table 18. Continued.

- Terrain data (multiple stations):
  - Station distance
  - Ground cross slope
  - Center line cut
  - Rock center line cut
  - Station code
  - Prism code

Rehabilitation earthwork option (RECHAN):
- Existing channel section description:
  - Base width
  - Inside side slope
  - Height of channel sides
  - Top width of berms
  - Outside side slopes
  - Elevations of adjacent terrain at section inlet and outlet

Flow rate data:
- Minimum flow rate
- Maximum flow rate
- Flow rate interval for evaluation and design

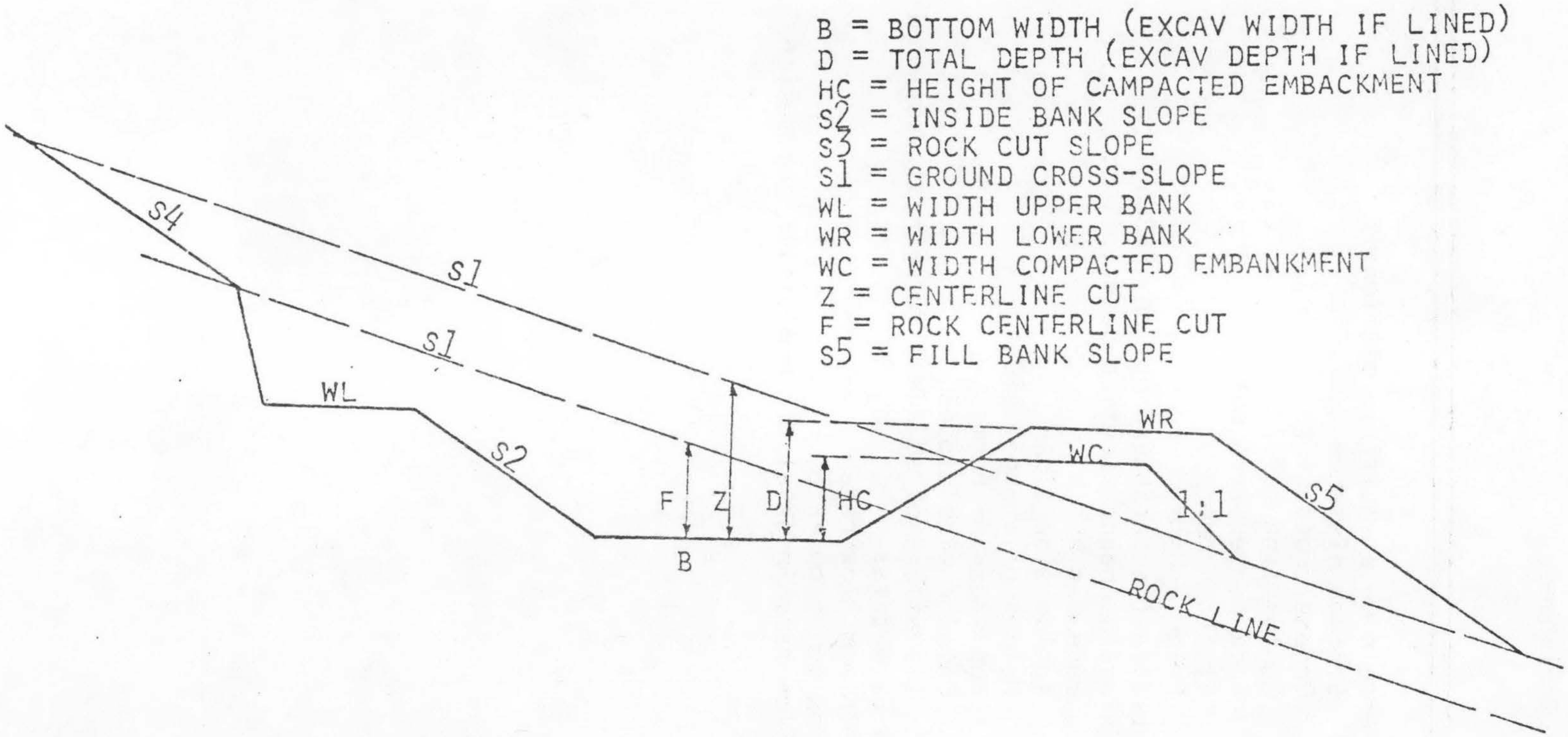


Figure 14. Terms relating to channel cross-section to be used with USBR planning procedures in EARTH subroutine.

OBW = BOTTOM WIDTH
OBMH = DEPTH (HEIGHT OF BERMS ABOVE BOTTOM)
OBMWL = TOP WIDTH OF LEFT BERM
OBMWR = TOP WIDTH OF RIGHT BERM
OZBML = OUTSIDE LEFT BANK SLOPE
OZBMR = OUTSIDE RIGHT BANK SLOPE
OZ = INSIDE BANK SLOPE
OELI = ELEVATION OF CHANNEL BOTTOM AT INLET
OELO = ELEVATION OF CHANNEL BOTTOM AT OUTLET
ETLI = ELEVATION OF LEFT ADJACENT TERRAIN, INLET
ETLO = ELEVATION OF LEFT ADJACENT TERRAIN, OUTLET
ETRI = ELEVATION OF RIGHT ADJACENT TERRAIN, INLET
ETRO = ELEVATION OF RIGHT ADJACENT TERRAIN, OUTLET

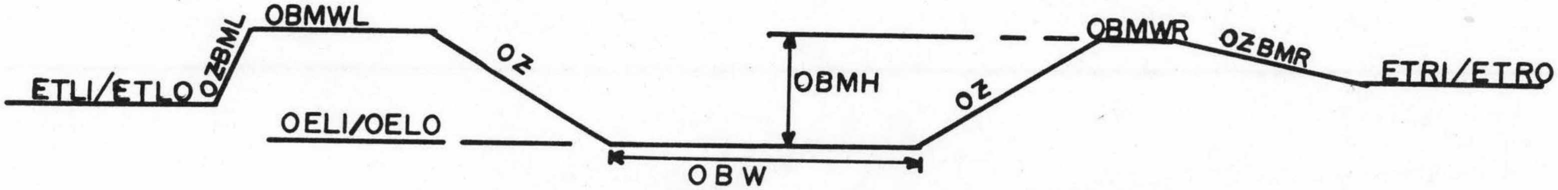


Figure 15. Prismatic and Terrain parameters input to subroutine REARTH.

Table 19. Sample CANAL computer routine output for a lined distribution system section, Salem Irrigation District

Lined Canal Reach Number One

Q (cfs)	Cost of struct.	Cost of earthwork	Cost of lining	Cost of right of way	Total const. cost	Annual equiv. cost*	Convey. Effic.
40.	9555.	17895.	31118.	0.	58568.	4243.9	97.6
45.	9923.	18755.	32096.	0.	60774.	4403.7	97.6
50.	10279.	19549.	33260.	0.	63088.	4571.3	97.6
55.	10625.	20272.	34353.	0.	65250.	4728.0	97.7
60.	10963.	20955.	35387.	0.	67304.	4876.9	97.7
65.	11293.	22560.	36369.	0.	70221.	5088.2	97.7
70.	11616.	22594.	37305.	0.	71515.	5182.0	97.7
75.	11933.	22670.	38200	0.	72803.	5275.3	97.7
80.	12244.	22780.	39060.	0.	74083.	5368.1	97.7
85.	12549.	22920.	39887.	0.	75356.	5460.3	97.8
90.	12850.	23084.	40684.	0.	76619.	5551.8	97.8
95.	13146.	23271.	41455.	0.	77871.	5642.5	97.8
100	13437.	23474	42201.	0.	79113.	5732.5	97.8
105.	13725.	23695.	42924.	0.	80344.	5821.7	97.8
110.	14009.	23927	43626	0.	81563.	5910.0	97.8
115.	14289.	24572.	44309.	0.	83170.	6026.5	97.8
120	14566	25148	44974	0.	84688.	6136.5	97.8

* Annual equivalent cost is computed for a system life of 50 years and for an annual interest rate of 7.0%.

Table 19. Continued.

Summary of Earthwork for Rehabilitation of This Reach

Q = 120 cfs

Common excavation total	9267.	cu yd
Fill from channel excavation	853.	cu yd
Channel compacted backfill total	9054.	cu yd
Compacted embankment total	7467.	cu yd
Fill from adjacent excavation	8201.	cu yd
Overhaul	0.	cu yd
Average minimum right of way	23.	feet

Old inlet and outlet elevation	4907.4	4891.4
Design inlet and outlet elevation	4907.4	4891.4

Design depth of channel	4.3	feet
Design width of channel	6.6	feet
Length of reach	6750.	feet

Lined Canal Reach Number One

Estimated Cost of Structures

Q = 120 cfs*

Estimated cost of siphon	0.
Estimated cost of tunnel	0.
Estimated cost of drops	0.
Estimated cost of concrete checks	8333.
Estimated cost of modified p. flume	0.
Estimated cost of turnouts	4909.
Estimated cost of county bridge	0.
Estimated cost of farm bridge	0.
Estimated cost of drainage crossings	0.
contingencies (10%)	1324.
Total cost of structures for this reach	14566.

Average canal seepage (AF-FT/CFS of flow) = 0.6391

Cost Function coefficients
a = 3491.
b = 22.6
c = 0.991

---

* Maximum design flow rate.

includes costs of structures, earthwork, lining, and rights-of-way for each flow rate interval, along with annual equivalent costs and conveyance efficiencies. Included also are estimated earthwork volumes and structural cost itemizations for the maximum design flow rate. The annual cost function coefficients and a correlation coefficient describing the regression analysis are also listed in the computer output.

Gravity and high pressure pipe systems

Annual ownership and operation costs of gravity and high pressure pipe system sections are calculated by computer routine PIPE over the range of design flow rates specified for each pipe section. Power and pumping requirements of high pressure systems are not estimated in this routine.

A simple flow chart listing subroutines called by the PIPE program is shown in Figure 16. Dashed lines in the figure represent input and output flows of data, and solid lines depict the order and flow paths of calculations and data within the routine. A documented listing of the PIPE program is included in Appendix B.

Data input, design, and cost estimation. Most of the data utilized by PIPE are read with the free-form format subroutine INPUT. Section labels are read from alphanumerically formatted cards or card images. Table 20 is a list of data required for execution of the PIPE routine.

A rehabilitation code concerning the placement of the pipe sections is first entered into PIPE. PIPE sections can be layed in natural,

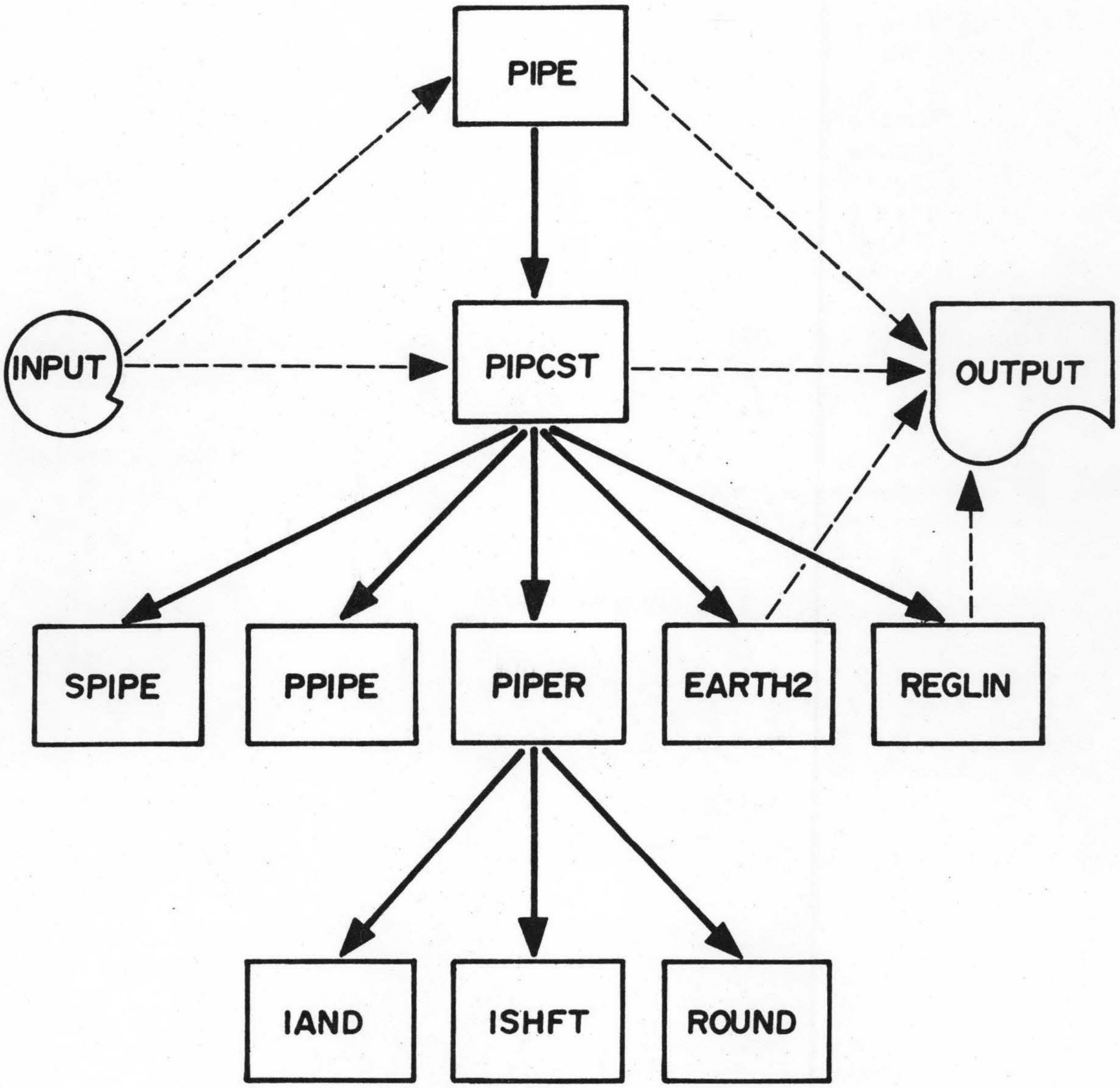


Figure 16. Flow chart for PIPE program used to calculate annual costs of pipe distribution systems.

Table 20. Input parameters used to calculate annual costs of gravity and high-pressure pipe distribution systems.

Input Parameters for PIPE

- Rehabilitation code
- Unit costs for excavation, backfill, and compaction:
    - Canals
    - Structures
    - Siphons
    - Pipe trenches
- Unit costs for concrete:
    - Canal lining
    - Structures
    - Siphons
- Unit costs for steel

Input parameters for subroutine PIPCST

- Cost indices for estimation of concrete pipe costs (USBR parameters):
    - Hourly wage rates
    - Equipment index
    - Area factor
    - Haul distances
    - Steel index
    - Cement index
    - Depth of backfill
    - Head class
- Cost contingencies (percentages):
    - Earth work
    - Steel reservoir
    - Right of way
- Cost contingencies for pipes, valves, etc. (percentages):
    - Concrete pipe
    - Steel pipe
    - Polyvinyl chloride pipe (PVC)
- Head class of PVC pipe
- Project life
- Annual interest rate
- Salvage value (% of original cost)

Input Parameters for PIPCST for Each Specific Pipe Section

- Length of section
- Hydraulic gradeline elevations at section inlet and outlet

Table 20. Continued.

- Elevations of pipe section at inlet and outlet
- Pipe type:
    - Concrete
    - Coal-tar-enameled steel
    - PVC (4 to 14 inch diameters)
- Water hammer factor
- Width and values of easement for cropped and uncropped land
- Rock excavation (%)
- Turnout code
- Miscellaneous turnout or pipeline items ($)
- Number and sites of turnouts
- Rehabilitation options:
    - Pipe trench data for natural terrain:
        - Station (feet)
        - Ground line elevation
        - Profile grade elevation
    - Existing channel description for rehabilitation:
        - Base width
        - Inside side slope
        - Height of channel sides
        - Top width of berms
        - Outside side slopes
        - Elevations of adjacent terrain at inlet and outlet
- Flow rate data:
    - Minimum flow rate
    - Maximum flow rate
    - Flow rate interval for evaluation and design

undisturbed terrain, or they can be placed above, on, or below the bottom of an existing canal route. Unit prices and cost indices for earthwork and system structures are also entered into this routine. These parameters coincide with unit costs used by the USBR and can normally be obtained for the region of study from the USBR or by contacting area construction companies. These parameters compare with those required by the CANAL routine.

Subroutine PIPCST is called to design and estimate costs for the pipe sections. Engineering, economics, and hydraulic data common to all pipe sections are read into this routine along with codes and cost indices used to determine pipe costs. Three major pipe types can be evaluated in this subroutine, namely concrete, coal-tar-enameled steel, and polyvinyl chloride (PVC). Cost estimates can be made for a preselected pipe type, or all three types can be evaluated, with the least cost type selected for study.

In addition to the length of the section under consideration and the elevations at each end of a section, the hydraulic head at the section inlet and outlet is also required to establish the allowable hydraulic gradient along the pipe. Concrete and steel pipe diameters are calculated by Scobey's equation, and PVC pipe is sized according to the Hazen-William's formula. All pipe diameters estimated are inside diameters and are sized in multiplies of 2 inches.

Subroutines SPIPE, PPIPE, and the modified USBR subroutine PIPER are used to estimate pipe costs for steel, PVC, and concrete pipe sections. Costs for PVC pipe are estimated only for pipe diameters up to 14 inches since costs of larger PVC pipe do not currently compare economically with those of concrete and steel. Pipe costs include transportation and laying costs of the pipe sections. Earthwork costs are calculated separately. Turnout costs are estimated for high pressure or for gravity pipe, and pressure regulating valves may be included.

Ground line and profile grade elevations for multiple stations along each pipe section are necessary to determine earthwork volumes and costs incurred by laying pipe along natural, undisturbed terrain. If the pipe sections are to be placed along an existing open channel, data listed in Table 20 describing old channel sections are required. A modified USBR subroutine EARTH2 is called to calculate all earthwork costs.

Subroutine PIPCST computes total construction and annual equivalent costs for intervals within the range of flow rates specified for a particular section. Subroutine REGLIN is then called to determine the linear regression coefficients of the annual cost function. This process is repeated for all sections of the pipe distribution system.

Subroutine PIPCST will also estimate construction costs for elevated steel tanks or regulating reservoirs. The sizes and steel requirements of the tanks and towers are computed using USBR sizing curves over a specified range of system flow rates. These costs are regressed into a separate annual cost function.

PIPE output. A sample of a PIPE program solution for evaluating the construction of a gravity pipe section along an existing open channel section is shown in Table 21, and output for a high pressure pipe section in natural terrain is listed in Table 22. Program output includes costs of pipe, turnouts, rights-of-way and earthwork for each flow rate interval evaluated. Included also are estimated earthwork volumes and an engineering summary. The annual cost function coefficients and corresponding correlation coefficient for each conveyance section are also included.

Limitations of CANAL and PIPE programs

The routines CANAL and PIPE have been written to be general in application, yet fairly accurate in system cost and size evaluation. Both routines are limited, however, in the types of systems they can be used to evaluate.

The CANAL routine is currently designed to analyze trapezoidal channels only, although channel side slope can be allowed to approach infinity. Each channel and pipe section is sized as though all turnouts were placed at the section outlet, thus avoiding required reductions in cross section along the section due to diminishing flow. If substantial volumes of water are diverted near the inlet of a section, then that section may require further subsectioning before input to the CANAL routine to facilitate accurate sizing and cost estimation.

All conveyance sections are sized for periods of peak consumptive use. Inclusion of adjustable checks may be necessary in evaluating open channel systems so that water may be elevated to levels required

Table 21. Sample PIPE computer routine output for a gravity pipe system section in a rehabilitation plan, Salem Irrigation District.

Gravity pipe reach -- Number 1. Length = 6750 feet

Q (cfs)	Diam. (in)	Length (ft)	Pipe Cost[1] ($)	Turnouts[2] ($)	Right of Way ($)	Earthwork[3] ($)	Total Cost ($)	Annual[4] Cost ($)	Pipe Type
40	40	6750	202500.	12749.	0.	47734.	262982.	19029.	Concrete
45	42	6750	202500.	12749.	0.	47917.	263165.	19042.	Concrete
50	44	6750	218700.	12749.	0.	49073.	280522.	20298.	Concrete
55	46	6750	243000.	12749.	0.	50265.	306014.	22142.	Concrete
60	48	6750	243000.	12749.	0.	51558.	307306.	22236.	Concrete
65	48	6750	243000.	12749.	0.	51558.	307306.	22236.	Concrete
70	50	6750	267300.	12749.	0.	52866.	332915.	24088.	Concrete
75	52	6750	291600	12749.	0.	54191.	358540.	25942.	Concrete
80	52	6750	291600.	12749.	0.	54191.	358540.	25942.	Concrete
85	54	6750	291600.	12749.	0.	55532.	359881.	26039.	Concrete
90	56	6750	315900.	12749.	0.	56889.	385538.	27896.	Concrete
95	56	6750	315900.	12749.	0.	56889.	385538.	27896.	Concrete
100	58	6750	340200.	12749.	0.	58614.	411563.	29778.	Concrete
105	58	6750	340200.	12749.	0.	58614.	411563.	29778.	Concrete
110	60	6750	340200.	12749.	0.	60393.	413342.	29907.	Concrete
115	60	6750	340200.	12749.	0.	60393.	413342.	29907.	Concrete
120	62	6750	364500.	12749	0.	62207.	439455.	31796.	Concrete

Table 21 Continued.

Note:

1 Pipe cost includes cost of pipe, laying of pipe, cost of fittings, valves, blocking, etc.
2 Turnout cost includes gate valve, line meter, pressure reducing valve, concrete pipe, steel pipe delivery, etc.
3 Earthwork cost includes trenching, backfilling and compacting backfill.
4 Annual equivalent cost assuming interest at 7.0%, a system life of 50 years, and 5.0% salvage value.

Example of PIPE computer routine output for a gravity pipe system in a rehabilitation plan. Salem Irrigation District

```
            Pipe earthwork for gravity pipe -- Reach 1

         Rehabilitation plan -- laying pipe in old channel

          Q = 120 cfs

          Total excavation                  9757 cubic yards

          Total compacted backfill          5027 cubic yards

          Total backfill (old channel)         0 cubic yards

          Total overhaul                       0 cubic yards

          Adjacent excavation              14831 cubic yards

          Total backfill                      53 cubic yards
------------------------------------------------------------------
Summary for this reach:

   Cost index for pipe system (B=1976)          1.
   Length of reach in feet                   6750.
   Elevation of pipe outlet, feet            4887.
   Elevation of pipe inlet, feet             4904.
   H.G.L. req. at pipe outlet, feet          4901.
   H.G.L. req. at pipe inlet, feet           4911.
   Width of easement, feet                     45.
   Value of easement for cropped land           0.
   Value of easement for other land             0.
   Percent length of other easement             0.

   Number of turnouts:

       Number = 5          Size (in) = 8
       Number = 1          Size (in) = 12
```

Table 21. Continued.

Check data for . . . . Q = 120 cfs

Capacity, cfs	120
Diameter, inches (rounded)	62
Average head class, feet	25
Type of cover	A*
Pipe cost, $/ft	45.00
Miscellaneous cost (dollars)	1275.00

Cost Function Coefficients

a = 12629.
b = 161.2
r = 0.986

* Cover depth is less than 5 feet.

Table 22. Sample PIPE computer routine output for a high-pressure pipe system section, Salem Irrigation District.

High pressure pipe -- Reach I.

Q (cfs)	Diam. (in)	Length (ft)	Pipe Cost[1] ($)	Turnouts[2] ($)	Right of Way ($)	Earthwork[3] ($)	Total Cost ($)	Annual[4] Cost ($)	Pipe Type
27	34	5060	117215.	31682.	0.	42077.	190974.	13820.	Steel
30	36	5060	124240.	31682.	0.	43447.	199370.	14427.	Steel
33	38	5060	221643.	31682.	0.	44819.	298144.	21572.	Steel
36	38	5060	221643.	31682.	0.	44819.	298144.	21572.	Steel
39	40	5060	233298.	31682.	0.	46191.	311171.	22515.	Steel
42	40	5060	233298.	31682.	0.	46191.	311171.	22515.	Steel
45	42	5060	245154.	31682.	0.	47565.	324401.	23472.	Steel
48	42	5060	245154	31682.	0.	47565.	324401.	23472.	Steel
51	44	5060	256809.	31682.	0.	48940.	337431.	24415.	Steel
54	44	5060	256809.	31682.	0.	48940.	337431.	24415.	Steel
57	46	5060	268665.	31682.	0.	50317.	350664.	25372.	Steel
60	46	5060	268665.	31682.	0.	50317.	350664.	25372.	Steel

Note:
1 Pipe cost includes cost of pipe, laying of pipe, cost of fittings, valves, blocking, etc.
2 Turnout cost includes gate valve, line meter, pressure reducing valve, concrete pipe, steel pipe delivery, etc.
3 Earthwork cost includes trenching, backfilling and compacting backfill.
4 Same as Table 21.

Table 22. Continued.

High pressure pipe -- Reach 1.
Q = 60 cfs

			Volumes				
Station	Pipe Dia.	Excavation	Backfill	C. Backfill	GLE-PGE	Diameter + Design Cover	Trench Width
0	46	4478.06	2983.00	640.17	8.20	7.83	7.46
2000	46	4478.06	2983.00	640.17	8.00	7.83	7.46
4000	46	2373.37	1580.99	339.29	8.00	7.83	7.46
5060	46				8.00	7.83	7.46

Total excavation	11329 cubic yards
Total compacted backfill	1620 cubic yards
Total overhaul	0 cubic yards
Total backfill	7547 cubic yards

Summary for this reach:

Cost index for pipe system (B=1976)	1.
Length of reach in feet	5060.
Elevation of pipe outlet, feet	4896.
Elevation of pipe inlet, feet	4904.
H.G.L. req. at pipe outlet, feet	5036.
H.G.L. req. at pipe inlet, feet	5044.
Width of easement, feet	50.
Value of easement for cropped land	0.
Value of easement for other land	0.
Percent of other easement	0.

Number of turnouts:
Number = 1 Size (in) = 12
Number = 1 Size (in) = 14

Check data for . . . . Q=60 cfs

Capacity, cfs	60
Diameter, inches (rounded)	46
Average head class, feet	200
Type of cover	A
Pipe cost, $/ft.	45.38
Miscellaneous cost, dollars	20900

Cost Function Coefficients
a = 8551.
b = 307.1
r = 0.861

for adequate turnout operation over a wide range of canal flow rates. Pressure buildups in pipe systems due to decreased friction losses which result from reduced flow rates may also occur, necessitating pressure control devices along the sections.

Most of the material quantities and cost curves used to describe structures in CANAL and PIPE, as well as in the subroutines TUNNEL, SIPHON, and PIPER, use design specifications formulated by the Bureau of Reclamation. These specifications may overestimate costs of structures planned for private irrigation systems unless appropriate unit prices and cost indices are used.

Existing canal sections evaluated in the rehabilitation options are assumed to be uniform in cross sectional area and channel slope, and are assumed to have trapezoidal shapes. Large variations in these parameters within a section may dictate further subsectioning. Channels and pipe systems planned for new areas can have multiple breaks in slope. Slope variations are accommodated using the terrain information input to the earthwork subroutines. All sections are sized, however, with the assumption of uniform slope along each section.

Application of the CANAL and PIPE routines to the Salem Irrigation District.

Four types of water conveyance (distribution) systems were evaluated for the Salem Irrigation District. These systems, unlined channel, lined channel, gravity pipe, and high pressure pipe, follow the routes shown in Figures 6 and 7. Basic descriptions of the gravity and pressure conveyance sections are listed in Tables 3 and 4. Routes for these systems are defined in Chapter IV.

The unlined channel route evaluated for planning purposes is that of the existing Salem Canal. The present canal system was chosen to represent the unlined channel planning alternative, so that evaluations and modelling of the present system could be made. As the Salem Canal is already in existence, construction costs of this alternative are essentially zero. Costs associated with this alternative are those costs incurred by replacement of canal water control structures and turnout devices with the same size and capacity during the canal system's expected service life. Since the present canal is of fixed size, the structures along the canal are also of a constant size. Thus, the coefficient b, in the cost function $C = a + bQ$, is zero. This coefficient has been arbitrarily set to 0.0001 for input to the linear programming matrix described in Chapter VI.

Lined channel route sections in the Salem Irrigation District were evaluated and modelled by the routine CANAL, and gravity and high-pressure pipe systems were studied with the computer routine PIPE. These routines have been described earlier in this chapter. All computer data used in evaluating these system alternatives are listed in Appendix C.

Annual costs for each system section were computed for a range of design flow rates comparable to those expected in each component and linear cost function coefficients were computed. These flow rates are listed in Tables 3 and 4 for the gravity and high pressure systems.

A least-squares linear regression analysis was run in the computer routine to determine the linear cost function of each section in terms of the design flow rates. Annual cost function coefficients and water conveyance efficiencies and losses of the systems are shown in Table 23. Also included in that table are coefficients describing the unlined channel alternative.

The high correlation coefficients, r, listed for the system sections in Table 23 indicate that the cost-discharge relationship of each section is estimated well by a linear equation in the form of equation 3-4.

Although canal seepage is often expressed as a function of flow rate due to variation in wetted perimeter, canal seepage losses in this study were assumed to be constant regardless of the flow rate, due to constant channel cross sections. Since the water level in many canals is held constant over a broad range of flow rates to enable proper turnout operation, seepage losses will often remain constant for a set canal section area.

Because channel areas in the lined canal alternative do vary with the design flow rate, seepage losses will vary also, but normally not in a linear fashion. These losses were assumed fixed also, to remain compatable with the unlined channel alternative. Seepage losses can be described in fixed and/or variable terms in the linear-programming model.

The system life estimated for all conveyance systems is 50 years,

Table 23. Annual cost function coefficients and water conveyance efficiencies and losses for planned distribution systems in the Salem Irrigation District.

System Section	a	b	r	Conveyance Efficiency %	Canal Losses (AF/yr)
UC1	642	.0001		95.7	641
UC2	1665	.0001		94.9	542
UC3	676	.0001		96.4	194
UC4	88	.0001		96.3	74
UC5	635	.0001		90.6	325
UC6	133	.0001		94.2	104
UC7	200	.0001		89.7	129
UC8	674	.0001		89.2	205
UC9	275	.0001		88.3	79
UC10	743	.0001		86.7	315
UC11	110	.0001		89.8	71
UC12	230	.0001		100.0	0
LC1	3491	22.6	.991	97.7	77
LC2	3051	28.7	1.000	97.6	76
LC3	1969	11.7	.897	98.8	24
LC4	683	6.9	.996	97.9	8
LC5	2416	30.8	.991	97.4	42
LC6	595	20.2	.951	97.7	12
LC7	924	21.3	.982	97.5	13
LC8	2180	53.7	.994	97.0	41
LC9	767	34.3	.996	97.4	9
LC10	1888	41.2	.998	97.3	32
LC11	926	48.5	.997	97.2	13

Table 23. Continued

System Section	a	b	r	Conveyance Efficiency %	Canal Losses (AF/yr)
GP1	12629	161.2	.986	100.	0
GP2	10795	184.9	.988	100.	0
GP3	4142	98.2	.981	100.	0
GP4	1438	33.3	.982	100.	0
GP5	6636	219.6	.967	100.	0
GP6	1180	125.3	.967	100.	0
GP7	1528	204.7	.954	100.	0
GP8	6555	376.4	.978	100.	0
GP9	1382	135.7	.973	100.	0
GP10	3841	286.2	.974	100.	0
GP11	1822	168.1	.967	100.	0
PP1	8551	307.1	.861	100.	0
PP2	803	808.3	.933	100.	0
PP3	5659	112.2	.986	100.	0
PP4	4390	127.6	.946	100.	0
PP5	6461	733.1	.931	100.	0
PP6	2685	142.4	.970	100.	0
PP7	2363	229.0	.877	100.	0
PP8	3499	556.4	.941	100.	0

UC = unlined channel
LC = lined channel
GP = gravity pipe
PP = high pressure pipe

and an interest rate of 7.0% was used in the annual cost estimation.

Listings of computer output for the lined channel, gravity pipe, and high pressure system alternatives have been included in Appendix D. Sample outputs describing the evaluation of section I of the three alternative sections are shown in Tables 19, 21, and 22.

Pumping System Annual Costs

Annual costs of owning, operating, and maintaining irrigation pumping systems are calculated by the computer routine PUMP. Costs can be computed for large pumping plants operating from rivers, canals, or reservoirs, and for smaller pumping stations designed for on-farm operation. Total construction and power costs associated with each system are calculated in relation to the flow rate capacity of the pump units. Figure 17 is a diagram of the cost-estimating computer subroutines utilized by the PUMP program. Dashed lines in the figure represent input and output flow of data, and solid lines depict the order and flow paths of calculations and data within the routine. A documented listing of the PUMP program is included in Appendix B.

Data required by the PUMP routine are read in with the free-form subroutine INPUT. System labels and output headings are entered directly to the PUMP routine on alphanumerically formatted cards or card images. Pump system parameters input to the PUMP program for systems cost estimation are listed in Table 24.

Large pumping systems

Subroutine PMPCST is called by PUMP to estimate costs of large

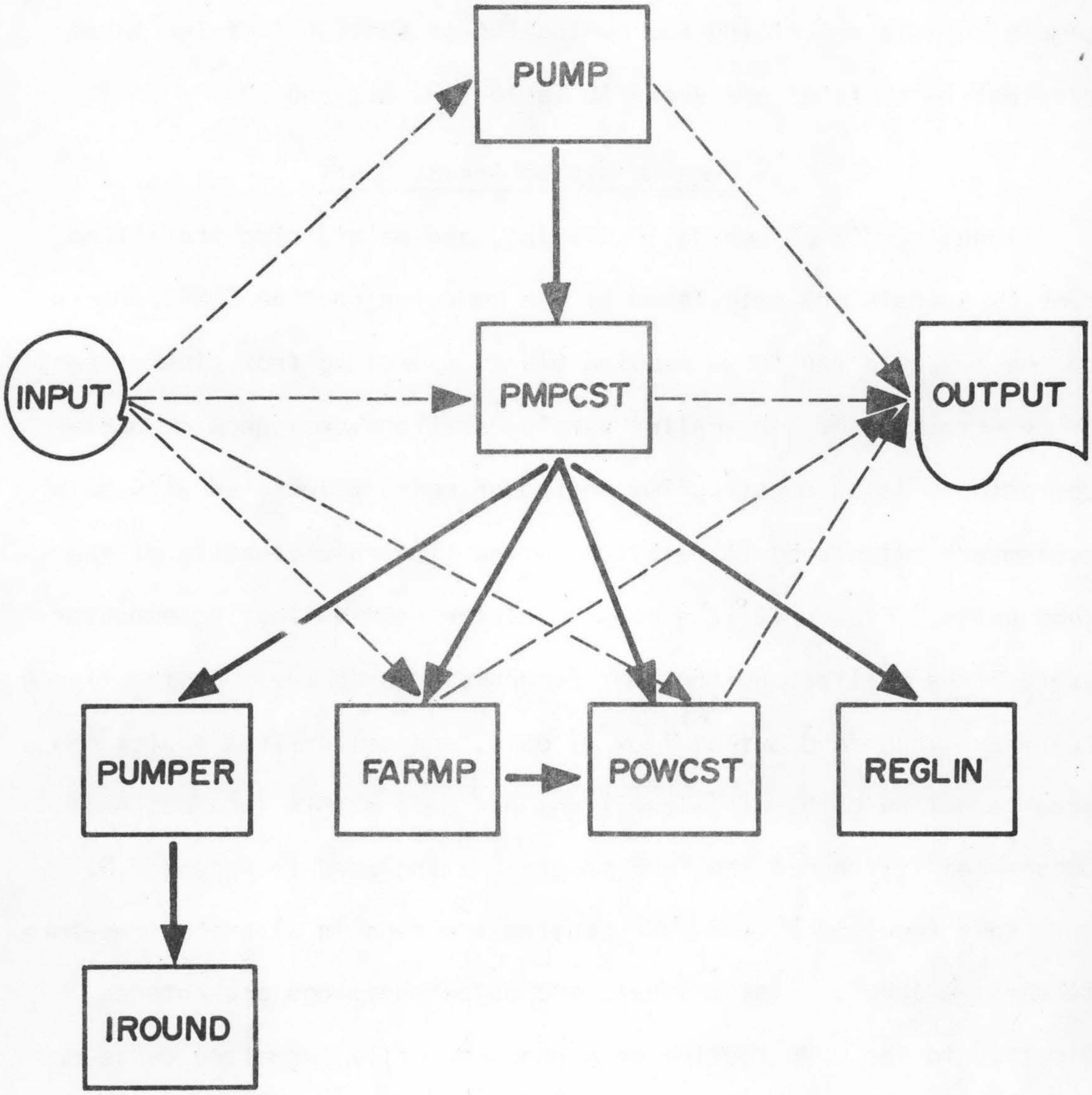


Figure 17. Flow chart for PUMP program used to calculate annual costs of large and small pumping systems.

Table 24. Input parameters used to calculate annual costs of electric pumping systems.

Input Parameters for PUMP

- Type of pumping station:
  - River pump (large station)
  - Farm pump (small station)

Input Parameters for PMPCST (large station)

- Number of units
- Unit type:
  - Vertical
  - Horizontal
- Total dynamic head
- Month and year of estimate
- Contingency cost for pumping plant (%)
- Cost of forebay, discharge lines, etc. (% of pumping unit cost)
- Cost of power (¢/kw-hr)
- General cost index (I. = 1976)
- Type of pumping station:
  - Unattended plant
  - Semi-attended plant
  - Attended plant
- Sediment code for wear allowance
- Transmission line data:
  - Transmission line length
  - Terrain code
  - Foundation code
  - Contingency cost (%)
- Cost indices:
  - Transmission line (I. = 1976)
  - Irrigation operation and maintenance (I. = 1976)
- Switching bay data:
  - Contingency cost (%)
  - Cost index of bay (I. = 1976)
- Service life of transmission line and switching bay
- Salvage value (% of original cost of line and bay)
- Service life of pumping unit(s)
- Interest rate
- Salvage value of unit (% of original cost)
- Average escalation of energy over system life (%/year)
- Monthly irrigation requirement
- Length of operating season
- Hourly wage rates of mechanics and operators

Table 24. Continued.

Land area serviced by pumping system
Flow rate data:
    Minimum flow rate
    Maximum flow rate
    Flow rate interval for evaluation and design

Input Parameters for FARMP (small on-farm pumping station)

Total dynamic head
Cost index for pump facilities (1. = 1976)
Type of pumping unit:
  Centrifugal
  Turbine
Pumping unit efficiency (%)
Miscellaneous costs of pump, discharge lines, etc (% of cost of unit)
Contingency cost (% of field cost)
Service life
Interest rate
Salvage value (% of original cost)
Other expenses (% of original cost)
Average escalation of energy over system life (%/year)
Monthly irrigation requirement
O&M, taxes, and insurance (% of original cost)
Deep well data:
  Service life
  Interest rate
  Salvage value
  Well type:
    Alluvium
    Hard rock
  Miscellaneous costs of discharge lines, housing, etc (% of cost of unit)
  Contingency cost (% of field cost)
  Depth of well
Flow rate data:
  Minimum flow rate
  Maximum flow rate
  Flow rate interval for evaluation and design

Input Parameters for POWCST

Demand charge type (private utility):
  Flat rate over specific horse power range
  Rate schedule based on demanded power
Energy rate schedule (private utility)

pumping plants. These plants are assumed to draw water from an adjacent free water surface, or they function as booster stations along a pipeline. Multiple pumping units may be designed for each station, and units may be of vertical or horizontal design.

System costs for stations are evaluated over the same range of design flow rates used in the high pressure pipe system supplied by the pumping station. For each flow rate interval entered, pump units are sized, and pumping station and power costs are determined.

PMPCST computes annual operation and maintenance costs of the pumping system using the methodology developed by Eyer (1965), considering three types of pumping plants; (1) unattended, (2) semi-attended, and (3) attended. Efficiency of pumps and motors and wear allowance factors are selected based on USBR curves. Horsepower requirements of the motors are computed in increments of 5 horsepower. Annual kilowatthour consumption is based on monthly crop irrigation requirements, length of pumping season, and land area served by the station.

A USBR subroutine entitled PUMPER is used to estimate the following items related to large pumping plants; (1) structural improvement, (2) waterways, (3) pumps and motors, (4) electrical accesories, and (5) miscellaneous equipment and switchyards. The calculations used in this subroutine are based upon USBR costs curves and pump station specifications.

Three power supply options are considered in PMPCST for large pumping operations. These options are:

(1) Government agency (Bonneville Power Administration) builds transmission lines and charges a mill rate for power.

(2) Government agency supplies power and the utility company builds power transmission lines and charges a "wheeling cost." This cost is estimated to be 18 percent of the power transmission line cost.

(3) Private utility supplies power and builds transmission lines. Power cost is based on the demand and energy rate schedule of the utility.

Transmission line costs are calculated using USBR cost curves, and private utility power costs are estimated using subroutine POWCST. This subroutine estimates monthly power costs based on monthly demand and energy rate schedules by the private utility.

All three power supply alternative are analyzed, with the least cost option selected for further evaluation. The calculated power costs of the options are escalated over the system's service life using the equivalent annualizing factor discussed by Keller (1976). This factor compensates for possible power cost increases during the system's life span due to inflationary trends.

After total construction, operation, and power costs have been computed for each flow rate interval considered, the equivalent annual costs associated with each flow rate are linearly regressed by subroutine REGLIN to determine annual cost function coefficients of the pumping plant.

Small pumping systems

Subroutine FARMP is called by PUMP to estimate costs of on-farm pumping units. These units would consist of a turbine or centrifugal pump with an electric motor used as a power supply. The water source of the on-farm unit can be a free-water surface near ground level, such as a canal or gravity pipe, or water can be pumped from a deep well. On-farm pumping systems are assumed to be used to pressurize irrigation sprinkler systems.

The total dynamic head required by the pump, along with the pump type and "wire-to-water" efficiency is entered into FARMP. Pump and motor sizes and costs as well as power costs are then determined for a specified range of flow rates. This range should cover all possible flow rates demanded during the period of peak consumptive use by the various types, number, and sizes of sprinkler systems designed for planned farm sizes on soil types studied.

If a deep well is required to supply water to the area, then data concerning the well are entered. The cost of constructing the well is estimated using USBR cost information.

Power costs of on-farm pumping units are also escalated over the estimated service life to compensate for increasing energy costs. The escalation factor entered into the program is the estimated percent increase in energy costs per year during the period of pumping plant use. Monthly power costs are determined using the monthly irrigation water requirement entered into the computer routine.

If increments of pump flow rate evaluation are set small enough (5 to 10 gpm), then a comprehensive table can be printed concerning the specific dynamic pumping head, interest rate, system life, and power schedule entered into the program. Annual pumping costs needed to fulfill the water requirements of the various irrigation application system types can then be selected from the output table.

PUMP program output

A sample of PUMP program output for a large river or canal pump is listed in Table 25. Program output includes the pumping plant, operation, maintenance, and power costs estimated for each design flow rate interval. Also included in the output is a summary of component costs of the large pumping plant, based upon USBR specifications and cost curves. Coefficients of the equivalent annual cost function representing the annual system cost in relation to the design rate are also printed.

Table 26 is a list of PUMP output describing annual on-farm costs for pumping systems supplying canal water to a high pressure lateral at a head of 150 feet. Along with the horsepower required by the electric motor, costs associated with the pump and motor, operation and maintenance, taxes and insurance, power, and well costs are produced for each flow rate interval specified. Pump and motor cost equations used were computed from curves representing small system pump costs for the southern Idaho area.

Limitations of the PUMP routine

All pumping units in this routine are assumed to be powered by electricity supplied from an outside source. If alternative energy forms are desired, electric power costs estimated by routine PUMP can be itemized from total annual cost, and electric motor costs will need

Table 25. Sample of PUMP computer routine putput for a large pumping system, Salem Irrigation District

River pump -- Canal to high pressure pipe -- Teton Island Canal

Q (cfs) 1/	H.P. Used 2/	Pumping Plant cost ($)	Annual Equiv. cost ($/yr) 3/	Operation cost ($/yr)	Maintenance cost ($/yr)	Replacement cost ($/yr)	Power cost ($/yr) 4/	Annual pumping cost ($/yr) 5/
27.	980.	1011461.	74602.	1400.	7136.	6/	103761.	186899.
30.	1085.	1109136.	81806.	1471.	7220.	6/	114529.	205026.
33.	1185.	1206610.	88996.	1539.	7296.	6/	124784.	222614.
36.	1290.	1300590.	95927.	1603.	7366.	6/	135552.	240448.
39.	1390.	1397671.	103088.	1664.	7431.	6/	145807.	257990.
42.	1490.	1494549.	110233.	1723.	7492.	6/	156062.	275510.
45.	1590.	1587955.	117122.	1780.	7549.	6/	166317.	292769.
48.	1690.	1681173.	123998.	1835.	7603.	6/	176573.	310008.
51.	1790.	1775835.	130980.	1888.	7653.	6/	186828.	327349.
54.	1890.	1868675.	137827.	1939.	7702.	6/	197083.	344551.
57.	1990.	1964576.	144901.	1989.	7748.	6/	207338.	361976.
60.	2090.	2055416.	151601.	2038.	7792.	6/	217593.	379023.

Note:

1/ Wear allowance was included.
2/ Horsepower used was rounded to the nearest 5 HP.
3/ Includes indirect costs (engineering costs).
4/ Includes Trans, and SW bav costs if applicable.
5/ Annual pumping cost includes annual equiv. cost of pumping plant, OM and R, and power cost.
6/ 15 percent for replacement was added to maintenance cost.

Table 25. Continued.

Number of pumping units	4.
Type of pumping unit -- verticle pump	
Total dynamic head, feet	175.
Date of estimate	6/76
Check cost for the last "Q" considered:	
Plant capacity, cfs	60.
Structures and improvements	422000.
Waterways	112000.
Pumps and motors	229000.
Electrical acessories	137000.
Miscellaneous Equipment	23000.
Switchyards	89000.
Subtotal of pumping plant	1012000.
Cost of intake, discharge lines, etc.	229000.
Contingency cost	248200.
Pump field cost	1489199.
Indirect cost	566217.
Pump total construction costs	2055416.
Transmission line cost	281457.
Add 50 percent for mountainous terrain	0.
Add 50 percent for rocky/swamply ground	0.
Add 100 percent for line under 5 miles	281457.
Add 50 percent for line 5 to 20 miles	0.
Subtotal	562915.
Switching bay cost	339463.
Contingencies (TL and SB)	62092.
Total Field Costs	964470.
Indirect cost	310686.
Total power line construction costs	1275156.

	Present rate	Inflated rate
Annual power cost -- Opt 1 F. rate, own line	183919.	757034.
Annual power cost -- Opt 2 Wheeling charge	229528.	944766.
Annual power cost -- Opt 3 Private utility	52864.	217593.

Cost function coefficients:
a = 30822.
b = 5812.8
r = 1.000

Table 26. Sample PUMP computer routine output for a small on-farm pumping system, Salem Irrigation District.

Farm Pump -- Canal to Sprinkler -- 150. TDH 9.5% Interest

Q (GPM)	H.P. 1/ used	Pump cost ($) 2/	Pump fixed Cost ($/yr)	O & M 3/ ($/yr)	Taxes & Ins. ($/yr)	Power cost ($)	Well cost ($) 4/	Pumping cost ($/yr) 5/
650	35	5604.	688	168.	97.	2124.	0.	2977.
660	36	5635.	692.	169.	97.	2053.	0.	3011.
670	36	5665.	696.	170.	98.	2081.	0.	3045.
680	37	5695.	700.	171.	98.	2110.	0.	3079.
690	37	5724.	703.	172.	99.	2139.	0.	3113.
700	38	5724.	707.	173.	99.	2168.	0.	3146.
710	38	5783.	710	173.	100.	2196.	0.	3180.
720	39	5812.	714.	174.	100.	2225.	0.	3214.
730	40	5840.	717.	175.	101.	2254.	0.	3247.
740	40	5869.	721.	176.	101.	2283.	0.	3281.
750	41	5897.	724.	177.	102.	2312.	0.	3314.
760	41	5924.	728.	178.	102.	2340.	0.	3348.
770	42	5952.	731.	179.	103.	2369.	0.	3381.
780	42	5979.	734.	179.	103.	2398.	0.	3415.
790	43	6007.	738.	180.	104.	2427.	0.	3448.
800	43	6033.	741.	181.	104.	2455.	0.	3482.
810	44	6060.	744.	182.	105.	2284.	0.	3515.
820	44	6087.	748.	183.	105.	2513.	0.	3548.
830	45	6113.	751.	183.	105.	2542.	0.	3581.
840	45	6139.	754.	184.	106.	2570.	0.	3615.
850	46	6165.	757.	185.	106.	2599.	0.	3648.

1/ HP used was rounded to the nearest 5.0 HP.
2/ Pump cost includes housing, discharge facilities, sump, etc.
3/ O & M includes minor replacement cost.
4/ Well cost includes drilling, casing, testing, screen assembly, etc.
5/ Annual pumping cost includes amortization of pump unit and well, O & M, taxes, and Ins. and power cost.

to be separated from the pumping unit costs.

All cost estimation techniques and design specifications used in the subroutine PMPCST to calculate costs for large pumping plants were obtained from the Bureau of Reclamation. These estimation techniques tend to over estimate costs of pumping systems used on small non-federal projects. Component costs of the large pump program output should be checked with local or regional sources to verify their accuracy in describing costs for planned systems.

Power costs can be escalated in this routine to compensate for current inflationary increases in electrical power costs. As this escalation factor is an extrapolation of current or historical price trends, judgement must be excercised in application and presentation of annual power cost estimations computed using this factor.

Pumps are sized in this routine for the design flow rate intervals entered. Since pumping demands are normally less than the design value early and late in the irrigation season, several small pumping units, rather than one large unit, may be desired in systems planning. Individual units can then be used in slack demand periods to maintain a high pumping efficiency.

Application of the PUMP routine to the Salem Irrigation District

Annual costs were estimated by routine PUMP for a large pumping station designed to supply the entire Salem Irrigation District with pressurized water sufficient for high pressure sprinkler operation.

Water would be pumped from a forebay along the Teton Island Feeder into the high pressure pipe system shown in Figure 7 and discussed in Chapters IV and V. The life of the large pumping unit was estimated to be 40 years, and annual costs were computed with an interest rate of 7.0 percent, with salvage value of the station equal to 25% of initial cost.

On farm pumping costs were estimated by the PUMP routine for units supplying water from a gravity conveyance system to sprinkler mains and laterals at a pressure of 65 psig. System life expectancies of on-farm pumps and motors were estimated to be 15 years. Annual costs were calculated at 9.5 percent interest.

Computer solutions describing the large pumping station and on-farm pumps are listed in Table 25 and 26. A summary of the various pumping system characteristics and costs is listed in Table 27. Itemized costs of the large pumping station as estimated by the PMPCST subroutine were reduced by 80 percent to more realistically represent fixed annual costs of an unattended pumping station privately owned and operated. The magnitude of cost reduction necessary was calculated using cost estimates of pump units and motors obtained from local dealers. All other component costs of the USBR specified pumping station were reduced by similar percentages. On-farm cost estimates for turbine pumps were found to be quite accurate, as these cost function were computed using 1977 cost data obtained from regional irrigation pump dealers in southern Idaho.

Table 27. Annual cost relationships for pumping plants planned for the Salem Irrigation District.

Type of Pumping Plant	Plant Efficiency (percent)	a[1] ($/cfs)	b[1] ($)	r^2
Pumping plant and inlet structure designed to receive surface flows from the Teton Island Feeder and discharge water at a pressure of 75 psig into the planned high pressure pipe system	56[3]	23620.	3060.	1.000
Small on-farm pumping plant designed to receive surface flows from an irrigation conveyance system and discharge water at a pressure of 65 psig into on-farm irrigation mains	70	693.	3.4	0.999

[1] Coefficients of Equation 3.4, annual cost = $a + bQ$

[2] Correlation coefficient relating actual computed cost values with those estimated by Equation 3.4.

[3] Value computed in PMPCST subroutine.

Alternative Gravity High-Pressure System

An alternative to the proposed large pumping station to be used to supply pressurized water to the Salem Irrigation District was studied during this project. This alternative would include the construction of a large buried pipeline connecting all land areas presently irrigated with water from the lower Teton River to a diversion point located on the Teton River at an elevation 175 feet above Sugar City, Idaho.

The irrigation districts to be served by this pipeline system would include the Wilford-Stewart, Teton Sidoway, Teton Island, Salem, and Rexburg Irrigation Districts. The land area supplied with water of sufficient pressure for operation of most sprinkler systems would total 24,100 acres. Water would be supplied from the 25 mile long pipe system to one or two locations within each district. Distribution systems within the districts, themselves, would not be included as part of the proposed system.

Table 28 is a summary of diversion and outlet locations along the large pipeline route and includes the estimated pipe diameter, pipe flow rate, and water pressure at each turnout location. Because of the gentle slope of the terrian along much of the pipeline route, large pipe diameters are required to decrease friction losses in the pipe so that sufficient water pressure can be developed due to elevation.

Table 28. Parameters concerning the gravity pressurized pipe system planned to service the lower Teton River flood plain with high pressure water. Teton Rehabilitation Study, University of Idaho, 1978

Location	Elevation (feet)	Pipe Section Length (feet)	Flow Rate (cfs)	Pipe Diam. (inches)	Press. (psig)	Pipe Cost ($/ft)
Inlet	5080				4	
		78,000	434	128		188.
Wilford-Stewart District	4941				51	
		14,000	380	118		172.
Teton-Sidoway District	4940				48	
		13,000	300	108		158,
Salem District and upper Teton Island District	4905				60	
		16,000	200	74		108.
lower Teton Island District	4880				60	
		10,000	125	60		88.
Rexburg District	4860				60	

Coal-tar-enamel coated steel pipe was selected for economic reasons and also due to ease of installation and light weight of this pipe type as compared to concrete pipe. The inlet of the pipe system would be located in the Teton River Canyon at a point about one mile above the location of the Teton Dam site. A diversion dam approximately ten feet in height would be required to divert water from the river into the pipe system.

The proposed pipeline would run west along the Teton River Canyon to the lower Teton River flood plan, where it would then follow a fairly direct path to each irrigation district. Rights-of-way along county roads were used where possible to minimize disturbance of farming areas. The pipeline route could follow U.S. highway 191-20 between Sugar City and Rexburg.

Table 29 is an itemization of estimated costs for the pipe system. The cost of this system could be charged to each irrigation district according to irrigated area. Overall construction costs of the system were estimated to total $25,390,000. The total cost of the pipeline system to be charged to the Salem Irrigation District, based on irrigated area, would be $2,950,000 or $1050/acre. Annual costs for the Salem District would total $284,000 ($101/acre) at 9.5 percent interest, or $214,000 ($76/acre) at an interest rate of 7.0 percent. These figures include costs of pipe, excavation, installation, and turnouts, as well as the cost of the diversion structure at the system inlet. Annual costs estimated for the gravity high-pressure pipe system correspond to a flow

Table 29. Estimated costs of a proposed pipe system designed to supply gravity pressurized water to the lower Teton River flood plain.

Total pipeline length, feet	131,000
Area served, acres	24,000
Estimated service life, years	50
Total pipe cost	$21,670,000
Earthwork cost	$3,340,000
Diversion dam cost	$250,000
Cost of turnouts	$130,000
Total cost	$25,390,000
Annual cost @ 9.5% interest	$2,438,000
@ 7.0% interest	$1,840,000
Annual cost to Salem District	
@ 9.5% interest	$284,000
@ 7.0% interest	$214,000

rate of 50 cfs supplied to the Salem Irrigation District. These costs are substantially higher than the $177,000 annual cost estimated at the same flow rate for the pumping system described in the previous section in this chapter, although the life expectancy of the pumping system was estimated at 40 years, compared to 50 years for the pipe system.

The annual pumping plant cost estimated for the Salem Irrigation District includes an electric power escalation factor of 9 percent per year. If power costs can be foreseen to escalate at a rate greater than 9 percent during the service life of these systems, then a gravity pipe system supplying high pressure water to the lower Teton River flood plain may become economically feasible. Inclusion of a high head turbine in the system for the purpose of generation of electric power in the non-irrigation season months could make the cost of the pipe system alternative feasible, providing the generated power could be used in the general area or could be sold to private utility companies.

Construction of this proposed system alternative would necessitate conversion of most of the Teton plain area to high pressure sprinkler systems. This conversion could result in much higher water-use efficiencies for the area along with more uniform and increased crop yields through increased irrigation control. Use of the pipe system to furnish sprinkler pressure would be beneficial if power supplies in the area were limited. The cost per acre of conversion to high pressure sprinkler systems, along with the annual cost of the gravity high-pressure system, may prove prohibitive to the area land owners, however, unless benefits realized by this conversion could prove to be beneficial to the water users.

CHAPTER VI

SYSTEMS OPTIMIZATION PROCEDURES

Whenever two or more system component alternatives are available for selection and use within any type of system, some sort of decision-making process or methodology is required to select the most favorable alternative. In irrigation systems planning, several alternative distribution and application system types with varying costs, water-use efficiencies, and operating requirements are possible. Various forms of optimization techniques can be used to build combinations of system component alternatives which fulfill necessary functions and constraints in the systems. These constraints may include minimum water-use efficiencies, energy and water limitations, water quality levels, and the total systems cost.

Optimization Techniques

Two types of optimization techniques are used in this model to formulate combinations of irrigation distribution and application systems subject to both external and internal system requirements. Dynamic programming is the optimization procedure used to select the best possible conveyance (distribution) system alternative combinations to be used in supplying the various on-farm application systems. A linear-programming routine utilizes the dynamic-programming output to select optimal least cost multiple application and distribution system combinations. The particular dynamic-programming routine used has been written specifically for use with this irrigation systems planning model although the decision theory incorporated into the routine is universal in application.

Dynamic Programming Procedure

The number of section component combinations possible in an irrigation distribution system is dependent upon the number of alternative components to be considered for any one section and the total number of sections in the distribution system. If two section component alternatives, lined and unlined channels, are to be considered at any of three sections, the number of possible system alternatives is 2^3 or 8, as illustrated in Figure 18 and Table 30. It must be assumed that these components are compatible, i.e., that both types may receive water from and discharge water to each type. If M different components are to be equally considered for each of N sections of a distribution system, the total number of possible combinations for the system is equal to M^N. Incompatible components such as open channels and pressurized pipelines must be considered in systems independent of each other. In the Salem Irrigation District planning situation, there are 3 possible distribution system alternatives for each of 11 sections in the distribution system. Thus, the total number of distribution system section combinations possible is equal to 3^{11} or 177,147. Dynamic programming may be employed to eliminate or prune out combinations of alternatives that are dominated by more attractive solutions, such as those with lower annual costs and higher conveyance efficiencies. The process is a simple, multi-staged process based upon Bellman's <u>Principle</u>

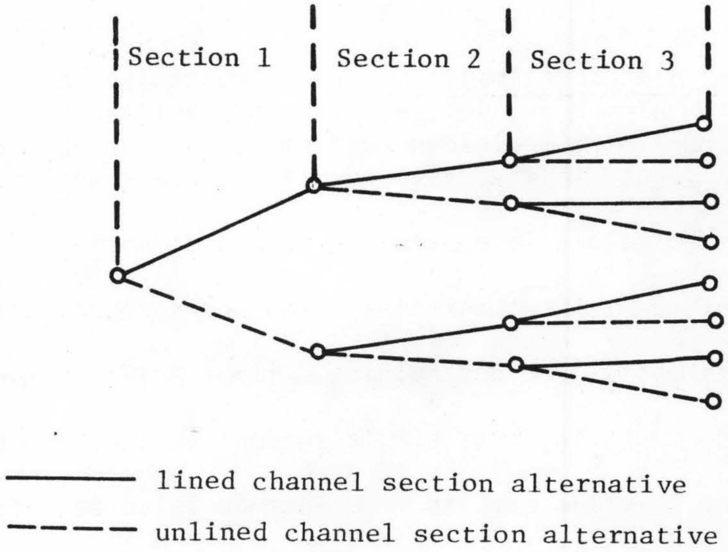


Figure 18. Section component combinations for an irrigation distribution system.

Table 30. Possible alternative component combinations of a simple irrigation distribution system.

Combination Number	Section Number		
	1	2	3
1	LC	LC	LC
2	LC	LC	UC
3	LC	UC	LC
4	LC	UC	UC
5	UC	LC	LC
6	UC	LC	UC
7	UC	UC	LC
8	UC	UC	UC

LC = lined channel
UC = unlined channel

of Optimality, (1957), defined as follows:

> Principle of Optimality. An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision.

This principle is applicable to a wide variety of problems including those dealing with sequential systems and resource allocation. It is especially useful for determining optimal policies for large complex systems by requiring that single sequential decision be made (Bellman, 1962), and that the payoffs from each decision be additive or multiplicative (de Neufville and Stafford, 1971). The dynamic-programming approach can provide a means of solving some problems considered unsolvable by other optimization routines. If the decision is made to not include one possible alternative combination somewhere in the optimization process, all future decisions must constitute an optimal policy with regard to this first decision. The combination building process must take into account non-uniform flow within the irrigation system due to the dendritic nature of distribution systems and also due to the range of system diversions caused by variations in operating efficiencies of on-farm application systems (Busch, 1974).

Programming objective

As with any optimization process, an objective must be defined which the process must seek to optimize. The objective for distribution system component selection is to select those components and combinations thereof that will most efficiently convey water at the least cost. Constraints for the objective include the range of discharges possible for any given section and the types of components will be pruned if the cost of delivering water within a specified range of discharges at a computed conveyance efficiency is greater than the cost for another component or combination delivering water at an equal or greater conveyance efficiency. A component may also be pruned if it does not meet the criterion of being a specific type specified for a given section.

Combination elimination procedure

The pruning process used in this dynamic procedure eliminates those component combinations having greater costs and lower efficiencies than other more efficient, lower cost combinations. The computational technique of the process utilizes the annual system component costs described by Equation 3.4 and the component water conveyance efficiencies computed using Equation 3.1.

Two compatible alternative components, component 1 and component 2 are considered in the following example. The annual costs and water conveyance efficiencies for components 1 and 2 are $C_1 = a_1 + b_1 Q$, $C_2 = a_2 + b_2 Q$, E_{c_1} and E_{c_2}. If $a_1 > a_2$ and $b_1 > b_2$, then the annual cost for component 1 is greater than the cost for component 2 for all possible values of Q. This point is illustrated in Figure 19. If $E_{c_2} \geq E_{c_1}$, the less desirable component 1 can be eliminated because of the higher cost and lower conveyance efficiency. If $E_{c_1} > E_{c_2}$, component 1 must be retained because the higher efficiency may warrant the increased cost.

Frequently, when comparing the costs and efficiencies for two components 1 and 2, the constant terms of the annual cost functions have values such that $a_1 > a_2$ when $b_1 < b_2$. The result is that the cost functions are lines that intersect at some point, Q_1', as illustrated in Figure 20. The total annual costs for component 2 are less than those for component 1 for all discharges less than Q_1'. If $E_{c_1} \leq E_{c_2}$ and if the specified range of discharges is $0 \leq Q \leq Q_1'$ then component 1 can be eliminated because of the lower efficiency and higher costs for the range of discharges specified.

Formulation of component combinations

The overall size of a distribution system depends upon the amount of water conveyed by the system and(or) diverted from the system for application. If the diversion from a downstream section, labelled section 2, in a distribution system is d_2, the flow rate entering that reach must be $\frac{d_2}{E_2}$ where E_2 is the conveyance efficiency of that particular section. This size of flow rate is necessary if the diversion requirement, d_2, is to be fulfilled. Likewise if the supplying section (section 1) has a diversion rate of d_1, the total flow rate entering section 1 must satisfy the diversion rates and conveyance losses of both sections 1 and 2. The flow rate entering section 1 must be:

$$Q_1 = \frac{d_1}{E_1} + \frac{d_2}{E_1 E_2} \qquad (6.1)$$

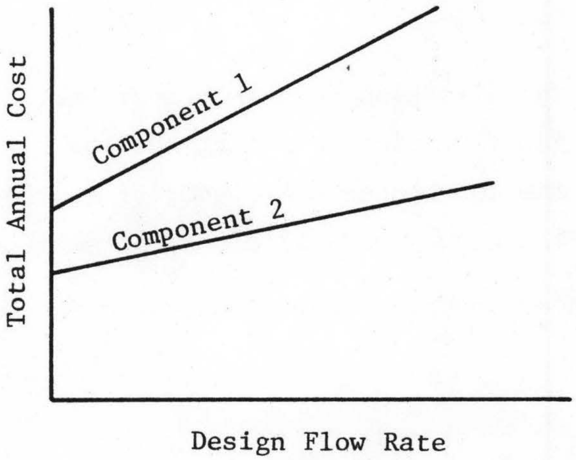


Figure 19. Non-intersecting distribution system alternative component cost functions.

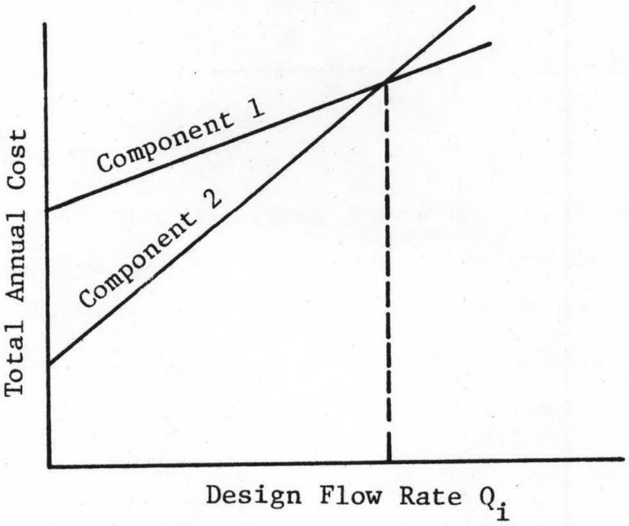


Figure 20. Intersecting distribution system alternative component cost functions.

The total annual cost for a component branch (combination) consisting of two sections where section 2 is downstream from section 1 is:

$$\text{Cost} = (b_1 \left(\frac{d_1}{E_1} + \frac{d_2}{E_1 E_2}\right) + b_2 \left(\frac{d_2}{E_2}\right)) + (a_1 + a_2) \qquad (6.2)$$

Where d_1 is the diversion rate from section 1
d_2 is the diversion rate from section 2
E_1 is the conveyance efficiency of section 1
E_2 is the conveyance efficiency of section 2

The total water conveyance efficiency for the same two combined components is:

$$E_c = (d_1 + d_2) \,/\, \left(\frac{d_1}{E_1} + \frac{d_2}{E_1 E_2}\right) \qquad (6.3)$$

For the general case of n components within a distribution system branch with no diverging forks, the cost and water conveyance efficiency of the entire system are determined as follows:

$$\text{Annual cost} = \sum_{i=1}^{n} \left(d_i \left(\sum_{j=i}^{n} \frac{b_j}{\prod_{k=i}^{j} E_k}\right)\right) + \sum_{i=1}^{n} a_i \qquad (6.4)$$

Where b_i = annual component costs per unit flow rate
d_i = diversion flow rate of the $i^{\underline{th}}$ section
E = conveyance efficiency of the $k^{\underline{th}}$ section
Π = product symbolizing $E_i \, (E_{i+1})(E_{i+2})(E_{i+3})(E_j)$
a_i = annual component fixed costs

$$OE = \sum_{i=1}^{n} \left(d_i / \left(\sum_{i=1}^{n} \left(d_i \,/\, \prod_{k=i}^{n} E_k \right)\right)\right) \qquad (6.5)$$

Where OE = overall water conveyance efficiency

d_i = the minimum or maximum diversion flow rate of the $i^{\underline{th}}$ section

E_k = individual component water conveyance efficiency

and i progresses from 1, representing the section furthest from the source of the distribution system, to n, representing the section nearest the water source.

The annual system cost will vary from a minimum when minimum diversion flow rates from all sections are used for system design, to a maximum when the maximum possible diversion flow rates from all sections are expected to occur. The magnitude of the diversion flow rates actually used for sizing of the distribution system is dependent upon the type(s) of application system(s) chosen by the linear-programming model for the specific areas served by the diversions.

Costs and efficiencies are compared for each system combination for all i = 1, n, and all higher cost, less efficient combinations are pruned at each step. A less efficient combination can be pruned only if the total annual cost is higher for all ranges of minimum and maximum diversion flow rates in its respective sections.

For computational ease, combinations are formulated in this dynamic-programming procedure beginning with the section farthest downstream from the source, and progressing in a sequential manner upstream toward the source.

The total number of combination comparisons and thus the amount of computation time required by this optimization procedure is reduced as a result of pruning less desirable component combinations at each step in the decision process. The decision theory used does constitute an optimal policy because all decisions (combination eliminations) at each succeeding procedural step (section addition) constitute an optimal policy with regard to the problem status resulting from those decisions.

Dynamic programming computer routine

Because of the large number of decisions involved in the formulation of optimal alternative combinations for large distribution systems, a digital computer program utilizing the dynamic-programming theory discussed in the previous section of this chapter is used in this irrigation planning model. A listing of the documented program DYNAM, written in FORTRAN IV, has been included in Appendix B.

Program input and output

Table 31 is a list of input parameters required by DYNAM for distribution system optimization. Input into this routine is accomplished by using the free-format subroutine INPUT discussed in Chapter V and listed in Appendix B. A total of six different conveyance system alternatives may be used in this routine to build system combinations. The types of system alternatives evaluated in DYNAM do not necessarily need to correspond with the alternatives listed in Table 31. All codes input into DYNAM are used for labelling purposes only.

Data concerning the section identification number and minimum and maximum expected diversion rates are read into DYNAM for each section of the conveyance system to be optimized. The order that the sections are input into DYNAM is quite important, as this order dictates the sequence of section combination building. In this routine, the first section entered should be the section directly downstream of the system source. This is the section which supplies all other sections within the system. Data are then entered for those sections lying along the main branch of the conveyance system, with the order of entry corresponding with the direction of water flow through the system. Data must be entered for all sections branching from the main conveyances system as they are encountered. The last section entered into the DYNAM routine should be the end section of the main branch of the conveyance system.

Figure 21 is a simplified illustration of the gravity distribution system planned for the Salem Irrigation District. The actual system configuration is shown in Figure 6. The order of section data entry into DYNAM is depicted by the letters in Figure 21. All diversion points and distribution system laterals are assumed to be located at the end of the various distribution sections.

Coefficients of the annual cost function of each system alternative, along with the corresponding conveyance efficiency, are also entered into the computer routine for each section. These coefficients are the a and b terms listed in equation 3.4 in Chapter III.

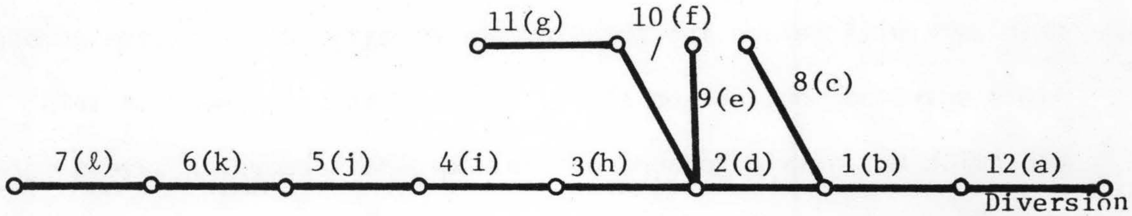
DYNAM has been written in conversational mode to facilitate data

Table 31. Input parameters required by the dynamic-programming routine to select optimal distribution system alternative combinations.

Input Parameters for DYNAM

- Codes for component alternatives considered:
  - Unlined channel
  - Concrete lined channel (unreinforced)
  - Gravity pipe
  - Concrete lined channel (reinforced)
  - Asphaltic lined channel
  - Shotcrete lined channel
- Data describing each conveyance section:
  - Section identification number
  - Maximum diversion rate from section
  - Minimum diversion rate from section
  - Identification number of section supplying this section
  - Component alternative code of this section
  - Y-intercept of annual cost function (a)
  - Slope of annual cost function (b)
  - Conveyance efficiency of this section (percent)
  - Codes of any component alternatives not allowed to supply this section (i.e., no unlined channel sections may supply gravity pipe sections, etc.)

entry with a CRT-type terminal. If data are to be input from cards or direct access system devices, the conversational option can be suppressed.



(Letters depict the sequence of section data entry to the DYNAM dynamic-programming routine)

Figure 21. Representative sketch of the gravity distribution system of the Salem Irrigation District.

Program output consists of a list of the optimum alternative combinations selected by the DYNAM routine. Included in the output are the computed minimum and maximum system flow rates, annual costs, and conveyance efficiencies associated with each of the combinations selected. These values are based upon the estimated minimum and maximum diversion rates of each conveyance section.

A required input to the DYNAM routine is a variable entitled EMARGN. This term provides a bias used to reduce the number of optimum alternative section combinations retained in the dynamic-programming routine. EMARGN is equal to the magnitude of increased efficiency of a combination over that of combinations with lower annual costs, necessary to authorize the retainment of that combination for further analysis. EMARGN may range from 0.0 to 0.01 (1.0 percent) or higher, depending upon the magnitude of increased efficiency which is felt by the systems planner to warrant an increased annual cost of the irrigation system. The use of the EMARGN term with a value greater than zero will reduce the total number of alternative system combinations selected for further study, although the bias used in this reduction may eliminate some optimal combinations which have a more favorable arrangement of system alternatives (i.e., all lined channel sections as compared to an assorted combination of unlined and lined channel sections mixed with gravity pipe).

Application of DYNAM to the Salem Irrigation District

Estimated diversion rates, annual costs, and conveyance efficiencies of the alternatives considered in each section were entered into DYNAM for the 12 sections of the gravity conveyance system (Figure 6) planned for the Salem Irrigation District. A listing of these data has been included in Appendix C along with program output for the gravity system. The number of combinations retained by DYNAM in this output was 184, as compared to the 177,147 combinations possible. EMARGN was set equal to zero in this programming run so that a wide range of feasible combinations would be output.

Twenty-four combinations were selected from the DYNAM output list which were felt to be more feasible to construct, operate, and maintain, than other combinations. Combinations were also selected on the basis of esthetics and safety to the irrigation district. Combinations were not selected, for example, in which sections consistantly alternated between the open channel and gravity pipe alternatives. These combinations could prove to be difficult or more costly to construct, and the large number of transitions from open channel to gravity pipe could prove to be a safety hazard. Table 32 is a summary of the alternative distribution system combinations selected from the DYNAM output listed in Appendix C. Included in this table are the average annual costs, total system flow rates, and conveyance efficiencies of the combinations at the average estimated diversion rate of each section. These selected combinations were optimized in conjunction with on-farm application system alternatives discussed in Chapter V in the linear-programming procedure described in this report.

Limitations of the DYNAM routine

The size of computer memory required to execute DYNAM is dependent upon the number of distribution system sections, the number of section alternatives, and the general configuration of the conveyance system. Dimensional arrays within the routine are required to store information concerning the optimal alternative combinations retained by the routine during each formulation, comparison, and decision step. The routine currently requires about 500,000 bytes of computer memory, enough to store information on 1800 system combinations. If a smaller irrigation distribution system is modelled, or if available computer memory is less

Table 32. Summary of selected distribution system alternative combinations from DYNAM output.

Combin-ation	Section												Average Annual Cost ($)	Average System Flow Rate (cfs)	Conveyance Efficiency (percent)
	1	2	3	4	5	6	7	8	9	10	11	12			
A	U	U	U	U	U	U	U	U	U	U	U	U[1/]	6570.[2/]	66.3[3/]	82.9
B	U	U	U	L	U	L	U	U	U	U	U	U	7380.	65.6	83.8
C	U	U	U	U	U	L	L	U	L	U	U	U	8070.	65.1	84.5
D	U	U	U	U	U	L	L	U	U	L	U	U	8990.	64.2	85.6
E	U	L	U	U	U	U	U	U	U	L	U	U	10,150.	63.9	86.1
F	U	U	U	U	L	L	L	U	U	L	U	U	11,160.	63.1	87.1
G	U	L	U	U	L	L	U	U	U	L	U	U	12,890.	62.4	88.1
H	U	L	U	L	L	L	L	U	U	L	U	U	14,370.	61.1	89.2
I	U	L	U	U	L	L	L	L	U	L	U	U	15,570.	61.3	89.7
J	U	L	U	L	L	L	L	L	U	L	U	U	16,260.	61.0	90.1
K	U	L	L	G	L	L	L	L	L	L	U	U	19,480.	60.1	91.5
L	L	L	U	L	L	L	L	L	U	L	U	U	20,340.	59.9	91.8
M	L	L	U	L	L	L	L	L	L	L	U	U	20,900	59.6	92.3
X	L	L	L	L	L	L	L	L	L	L	L	L	23,190.	59.1	93.1
N	L	L	L	G	L	L	L	L	L	L	U	U	23,540.	59.0	93.3
O	L	L	G	G	L	L	L	L	L	L	U	U	28,250.	58.3	94.3
P	L	L	G	G	G	G	L	L	L	G	G	U	41,000.	57.5	95.7

Table 32. Continued.

Q	L G G G L L L L G L	L	U	42,550.	57.3	96.0
R	L G G G L G G L G L	L	U	45,140.	57.0	96.5
S	G L G G G G G L L G	G	U	58,500.	56.1	97.9
T	G G G G L L L L G L	L	U	58,660.	56.1	98.0
U	G G G G G G G L G G	G	U	72,530.	55.2	99.6
V	G G G G G G L G G G	G	U	77,770.	55.1	99.8
W	G G G G G G G G G G	G	U	79,110.	55.0	100.0

1/ U = Unlined channel
L = Lined channel
G = Gravity Pipe section

2/ Annual Cost of Conveyance system at mean system diversion rate.

3/ System flow rate requirement at mean system diversion rate.

than the amount presently required, the array dimensions in the DYNAM routine can be reduced, and EMARGN can be set greater than zero.

All decision-making processes within DYNAM are completed using only annual costs and conveyance efficiencies to select desirable alternative combinations. No real engineering judgement concerning the safety, esthetics, or construction feasibility of a specific combination is employed within the routine. Although DYNAM is a very useful tool when used to reduce the total number of possible conveyance system alternative combinations, discretion must be used in evaluation of the "best" combinations selected by this dynamic programming model.

Linear Programming

In some modelling and resource allocation procedures the objectives for a problem and all the associated constraints can be described by linear functions with respect to the independent variables. When the objective function and all constraint functions are linear, the problem is said to belong to the linear-programming (LP) class. Linear programming is the process of finding an optimal solution for an objective function subject to all linear constraint conditions and the nonnegativity of all independent variables. This process essentially involves the allocation of resources so that solution of simultaneous linear equations with more unknown variables than equations can be accomplished subject to some over all problem objective. References concerning linear programming have been written by Ackoff and Sasieni (1968), Beveridge and Schechter (1970), Dantzig (1963), and Hadley (1962), and methods concerning water resources allocation modelling using LP have been researched by Milligan (1971), Schreiber (1968), and Stark and Nicholls (1972).

The linear-programming problem may be expressed mathematically as follows:

Minimize (maximize):

$$C_1X_1 + C_2X_2 + \ldots\ldots\ldots\ldots + C_nX_n = Y \qquad (6.6)$$

Subject to:

$$\begin{array}{l}
a_{11}S_1 + a_{12}X_2 + \ldots\ldots\ldots\ldots + a_{1n}X_n\ (\leq,\ =,\ \geq)b_1 \\
a_{21}X_1 + a_{22}X_2 + \ldots\ldots\ldots\ldots + a_{2n}X_n\ (\leq,\ =,\ \geq)b_2 \qquad (6.7) \\
\qquad \vdots \qquad\qquad\qquad\qquad\qquad \vdots \\
a_{m1}X_1 + a_{m2}X_2 + \ldots\ldots\ldots\ldots + a_{mn}X_n\ (\leq,\ =,\ \geq)b_m
\end{array}$$

and

$$X_1, X_2, \ldots\ldots\ldots, X_n \geq 0 \qquad (6.8)$$

The above equations form a linear analytical model with n independent unknowns (decision variables) subject to m constraints. The left-hand side of Equation 6.6 is the linear objective function for which an optimal value (maximum or minimum) is sought. If the function represents costs, a minimum value is sought, whereas if it represents profits or net benefits, a maximum value is desired. The c_j's in the objective function represent the unit costs (profits) of associated alternative activities, X_j's. The various a_{ij}'s in the constraint equations are coefficients which relate a unit of activity, X_j, to the amount of resource used by that activity. Various physical and socio-economic boundaries and resource demands and availabilities are specified by the b_i's of the constraint equations. (Ackoff and Sasieni, 1968; Busch, 1974; Dantzig, 1963; Hadley, 1962; Schreiber, 1968).

Many parallel operations are performed on the system of equations in 6.6 and 6.7. For instance the variable in each column, X_j, is multiplied by one cost coefficient, c_j, and m constraint coefficients, a_{ij}. Elements in columns, column vectors, may be multiplied by unknowns and added across so that their sums will give the corresponding elements in the right-hand column (Dantzig, 1963). Using this principle, Equations 6.6 and 6.7 can be written in the form shown in Table 33. The m+1 elements in the column beneath each variable are a column vector, each element of which is multiplied by the variable. Likewise, the coefficients in each row, c_j, a_{1j}, a_{2j}, $j = 1,n$, may be considered a row vector. Table 33 is referred to as a linear-programming (LP) matrix. The matrix form provides an orderly manner for writing all coefficients, and it saves time and effort by not requiring repetitious writing of the variables. A blank element in the matrix is considered to be zero, and all elements are considered to be positive in sign unless otherwise indicated.

Physical interpretation of the linear-programming model is a necessity for the complete understanding of the model and the results obtained from it. Milligan (1971) describes the significance of the model as it pertains to water resources systems:

> The objective function describes the economic relationships of the area (system) being modelled. The values of the objective function might be the total cost of all of the alternative water activities considered in the solution, or it might represent the total net benefits, depending upon whether the problem is formulated as a cost minimization problem or a net benefit maximization problem. The system of constraints defines the technical relationships of the area (system) being modelled. For example, a group of constraints may define the condition of hydrologic continuity within the model, whereas another group of constraints might define the relationships between sources of water supply and areas of demand, including return flows and wastes that might occur due to the allocation from supply to demand. Still other constraints might describe the legal limitations on availability of a certain water supply, for example. Thus, the constraint system is the part of the model wherein the economic relationships, or measure of accomplishment of objectives, are spelled out.

Table 33. Matrix form of linear-programming problem.

Variables	X_1	X_2	X_n	Sign	Right-hand side
Objective	c_1	c_2	c_n	=	Y
Row 1	a_{11}	a_{12}	a_{1n}	$\leq = \geq$	b_1
Row 2	a_{21}	a_{22}	a_{2n}	$\leq = \geq$	b_2
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Row m	a_{m1}	a_{m2}	a mn	$\leq = \geq$	b_m

Linear-programming models have proven to be a powerful tool in the area of water resources research. Probably the greatest advantage of the linear-programming approach is the relative ease of solution. The development of high-speed electronic computers has provided large-scale routines such as IBM's MPS/360 that have capabilities of solving problems with hundreds of independent unknowns and constraints (IBM, 1969a). The biggest disadvantage of linear programming is that it may require the oversimplification of a real-life system in order to analytically describe the system in the form of Equations 6.6 and 6.7. However, the unusual success with which linear-programming problems have been solved has motivated many to seek means for reducing non-linear problems to linear forms. The versatility of linear programming makes it a powerful tool for use in conjunction with other optimization techniques such as dynamic programming and simulation. (Buras, 1972; Busch, 1974; Hall and Dracup, 1970).

Application of linear-programming to an irrigation planning and optimization problem

To accurately model costs and functions of irrigation system components within a large irrigation system, the economic and physical relationships of component parts as well as any system constraints must be defined. Provision for continuity of flow of water through the system must be included for proper allocation of the resource and for sizing of system components and land areas served.

Necessary data for linear programming optimization of irrigation alternatives include crop acreages and water requirements for the major soil types in the planning area and the areas of these soil types in relation to the service areas of the distribution system. Also required are annual cost function coefficients of the application systems and conveyance system sections, along with conveyance efficiencies of the distribution system.

Sample LP matrix formulation. The hypothetical irrigation system shown in Figure 22 consists of two separate distribution service areas, Area I and Area II. Water is supplied to these areas by the open channel sections shown. Section I supplies water to Area I and to Section II, whereas Section II supplies water to Area II only. Two soil types are also shown in Figure 22. Application system costs for crops considered are representative of a specific soil type. Alternative application systems considered for the two crops planned for the district are: sprinkler or furrow for potatoes and sprinkler or border for grain. Table 34 includes acreages of the two soil types to be planted to potatoes and grain and also the percentages of the soil types lying within each service area. Symbols representing coefficients of annual cost functions and efficiencies of the proposed application alternatives and distribution system sections planned in the hypothetical district are listed in Tables 35 and 36. The "Q" values in Table 35 (e.g. QPFI) are the expected continuous flow rate requirement of each soil-crop-system combination during the peak irrigation water-use period. These values are dependent upon the maximum

Table 34. Soil type distribution in a hypothetical irrigation district.

	Total acres	Potato acreage	Grain acreage	% soil type in Area I	% soil type in Area II
Soil 1	130	80	50	23	77
Soil 2	30	20	10	100	0

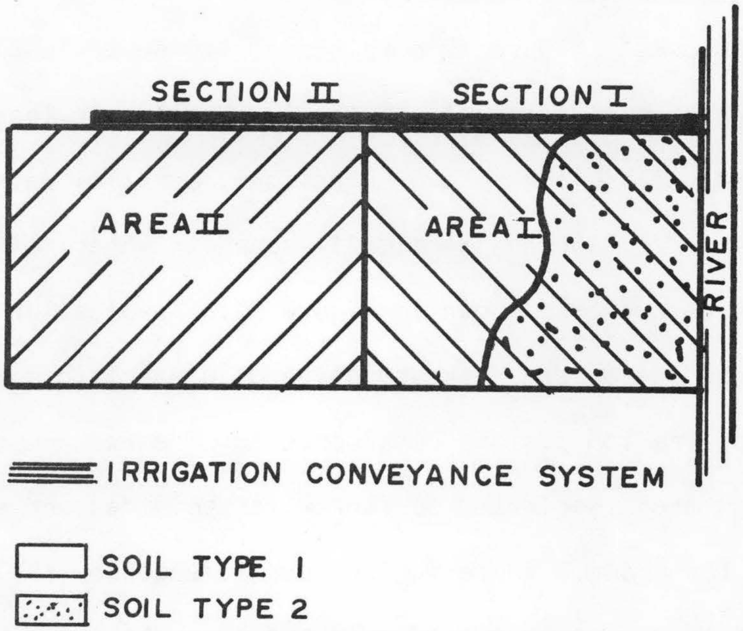


Figure 22. Schematic of an irrigation system showing conveyance sections, service areas, and soil types.

Table 35. Cost function and efficiency symbols for application systems in a hypothetical irrigation system model.

System	No. of acres	Cost per acre	Eff. (dec.)	cfs/acre at peak use
Potatoes-Furrow-Soil 1	PF1	CPF1	EPF1	QPF1
Potatoes-Sprinkler-Soil 1	PS1	CPS1[1]	EPS1	QPS1
Grain-Border-Soil 1	GB1	CGB1	EGB1	QGB1
Grain-Sprinkler-Soil 1	GS1	CGS1[1]	EGS1	QGS1
Potatoes-Furrow-Soil 2	PF2	CPF2	EPF2	QPF2
Potatoes-Sprinkler-Soil 2	PS2	CPS2[1]	EPS2	QPS2
Grain-Border-Soil 2	GB2	CGB2	EGB2	QGB2
Grain-Sprinkler-Soil 2	GS2	CGS2[1]	EGS2	QGS2

[1] Includes pumping costs

Table 36. Cost function and efficiency symbols for the distribution system in a hypothetical irrigation system model.

System	Flow rate in system	Cost per unit flow rate	Fixed cost	Efficiency (decimal)
Section I	Q1	CV1	CF1	E1
Section II	Q2	CV2	CF2	E2

evapotranspiration rate of the crops and application system efficiencies evaluated for the various soil-crop combinations. Annual costs and system efficiencies listed in Tables 35 and 36 could be obtained from solutions of the cost-evaluation computer routines described in Chapter V.

The linear-programming matrix for the hypothetical model is presented in Figure 23. The sum of the elements in the objective row, each multiplied by its proper variable, is the total annual cost of operating the entire system. Annual water costs for the volume of water entering the system, QENT, are related to the total system diversion by the factor CWTR shown in the objective and by the conversion factor in the VOLON row. The solution of the problem will give the minimum value for the objective subject to constraints given in the rows beneath the objective. The FIX term in the objective is a constant that is the sum of all fixed specified costs, CFI and CF2, for distribution system components. The ACOM term is the annual operation and maintenance cost associated with the specified distribution system. This term is considered to be dependent upon the distribution system and completely independent of the application systems.

The constraint rows define boundary conditions, continuity within the model, and relationships between the source of supply, the distribution sections, and service Areas I and II. The POTATO-SOIL I row simply indicates that the potato acreage irrigated by sprinkler and furrow systems on soil type I in both areas must total 80 acres. This same concept holds true for the other GRAIN and POTATO-SOIL type rows. Distribution system Section II must supply the demands imposed by the furrow, border, and sprinkler systems in Area II as indicated by the coefficients in row AREA II. The .77 value multiplied by the "Q" terms in these coefficients requires 77 percent of all application systems

Variables	PF1	PS1	GB1	GS1	PF2	PS2	GB2	GS2	QENT	Q1	Q2	FIX	OMC	SIGN	RHS
Objectives	CPF1	CPS1	CGB1	CGS1	CPF2	CPS2	CGB2	CGS2	CWTR	CV1	CV2	CF1 + CF2	ACOM		
POTATO-SOIL 1	1	1												=	80
GRAIN-SOIL 1			1	1										=	50
POTATO-SOIL 2					1	1								=	20
GRAIN-SOIL 2							1	1						=	10
AREA I	.23*QPF1	.23*QPS1	.23*QGB1	.23*QGS1	1.*QPF2	1.*QPS2	1.*QGB2	1.*QGS2		-E1	+1.0			≤	0.0
AREA II	.77*QPF1	.77*QPS1	.77*QGB1	.77*QGS1							-E2			≤	0.0
SUPPLY										1.0				≤	Q_{spec}
CONST												1.0		=	1.0
COEM													1.0	=	1.0
VOLON									-(cfs/AF)	1.0				=	0.0

Figure 23. Linear-programming matrix for a hypothetical model.

chosen for crops on soil type I to be located in service AREA II (Table 34). Efficiency figure, E2, signifies that the flow rate of water entering Section II must include conveyance losses in that section. In the AREA I row it can be seen that Section I must supply water to both Area I and Section II. The supply entering the entire system must not exceed the specified value of Qspec, representing the total system flow rate requirement during periods of peak water use at a set project efficiency. Qspec may also represent the maximum legal water right of the irrigation district. The CONST and COEM rows allow inclusion of the FIX and OMC variables in the objective function.

An optimal (least cost) solution can be obtained for the problem described through use of the linear-programming matrix and associated computer program. Results would indicate how the constrained resource, water, would be distributed among two crops in two service areas and how many acres would be served by each type of application system on each soil type. The effects of variations in water availability and cost could be incorporated into the same problem by using parametric programming to alter specified parameters within the matrix.

Parametric programming. In applied problems one is not only interested in solution of the problem, but also in how the solution changes when various parameters in the linear-programming model change. As Stark and Nicholls (1972) stated, the latter may be more important than the former. Milligan (1971) pointed out that the optimal solution of a linear-programming problem may be very sensitive to various parameters in the problem, and it is desirable to determine the effects of changing parameter values without resolving the entire problem.

Stark and Nicholls (1972) listed the following five basic types of parameter changes that affect solution of a linear-programming problem.

1. Changes in the objective coefficients, c_j
2. Changes in the resource limits, b_l
3. Changes in the constraint coefficients, a_{ij}
4. The effect of including additional constraints
5. The effect of including additional variables

In sensitivity analysis a given coefficient is allowed to vary while all others are held to their original values. Sensitivity analysis determines the range over which a given coefficient can vary without changing the configuation of the least-cost optimal design, and investigates changes in the optimal value of the objective function. In parametric programming values of one or more parameters are allowed to vary over a specified range. The resulting changes in the optimal objective value and design configuration are investigated relative to the parameter changes (de Neufville and Stafford, 1971).

Parametric programming can be performed on the linear-programming matrix in this model to evaluate the effects of increased water cost, charges or benefits accessed for deep percolation, seepage losses, and surface runoff, and also to evaluate the effects of further constraint of the water supply on the total irrigation system. Effects of these social, environmental, and physical constraints upon the irrigation system are reflected in the objective function cost, and also in the basis variables in the LP matrix which indicate inclusion of specific application system alternatives in the total system.

Linear programming modelling of an irrigation system

An irrigation system can be modelled and optimized for minimum annual cost and efficient water resource allocation by using the linear-programming matrix formulation procedure discussed in the preceding section in conjunction with the aforementioned parametric programming techniques. In addition to the rows and columns listed in the hypothetical problem matrix shown in Figure 23, rows and columns providing data representing seepage, deep percolation, and surface runoff costs and constraints can also be included in the matrix. Data concerning losses from commonly used types of application and distribution systems may be obtained through utilization of the systems routines discussed in Chapter V and listed in Appendix B.

System flow rate requirements. Specification of the maximum flow rate required by irrigation application systems during the period of peak consumptive-use is necessary in defining the size of the distribution system components selected to serve these systems. The maximum flow rate required for each acre irrigated by a specific application system can be expressed in equation form as:

$$Qmax = \frac{1}{23.8} \frac{ET'max}{Eff} \qquad (6.9)$$

where

Qmax = maximum required flow rate in cfs/acre

ET'max = maximum rate of evapotranspiration in inches per day

Eff = system application efficiency expressed as a decimal

Evapotranspiration values used in the above equation should be for a specific crop, and the efficiency used should be representative of one application system type evaluated for a specific soil-type combination. Qmax in equation 6.9 corresponds to the QPFI, QPSI, QGBI, etc. terms shown in the hypothetical LP matrix in Figure 23.

Equation 6.9 can also be used to calculate the overall flow rate required by an irrigation system or district. This flow rate, identified as Qspec in Figure 23, can be evaluated at various project efficiency levels. The ET'max term in equation 6.9 should represent a weighted average of evapotranspiration rates of the crops grown in the district, and the Qmax calculated should be multiplied by the total number of acres irrigated to obtain a value for Qspec representative of the total system.

Operation and maintenance costs. Operation and maintenance costs for irrigation distribution system alternative combinations evaluated in the linear programming model are entered separate from the distribution system annual cost function coefficients. This separation enables the use of O & M cost estimating equations derived for different irrigation regions or types of systems and management practices.

Operation and maintenance costs for distribution systems in this particular study were computed from relationships developed by Brockway and Reese (1973) for selected irrigated regions in the western United States. These relationships can be expressed as:

$$COM_o = 96.3\ L^{0.663}\ CV^{0.774} \tag{6.10}$$

and

$$COM_c = 89.5\ L^{1.072}\ CV^{0.351} \tag{6.11}$$

where

COM_o = annual operation and maintenance cost for an open distribution system

COM_c = annual operation and maintenance cost for a closed distribution system

L = system length in miles

CV = average annual gross crop value in dollars per acre.

Equations 6.10 and 6.11 were developed from data gathered from predominantly open or closed distribution systems. For varying combinations of open and closed systems, the operation and maintenance costs are determined for both open and closed systems using the total length of the combination under consideration. The cost for the composite system is then computed as a weighted average of the individual costs of open and closed systems as:

$$COM_{total} = \frac{L_o COM_o}{L} + \frac{L_c COM_c}{L} \tag{6.12}$$

where

COM_{total} = annual composite operation and maintenance cost

L_o = length of the open portion of the system

L_c = length of the closed portion of the system

The 1968 crop value used in Equations 6.10 and 6.11 for the Salem Irrigation District was $115. per acre. Since these equations were developed for 1968 O & M data, an appropriate cost index was applied to the result in the study to represent costs for the year 1977. A COM_{total} term must be calculated for each distribution system combination optimized in the linear programming model. Operation and maintenance costs for a distribution system are assumed to be independent of the application systems served.

Matrix formulation - gravity distribution system

The formulation of the linear-programming problem for the Salem Irrigation district was carried out in much the same manner as for the hypothetical model described in preceding sections of this chapter. Unit costs for all application systems evaluated and planned for each soil type and annual costs of system components for a given distribution system alternative combination are combined to form a linear objective function. The objective function denoting total annual cost is then minimized subject to constraints. Constraints establish continuity in the model and establish necessary relationships between the source(s) of supply (water into the system) and areas of demand (various application systems).

The linear-programming matrix map shown in Figure 24 describes the relationship of the gravity conveyance system and on-farm application systems planned for the Salem Irrigation District. The matrix map is given in abbreviated form; that is, all numbers other than 1.000 are represented by letter symbols whose ranges of value are shown in Figure 25. The application systems for all units represented in columns on the left-hand side of the matrix correspond to those symbols and systems listed in Tables 14 through Table 17 in Chapter V. All column headings beginning with "SYS" represent distribution system component sections. The lower number in these twelve distribution system headings represents the type of alternative: 1 = unlined channel, 2 = lined channel, 3 = gravity pipe. The number(s) immediately preceding the lower number indicate(s) the section which the alternative represents (referring to Figure 6.)

The VON, VDPB, VDPD, and VSR columns in the matrix represent annual volumes of water diverted into the system, entering the groundwater as beneficial and detrimental (non-beneficial) deep percolation, and surface runoff, respectively, for the entire system. The summation of annual fixed specified costs for all distribution system components is contained in the FIXA column, and annual operation and maintenance costs for the distribution system appears in the OMCA column. The SEEPAGEA column provides for inclusion of conveyance system seepage losses in the beneficial deep percolation category. The letter (A) included in the SYS column headings and FIX, OMC, and SEEPAGE column headings depicts which specific distribution system combination has been entered for optimization (Table 32).

Rows of the matrix in Figure 24 consist of the objective (OBJ) row,

```
                                                                                                                                                                                                                        S
                                                                                                                                                                                                                  S S S E
                                                                                                                                                                                                S S S S S S S S S Y Y Y E
              S S S S U U U U I I I I H H H H S S S S S S S S S U U U U I I I I H H H H S S S S S S S S U U U I I I I I H H H S S S S S S S S U U U U I I I I H H H H S S S S S C C C C         Y Y Y Y Y Y Y Y Y S S S P
              U U U U N N N N M M M M M M M M R R R R S U U U U N N N N M M M M M M M M R R R R S U U U N N N M M M M M M M M R R R S U U U U N N N N M M M M M M M M R R R R S P P P P   V V   S S S S S S S S S A A A A F O P R
              B B B B G G G G G G G P P P P P P P P P P B B B B G G G G G G G G P P P P P P P P P B B B G G G G G G G G P P P P P P P B B B B G G G G G G G G P P P P P P P P P P P P P V D D V A A A A A A A A A 1 1 1 G I M H H
              P G A B P G A B P G A B P G A B P G A B P P G A B P G A B P G A B P G A B P G A B P P G A P G A P G A G A P G A P G A P P G A B P G A B P G A B P G A B P G A B P P G A B O P P S 1 2 3 4 5 6 7 8 9 0 1 2 E X C S S
              1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 N B D R 1 1 1 1 1 1 1 1 1 1 1 1 A A A A B

OBJ       N   B B B B B B B B B B B B B B B B B B B B C B B B B B B B B B B B B B B B B B B B B C B B B B B B B B B B B B B B B B B C B B B B B B B B C B B B B B B B B B B B C B B B B         X X X X X X X X X X X X   D E
SOIL1P    E   1       1       1       1       1       1                                                                                                                                                                       C
SOIL1G    E     1       1       1       1       1                                                                                                                                                                             C
SOIL1A    E       1       1       1       1       1                                                                                                                                                                           C
SOIL1B    E         1       1       1       1       1                                                                                                                                                                         C
SOIL2P    E                                             1       1       1       1       1       1                                                                                                                             C
SOIL2G    E                                               1       1       1       1       1                                                                                                                                   C
SOIL2A    E                                                 1       1       1       1       1                                                                                                                                 C
SOIL2B    E                                                   1       1       1       1       1                                                                                                                               C
SOIL3P    E                                                                                     1     1     1         1     1     1                                                                                         C
SOIL3G    E                                                                                       1     1     1   1     1     1                                                                                               C
SOIL3A    E                                                                                         1     1     1   1     1     1                                                                                             C
SOIL4P    E                                                                                                                         1       1       1       1       1       1 1                                             C
SOIL4G    E                                                                                                                           1       1       1       1       1         1                                           C
SOIL4A    E                                                                                                                             1       1       1       1       1         1                                         C
SOIL4B    E                                                                                                                               1       1       1       1       1         1                                       C
AREA1     L   V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V U U V V V V V V V V V V V V V V V V                                                           1                    -1
AREA2     L                                             V V V V V V V V V V V V V V V V V V V V V U U U U U U U U U U U U V U U V U U                                                          -T 1           1
AREA3     L   V V V V V V V V V W V V V W V W V W V W V U U U U V V V V V V V V V V V V V V V V V                                                                                                            -T
AREA4     L   V V V V V V V V V V V V V V V V V V V V V U U U V V V V V V V V V V V V V V V V V V                                                                                                -T 1           1 1
AREA5     L   V V V V V V V V V W V V V W V W V W V W V V V V V V V V V V V W W W W W W W W W W W                                                                                                              -T
AREA6     L   U U U U V V V V V V V V V V V V V V V V V                                                                               V V V V V V V V V W W V W W W W W W W W W W W W W            -T 1
AREA7     L   V V V V V V V V V W V V V W W W V W W W V V V V V V V V V V W V V V W W W V W W W W                                                                                                    -T 1
AREA8     L   U U V V V V V V V V V V V V V V V V V V V                                                                                                                                                            -T
AREA9     L   V V V V V V V V V W V V V W W W V W W W V                                                                               U U U U U U U U U V V V V V V V V V V V V V V V V                          -T 1
AREA10    L   V V V V V V V V V W W W V W W W V W W W W V V V V V V V V V W W W W W W W W W W W W                                     U U U U V U U U V V V V V V V V V V V V V V V V V                -T 1
AREA11    L                                             U U V V V V V V V V V V V V V V V V V V V                                     V V V V V V V V V W W W W W W W W W W W W W W W W                    -T
AREA12    L                                                                                                                         U U V V V U U U V V V V V V V V V V V V V V V V V                  -T 1
WTON      L                                                                                                                                                                                                         1       C 1
VOLON     E                                                                                                                                                                          -V                             1
DEPERB    E   A A A A                                   A A A A                                   A A A                               A A A A                                            -1                             D
DEPERD    E           T T   A T   U T T T T T T T T T T         T A A A T U U T T T T T T T T T T       T     T   U   U T T T T T T T         A A A A A     T T T T T T T T T T T T T T    -1
SURCFF    E           A A A A A T A A                           A A A A A T A A                         A A A A T A T A                       T A A A   T Y A                                -1
CONSP     E                                                                                                                                                                                                           1     1
CONST     E                                                                                                                                                                                                             1   1
CORM      E                                                                                                                                                                                                               1 1
CHON      N                                                                                                                                                                           1
CHDPB     N                                                                                                                                                                            -1
CHDPD     N                                                                                                                                                                               1
CHSR      N                                                                                                                                                                                 1
```

Figure 24. Linear-programming matrix for gravity pressure distribution system in Salem Irrigation District. (See Figure 25 for symbol explanation.)

SUMMARY OF MATRIX

SYMBOL	RANGE	
Z	Less than	.000001
Y	.000001 thru	.000009
X	.000010	.000099
W	.000100	.000999
V	.001000	.009999
U	.010000	.099999
T	.100000	.999999
I	1.000000	1.000000
A	1.000001	10.000000
B	10.000001	100.000000
C	100.000001	1,000.000000
D	1,000.000001	10,000.000000
E	10,000.000001	100,000.000000
F	100,000.000001	1,000,000.000000
G	Greater than	1,000,000.000000

Figure 25. Summary of linear-programming matrix.

constraint rows, and change rows. The elements of the objective row are unit costs, the sum of which is minimized in the problem solution. Constraint rows assure continuity and establish necessary relationships.

The "SOIL" rows ensure that each soil-crop combination receives irrigation water via one or more of the listed application system alternatives. Total acreages of each of these rows must equal the total land area of the soil-crop combinations listed in the RHSA column. The "AREA" rows provide for continuity of water flowing through the distribution system and for distribution of water to application systems from the proper section. For example, the coefficients in the AREA2 row indicate that distribution section SYSA11 must convey enough water, considering the efficiency (T) of that section alternative, to supply the soil-crop-application systems selected for service area two in addition to section alternatives SYSAZ2 and SYSA81. The coefficients in the AREA2 row appearing in the application system alternatives columns dictate the flow rate required per acre served by those systems selected. The total flow rate of water entering the entire system is depicted and controlled by elements of the WTON row. The coefficient in the RHSA column of this row is representative of the Qspec value discussed in a previous section of this chapter. The VOLON row is necessary to convert the total system flow rate to a total annual volume. The coefficient necessary for this conversion, entered in the VON column has been set equal to 0.00528 CFS/AF for this particular study. This coefficient was estimated, using a seasonal

ET' curve for the area, by setting the maximum flow rate required by the system equal to the high point of the seasonal ET' curve and integrating under the curve over the total length of the irrigation season.

The DEPERB, DEPERD, and SUROFF rows are necessary for calculation of beneficial and non-beneficial deep percolation of program-selected application system alternatives as well as surface runoff of selected surface systems. Coefficients entered into these rows were obtained from output of the APSYS application system evaluation computer routine described in Chapter V and listed in Appendix D. The CONSP, CONST, and COEM rows guarantee inclusion of the values entered for the SEEPAGEA, FIXA, and OMCA columns in the LP matrix. The change rows, whose names begin with the letters "CH", are rows whose elements are multiplied by some factor and added to another row in the process of parametric programming.

Right-hand-side, RHS, elements are the b's in the linear-programming constraints (Equation 6.2). These elements represent the limits placed on all constraints. The RHSB column is in effect a change column whose elements are multiplied by some factor in the process of parametric programming and added to another column.

The letter immediately to the right of each row name defines the type of row; i.e., the proper sign to be inserted between the row coefficients and the right-hand side. The symbols are defined as follows:

N	No constraint (change or objective row)
G	Greater than or equal to
E	Equality
L	Less than or equal to

Matrix formulation - high pressure distribution system

The linear-programming matrix map shown in Figure 26 contains elements representing an irrigation system in which application systems are supplied by a high pressure pipeline. Only sprinkler system alternatives are considered for the on-farm systems in this particular configuration to maintain compatibility with the high pressure distribution system used.

The VDPB, VSR, and SEEPAGE columns and SUROFF and DEPERB rows have been deleted from this matrix, in relation to the gravity system matrix listed in Figure 24, as there would be no beneficial deep percolation or surface runoff from the sprinkler systems evaluated for the Salem Irrigation District, and the high pressure pipeline would not have any seepage losses. The PMP column represents the variable costs of a large electric pumping plant in relation to the total system flow rate. The fixed pumping cost has been added into the total pipe system's fixed cost, represented by the FIX column. The eight "SYS" columns in this matrix are representative of the high-pressure pipe system sections shown in Figure 7 and described in Chapter IV. Coefficients in the OBJ row of these columns are the slope of the

```
             H H H H S S S S S H H H H S S S S S H H H S S S S H H H H S S S S S C C C C
             M M M M R R R R S M M M M R R R R S M M M R R R S M M M M R R R R S P P P P   V S S S S S S S S       R R
             P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P P V D Y Y Y Y Y Y Y Y P F O H H
             P G A B P G A B P P G A B P G A B P P G A P G A P P G A B P G A B P P G A B O P S S S S S S S S M I M S S
             1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 N D 1 2 3 4 5 6 7 8 P X C A B

OBJ       N  B B B B B B B B C B B B B B B B B C B B B B B B C B B B B B B B B C B B B B     C C C C C C C C D E D
SOIL1P    E  1       1       1                                                                                     C
SOIL1G    E    1       1                                                                                           C
SOIL1A    E      1       1                                                                                         C
SOIL1B    E        1       1                                                                                       C
SOIL2P    E                    1       1       1                                                                   C
SOIL2G    E                      1       1                                                                         C
SOIL2A    E                        1       1                                                                       C
SOIL2B    E                          1       1                                                                     C
SOIL3P    E                                      1     1     1                                                     B
SOIL3G    E                                        1     1                                                         C
SOIL3A    E                                          1     1                                                       B
SOIL4P    E                                                    1       1       1 1                                 C
SOIL4G    E                                                      1       1         1                               C
SOIL4A    E                                                        1       1         1                             C
SOIL4B    E                                                          1       1         1                           C
AREA1     L  V V V V V V V V V V V V V V V V V V U U U U U U U                              -1 1
AREA2     L  V V V V V V V V V V V V V V V V V V                                              -1 1       1
AREA3     L  V V V V V V V V V V V V V V V V V V                                                -1 1
AREA4     L  V V V V V V V V V V W V W V W V W V                                                  -1 1
AREA5     L                    V V V V V V V V V               V V V V V V V V V V V V V            -1 1
AREA6     L                    W W W W W W W W W               V V V V V V V V V V V V V              -1
AREA7     L  V V V V V V V V V W W W W W W W W W                                                        -1 1
AREA8     L  V V V V V V V V V                                 V V V V V V V V V V V V V                  -1
WTON      L                                                                                                  1     C 1
VOLON     E                                                                             -V                   1
DEPERD    E  T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T T  -1
CONST     E                                                                                                    1   1
COEM      E                                                                                                      1 1
CHON      N                                                                              1
CHDPD     N                                                                                1
CONPMP    E                                                                                  1              -1
```

Figure 26. Linear-programming matrix for high pressure irrigation system in Salem Irrigation District.

annual cost versus flow rate function of each section described by equation 3.4.

The "SOIL" and "AREA" rows included in the high pressure system matrix in Figure 26 are similar to those used in the gravity pressure system matrix shown in Figure 24 and discussed in the previous section. The AREA rows in the high pressure matrix represent the service areas shown in Figure 9 planned for the high pressure system, whereas the AREA rows in the gravity system matrix depict those service areas used in planning of the gravity pressure system (Figure 8). The CONPMP row provides for continuity between the pumping unit and the high pressure pipe system. Multiple pumping plant locations can also be used in this model to supply the high pressure system (Busch, 1974).

Linear-programming solution and post-optimal analysis

Optimal least-cost solutions for problems such as those represented in Figure 24 and 26 can be obtained by use of a high-speed digital computer and a software package such as the MPS/360 routine furnished by the IBM Corporation. This routine, its capabilities and applications, are described in detail by the Programming User's Manual (IBM, 1969a), Application Description Manual (IBM, 1969b), and the Control Language User's Manual (IBM, 1969c).

Parametric programming can be used on the problem to determine effects of varying numerous parameters including availability of water, the cost of water flowing into the system, and the net value of water lost to deep peroclation and surface runoff.

Linear-programming matrix revision. After a set of optimal solutions are obtained for a linear programming problem by linear and parametric programming, the original problem can be revised. Problem revision means that one or more rows, columns, or individual elements in the original problem matrix are added, deleted, or replaced. The process of revision using IBM's MPS/360 is explained by Freeman and Lard (1970) and IBM (1969a).

The linear-programming problem represented by the matrix map in Figure 24 may be revised to include elements representing the various types of distribution system alternative combinations listed in Table 32. To accomplish this revision, it is necessary to replace the columns representing distribution system sections ("SYS" columns) and the "SEEPAGE", "FIX" and "OMC" columns.

The MPS/360 control program used for problem solution, parametric programming, and problem revision of the LP matrix representing the gravity distribution system and application systems planned for the Salem Irrigation District is shown in Table 37. Descriptions of the various statements, routines, and their functions may be found in the IBM manuals (IBM, 1969a, 1969b, 1969c) and the manual written by Freeman and Lard (1970). The specific function of the program in Table 37 is to determine optimal solutions of the matrix, using the various parameter ranges listed in Table 38, for each of the 24 different distribution system alternative combinations listed in Table 32.

Table 37. MPS/360 control program for the gravity-supplied irrigation system, Salem Irrigation District.

```
                 PROGRAM
                 INITIALZ
                 MACRO
                 SOLVE(A,B,C,D)
                 MVADR(XDOPREMX,INFS)
                 MOVE(XDATA,A)
                 MOVE(XPBNAME,B)
                 IF(IKT.GT.1,JMP)
                 IKT=IKT+1
                 MOVE(XOBJ, 'OBJ')
                 MOVE(XRHS, 'RHSA')
                 CONVERT('SUMMARY')
                 SETUP('MIN')
                 PICTURE
                 GOTO(PRI)
        JMP      MOVE(XOLDNAME,D)
                 REVISE
                 SETUP('MIN')
        PRI      PRIMAL
                 SOLUTION
                 MOVE(XOBJ,'OBJ')
                 XPARAM=0.
                 XPARMAX=15.
                 XPARDELT=3.
                 MOVE(XCHROW, 'CHON')
                 PARAOBJ('CONT')
                 SOLUTION
                 MOVE(XOBJ, 'OBJ')
                 XPARAM=0.
                 XPARAMAX=7.
                 XPARDELT=3.5
                 MOVE(XCHROW, 'CHDPD')
                 PARAOBJ('CONT')
                 SOLUTION
                 MOVE(XOBJ, 'OBJ')
                 XPARAM=0.
                 XPARMAX=1.
                 XPARDELT=.5
                 MOVE(XCHROW, 'CHDPB')
                 PARAOBJ('CONT')
                 SOLUTION
```

Table 37. Continued.

```
              MOVE(XOBJ, 'OBJ')
              XPARAM=0.
              XPARMAX=.5
              XPARDELT=.5
              MOVE(XCHROW, 'CHSR')
              PARAOBJ('CONT')
              SOLUTION
              MOVE(XOBJ, 'OBJ')
              MOVE(XCOLUMN,C)
              XPARAM=0.
              XPARMAX=8.
              XPARDELT=1.
              MOVE(XCHCOL, 'RHSB')
              PARACOL('CONT')
              SOLUTION
IKT           DC(1)
A             DC('ABC')
B             DC('DEF')
C             DC('GHI')
D             DC('JKL')
INFS          MEND
              SOLVE('TETON01','RUN01','SYSA121','RUN00')
              SOLVE('TETON02','RUN02','SYSB121','RUN01')
              SOLVE('TETON03','RUN03','SYSC121','RUN02')
              SOLVE('TETON04','RUN04','SYSD121','RUN03')
              SOLVE('TETON05','RUN05','SYSE121','RUN04')
              SOLVE('TETON06','RUN06','SYSF121','RUN05')
              SOLVE('TETON07','RUN07','SYSG121','RUN06')
              SOLVE('TETON08','RUN08','SYSH121','RUN07')
              SOLVE('TETON09','RUN09','SYSI121','RUN08')
              SOLVE('TETON10','RUN10','SYSJ121','RUN09')
              SOLVE('TETON11','RUN11','SYSK121','RUN10')
              SOLVE('TETON12','RUN12','SYSL121','RUN11')
              SOLVE('TETON13','RUN13','SYSM121','RUN12')
              SOLVE('TETON14','RUN14','SYSN121','RUN13')
              SOLVE('TETON15','RUN15','SYSO121','RUN14')
              SOLVE('TETON16','RUN16','SYSP121','RUN15')
              SOLVE('TETON17','RUN17','SYSQ121','RUN16')
              SOLVE('TETON18','RUN18','SYSR121','RUN17')
              SOLVE('TETON19','RUN19','SYSS121','RUN18')
```

Table 37. Continued.

```
SOLVE('TETON20','RUN20','SUSTI2I','RUNI9')
SOLVE('TETON2I','RUN2I','SYSUI2I','RUN20')
SOLVE('TETON22','RUN22','SYSVI2I','RUN2I')
SOLVE('TETON23','RUN23','SYSWI2I','RUN22')
SOLVE('TETON24','RUN24','SYSXI2I','RUN23')
EXIT
PEND
```

Table 38. Parameters and cost ranges used in parametric programming of the gravity pressure system linear-programming problem.

Parameter	Parameter change Row/Column Symbol	Parametric Command	Parametric Range	Change Increment
Water Cost($/AF)	CHON	PARAOBJ	0.-15.00	3.00
Non-beneficial Deep Percolation ($/AF)	CHDPD	PARAOBJ	0.-7.00	3.50
Beneficial Deep Percolation ($/AF)	CHDPB	PARAOBJ	0.-1.00	0.50
Surface Runoff ($/AF)	CHSR	PARAOBJ	0.-0.50	0.50
Total Water Supply (cfs)	RHSB	PARACOL	0.-8.00	1.00

The RHSB-PARACOL parametric programming function listed in Table 37 specifies the total flow rate allowed to enter the irrigation system. Increments of flow rate reductions in this problem correspond to increases of 10 percent in the overall project water-use efficiency. To use this parametric function, the value Qspec entered into the LP matrices shown in Figures 24 and 26 should be calculated for an overall project efficiency of 10 percent. This value is located at the intersection of the RHSA column and WTON row in the matrices. Each SOLVE statement appearing after the MACRO end statement (MEND) dictates the execution of the control program for each distribution system combination and revised linear-programming matrix. Necessary input into the MPS/360 linear-programming routine for matrix revision has been included in Appendix C. Optimal solutions computed over each of the parametric-programming ranges can be compared for each distribution system alternative. The least cost application and distribution system combination for each specific parameter value can then be selected as the most economically favorable irrigation system plan subject to all physical, environmental, and economic constraints evaluated.

Application of the linear-programming problem to the Salem Irrigation District

Irrigation water application and distribution systems described and evaluated in Chapter V for the Salem Irrigation District using the computer routines described in that same chapter have been modelled in linear form for optimization purposes. Annual cost function coefficients (equations 3.4 and 3.5) of these systems are listed in Tables 14, 15, 16, 17, and 23. By including necessary constraints, continuities, and economic relationships present in the gravity distribution systems and on-farm systems planned for the study area, the linear model of the system, shown in Figure 24, was formulated. Similarly, high-pressure distribution-application systems evaluated for the Salem Irrigation District are represented in the linear-programming matrix form shown in Figure 26. These matrices have been formulated to enable planning and selection of application systems on the basis of soil-crop combinations, and sizing distribution of systems according to geographical and topographical location.

Necessary input and formatting of data required to transfer the matrix data into the MPS/360 computer routine for solution has been included in Appendix C. Data necessary for matrix revision are also contained in this list. The method of data formatting and order of entry is discussed in detail in the MPS/360 Version 2 Users Manual (IBM,1969a).

Solution and parametric programming of the LP matrix shown in Figure 24 was accomplished using the MPS/360 control program listed in Table 37. The high pressure matrix (Figure 26) was optimized using a similar control program without the revision requirements.

Linear Programming Optimization Output for the Salem Irrigation District

The specific conditions considered in optimization of gravity and high pressure-supplied irrigation systems for the Salem Irrigation District were the overall irrigation efficiency, the price charged to water users for water entering the system, and prices assessed against water lost to deep percolation and surface runoff. Those combinations of distribution and application systems which achieve these conditions at minimum cost are the results discussed in this section.

The specified overall system efficiency during the peak ET period was computed for various flow rates of water allowed to enter the system as:

$$QAE = 100 \frac{QET}{Q_{in}} \qquad (6.13)$$

where

QAE = overall system efficiency

QET = flow rate required to satisfy maximum ET requirement

Q_{in} = flow rate entering the system

Efficiency levels were specified in increments of 10 percent by adjusting the value of Q_{in}, the rate at which water is allowed into the system, in the linear-programming matrix.

Variation in prices for water diverted to or lost from the total irrigation system was accomplished by changing the values of the appropriate cost coefficients in the objective function through the process of parametric programming. All parameter changes in this optimization process were considered independent of one another, although it is possible to vary multiple parameters simultaneously in the MPS/360 computer routine.

Efficiency constraints

Results of optimal linear-programming solutions for gravity-distribution and application system combinations operating at various efficiencies are summarized in Table 39, and results of optimal solutions obtained for the high-pressure-supplied irrigation system are listed in Table 40. The optimal gravity-distribution system combination at each efficiency level is listed in Table 39, along with those soil-crop-application system combinations selected to fulfill the efficiency constraints at least cost. Annual system costs have been itemized as distribution system and applications system costs on a total area and also unit area basis. On-farm pumping costs are included in the application system cost figures listed in Table 39, whereas annual costs of the large pumping station planned to service the high-pressure distribution system in Table 40 have been incorporated into the distribution system annual costs.

Because the high-pressure irrigation system is planned to operate at a minimum efficiency of 70 percent, an increase in available water to the system has no effect upon the system configuration or annual cost. Thus, only parameters describing the system layout at the 70 percent efficiency level have been included in Table 40.

Table 39. Total annual system costs and descriptions of optimal gravity-supplied irrigation systems at various system efficiencies. Salem Irrigation District.

System efficiency (%)	13[3]	20	30	40	50	60	70
Total annual cost ($)	95,150	121,400	155,990	180,390	199,200	221,220	266,170
Dist. system ($)	29,940	29,940	29,940	29,940	29,940	39,590	66,700
App. system ($)	65,210	91,460	126,050	150,450	169,260	181,630	199,470
Total annual cost ($/Ac)	30.07	38.37	49.30	57.01	62.96	69.92	84.12
Dist. system ($/Ac)	9.46	9.46	9.46	9.46	9.46	12.51	21.08
App. system ($/Ac)	20.61	28.91	39.84	47.55	53.50	57.41	63.04
Max. flow rate (cfs)	230.9	151.0	100.7	75.5	60.4	50.3	43.1
Vol. of Deep Percolation							
Beneficial (AF)	24,830	12,390	4,410	2,680	2,680	1,210	125
Non-beneficial (AF)		1,240	2,040	1,300	680	670	890
Vol. of Surface Runoff (AF)		2,350	3,520	3,160	1,960	1,070	160
Total Volume used (AF)	43,720	28,600	19,070	14,300	11,440	9,530	8,170
Distribution System							
Section: 1	UC[1]	UC	UC	UC	UC	UC	GP
2	UC	UC	UC	UC	UC	LC	LC
3	UC	UC	UC	UC	UC	UC	GP
4	UC	UC	UC	UC	UC	LC	GP
5	UC	UC	UC	UC	UC	LC	GP
6	UC	UC	UC	UC	UC	LC	GP
7	UC	UC	UC	UC	UC	LC	GP
8	UC	UC	UC	UC	UC	LC	LC
9	UC	UC	UC	UC	UC	UC	LC
10	UC	UC	UC	UC	UC	LC	GP
11	UC	UC	UC	UC	UC	UC	GP
12	UC	UC	UC	UC	UC	UC	UC

Table 39. Continued.

Application system:								
Annis:	Potatoes	SUB[2]	SUB	UNG	UNG	HMP	HMP	HMP
	Grain	SUB	UNG	UNG	UNG	UNG	UNG	IMG
	Alfalfa	SUB	UNG	UNG	UNG	UNG	IMG	HMP
	Pasture	SUB	SUB	SUB	UNG	HMP	HMP	HMP
Withers:	Potatoes	SUB	SUB	UNG	UNG	HMP	HMP	HMP
	Grain	SUB	UNG	UNG	IMG	IMG	IMG	HMP
	Alfalfa	SUB	UNG	UNG	UNG	IMG	SRP	SRP
	Pasture	SUB	SUB	UNG	IMG	IMG	SRP	SRP
Blackfoot:	Potatoes	SUB	SUB	UNG	HMP	HMP	HMP	HMP
	Grain	SUB	UNG	UNG	UNG	UNG	UNG	HMP
	Alfalfa	SUB	UNG	UNG	UNG	UNG	UNG	HMP
Hayeston:	Potatoes	SUB	SUB	CPP	CPP	CPP	CPP	CPP
	Grain	SUB	HMP	HMP	HMP	HMP	HMP	CPP
	Alfalfa	SUB	SUB	HMP	CPP	CPP	CPP	CPP
	Pasture	SUB	SUB	HMP	CPP	CPP	CPP	CPP

---

[1] UC = unlined channel
LC = lined channel
GP = gravity pipe

[2] symbols are defined in Tables 14-17.

[3] present irrigation system efficiency.

Table 40. Total annual system costs and descriptions of a high-pressure-supplied irrigation system at the design system efficiency. Salem Irrigation District

System efficiency (%)		70[1]
Total annual cost ($)		344,960
Dist. system ($)		250,760[2]
App. system ($)		94,200[3]
Total annual cost ($/ac)		109
Dist. system ($/ac)		79
App. system ($/ac)		30
Max. flow rate (cfs)		42.9
Total volume used (AF)		8120
Vol. of Deep Percolation (non-beneficial) (AF)		1030
Application systems:		
Annis:	Potatoes	HMS[4]
	Grain	HMS
	Alfalfa	HMS
	Pasture	HMS
Withers:	Potatoes	HMS
	Grain	HMS
	Alfalfa	HMS
	Pasture	HMS
Blackfoot:	Potatoes	HMS
	Grain	HMS
	Alfalfa	HMS
Hayeston:	Potatoes	CPS
	Grain	HMS
	Alfalfa	HMS
	Pasture	HMS

---

[1] Water-use efficiency of total system design is 70 percent.

[2] Distribution system cost includes cost of large pumping station.

[3] Application system cost includes cost of on-farm systems only.

[4] HMS - Hand-move sprinkler.
CPS - Center pivot sprinkler.

The selected system efficiencies considered in Tables 39 and 40 can be obtained with many other system combinations, although the costs of these combinations exceed those of the system combination specified. Although several types of application systems are optimized for each soil-crop combination, many of these systems may be incompatable with other applications systems used on crops on the same soil type (i.e., subirrigation with sprinkler). Likewise, if a crop rotation is assumed, designation of sprinkler and gravity systems on the same soil type may result in incompatibility due to the absense of leveling operations planned for sprinkler-irrigated areas. Designation of a center pivot sprinkler system on a soil type should encompass all crops irrigated on that soil for efficient operation. Those incongruities between the soil-crop combinations listed in Tables 39 and 40 do represent some basic system conflicts, although the ability to optimize systems based on individual soils and crops does provide valuable information concerning trends of the various combinations, thereby indicating those individual soil-crop-application system combinations which function most effectively at minimum cost for specified efficiency levels. In actual system design, system combinations listed in these tables would be generalized to resolve system conflicts present.

Water cost charges

Charges for water can be assessed for surface water delivered to an irrigation district from a feeder canal. The basis for charges can result from costs of supplying the water to the district through distribution systems, pumping systems, or inter-basin transfers. A charge for water can also occur due to negative impacts on power generation, ground water recharge, or recreational and wildlife habitat caused by the diversion. Cost of water is often charged per unit volume, usually dollars per acre-foot.

The charge for surface water entering the Salem Irrigation District was allowed to vary from $0 per acre-foot to $15 per acre-foot. This charge was considered for both gravity and pressure distribution systems. Optimization results related to the various water costs are summarized in Table 41 for the gravity distribution system. Optimal distribution and application system combinations along with annual ownership and operation costs are shown. The cost of water has been incorporated into application system annual costs in this table. Optimal application systems selected for the high pressure pipe system are essentially the same as those listed in Table 40. Annual costs for the system increase linearly in proportion to the charge assessed for water due to the insignificant change in system configuration. This relationship is shown in Figure 33 in Chapter VII.

Deep percolation and surface runoff charges

Deep percolation losses from application systems were divided into two categories in this study. Beneficial deep percolation was defined as that portion of water entering the groundwater system as a recharge source having negligible impact upon groundwater quality or soil nutrient losses. Non-beneficial or detrimental deep percolation

Table 41. Total annual system costs and descriptions of optimal gravity-supplied irrigation systems of various water costs. Salem Irrigation District.

Water Cost ($/AF)	0.00	3.00	6.00	9.00	12.00	15.00
Total annual cost ($)	95,150	207,180	266,110	301,870	333,850	363,690
Dist. System ($)	29,940	29,940	29,940	32,780	32,740	37,810
App. System ($)	65,210[1]	177,240	236,170	269,090	301,110	325,880
Total annual cost ($/Ac)	30.07	65.48	84.11	95.41	105.52	114.95
Dist. System ($/Ac)	9.46	9.46	9.46	10.36	10.35	11.95
App. System ($/Ac)	20.61	56.02	74.64	85.05	95.17	103.00
Max. flow rate (cfs)	230.9	148.6	77.6	58.3	53.9	51.8
System efficiency (%)	13.1	20.3	38.9	51.8	56.0	58.3
Vol. of Deep Percolation						
Beneficial (AF)	24,830	11,560	2,680	2,190	2,190	1,370
Non-beneficial (AF)		1,450	1,360	650	580	580
Vol. of Surface Runoff (AF)		2,620	3,290	1,930	1,400	1,400
Total Volume used (AF)	43,720	28,140	14,690	11,040	10,210	9,820
Distribution System						
Section: 1	UC[2]	UC	UC	UC	UC	UC
2	UC	UC	UC	UC	UC	LC
3	UC	UC	UC	UC	UC	UC
4	UC	UC	UC	UC	UC	LC
5	UC	UC	UC	UC	UC	LC
6	UC	UC	UC	LC	LC	LC
7	UC	UC	UC	LC	LC	LC
8	UC	UC	UC	UC	UC	UC
9	UC	UC	UC	UC	UC	UC
10	UC	UC	UC	LC	LC	LC
11	UC	UC	UC	UC	UC	UC
12	UC	UC	UC	UC	UC	UC

Table 41. Continued.

Application system:							
Annis:	Potatoes	SUB[3]	SUB	UNG	HMP	HMP	HMP
	Grain	SUB	UNG	UNG	UNG	IMG	IMG
	Alfalfa	SUB	UNG	UNG	UNG	UNG	UNG
	Pasture	SUB	SUB	UNG	HMP	HMP	HMP
Withers:	Potatoes	SUB	SUB	UNG	HMP	HMP	HMP
	Grain	SUB	UNG	IMG	IMG	IMG	IMG
	Alfalfa	SUB	UNG	UNG	IMG	IMG	IMG
	Pasture	SUB	UNG	IMG	IMG	SRP	SRP
Blackfoot:	Potatoes	SUB	SUB	HMP	HMP	HMP	HMP
	Grain	SUB	UNG	UNG	UNG	UNG	UNG
	Alfalfa	SUB	UNG	UNG	UNG	UNG	UNG
Hayeston:	Potatoes	SUB	SUB	CPP	CPP	CPP	CPP
	Grain	SUB	HMP	HMP	HMP	HMP	HMP
	Alfalfa	SUB	SUB	CPP	CPP	CPP	CPP
	Pasture	SUB	SUB	CPP	CPP	CPP	CPP

---

[1] Application system cost includes cost charged for water.

[2] UC = unlined channel
LC = lined channel
GP = gravity pipe

[3] Symbols are defined in Table 17.

was chosen to represent irrigation water which percolates through the soil profile, leaching soil nutrients into the groundwater supply. This form of percolation also recharges the groundwater supply, but at a loss to soil nutrients. In this study, all water recharged into groundwater through the processes of subirrigation and canal seepage was designated as beneficial, whereas deep percolation losses from all sprinkler and gravity irrigation systems were categorized as being non-beneficial.

Surface runoff losses from on-farm application systems result only with the use of unimproved and improved gravity systems. No runoff is apt to occur with properly designed sprinkler systems, and all water diverted for subirrigation normally enters the groundwater system through field laterals.

Annual system costs of gravity-supplied irrigation systems for various environmental costs or penalties charged against the system are summarized in Table 42. Beneficial deep percolation charges in this table are shown as negative values, as this form of water loss is defined as beneficial to the system. As can be expected, unlined channel and subirrigation remain as the optimum system for irrigation water application when subjected to these environmental restraints. This result occurs because of the absense of non-beneficial deep percolation and surface runoff from subirrigation systems. As beneficial deep percolation becomes worthwhile to the district, annual operation costs of subirrigation systems decrease. If the use of subirrigation or unlined canals in an area is a cause of damage due to high water table levels, then a positive

Table 42. Total annual system costs at various deep percolation and surface runoff charges for optimal gravity-supplied irrigation systems.

	Non-Beneficial Deep Percolation			Beneficial Deep Percolation		Surface Runoff
Environmental water charge ($/AF)	0.00	3.50	7.00	-0.50	-1.00	0.50
Total annual cost ($)	95,150	95,150	95,150	82,730	70,320	95,150
Dist. system ($)	29,940	29,940	29,940	29,940	29,940	29,940
App. System ($)	65,210	65,210	65,210	52,790	40,380	65,210
Total annual cost ($/Ac)	30.07	30.07	30.07	26.15	22.23	30.07
Dist. system ($/Ac)	9.46	9.46	9.46	9.46	9.46	9.46
App. System ($/Ac)	20.61	20.61	20.61	16.68	12.76	20.61
Max. flow rate (cfs)	230.9	230.9	230.9	230.9	230.9	230.9
Vol. of Deep Percolation						
Beneficial (AF)	24,830	24,830	24,830	24,830	24,830	24,830
Non-beneficial (AF)						
Vol. of Surface Runoff (AF)						
Total Volume used (AF)	43,720	43,720	43,720	43,720	43,720	43,720
Distribution System						
Section: 1	UC	UC	UC	UC	UC	UC
2	UC	UC	UC	UC	UC	UC
3	UC	UC	UC	UC	UC	UC
4	UC	UC	UC	UC	UC	UC
5	UC	UC	UC	UC	UC	UC
6	UC	UC	UC	UC	UC	UC
7	UC	UC	UC	UC	UC	UC

Table 42. Continued.

	8	UC	UC	UC	UC	UC	UC
	9	UC	UC	UC	UC	UC	UC
	10	UC	UC	UC	UC	UC	UC
	11	UC	UC	UC	UC	UC	UC
	12	UC	UC	UC	UC	UC	UC
Application system:							
Annis:	Potatoes	SUB	SUB	SUB	SUB	SUB	SUB[1]
	Grain	SUB	SUB	SUB	SUB	SUB	SUB
	Alfalfa	SUB	SUB	SUB	SUB	SUB	SUB
	Pasture	SUB	SUB	SUB	SUB	SUB	SUB
Withers:	Potatoes	SUB	SUB	SUB	SUB	SUB	SUB
	Grain	SUB	SUB	SUB	SUB	SUB	SUB
	Alfalfa	SUB	SUB	SUB	SUB	SUB	SUB
	Pasture	SUB	SUB	SUB	SUB	SUB	SUB
Blackfoot:	Potatoes	SUB	SUB	SUB	SUB	SUB	SUB
	Grain	SUB	SUB	SUB	SUB	SUB	SUB
	Alfalfa	SUB	SUB	SUB	SUB	SUB	SUB
Hayeston:	Potatoes	SUB	SUB	SUB	SUB	SUB	SUB
	Grain	SUB	SUB	SUB	SUB	SUB	SUB
	Alfalfa	SUB	SUB	SUB	SUB	SUB	SUB
	Pasture	SUB	SUB	SUB	SUB	SUB	SUB

[1] Subirrigation systems.

cost value should be levied against that system.

Because no beneficial deep percolation or surface runoff normally occurs with high pressure sprinkler systems, only non-beneficial percolation charges were incorporated into the high-pressure system optimization process. Results of this optimization are similar to those listed in Table 40. Hand-move sprinkler systems are designated as the least cost system for the Annis, Withers, and Blackfoot soil classes, and center pivot and hand-move sprinkler systems were chosen for use on the Hayeston soil. As the charge levied against deep percolation from sprinkler irrigation was increased to $7 per acre-foot the total annual cost of the high pressure system increased by $7140 ($2.26 per acre).

CHAPTER VII

DISCUSSION OF OPTIMIZATION RESULTS AND TRENDS

The linear-programming problems for irrigation system alternatives proposed for the Salem Irrigation District were formulated and solved as described in Chapter VI. Optimal solutions obtained were the least cost combinations of distribution and application systems necessary to meet various specified conditions. Summaries of the actual system components specified by the linear program are listed in Tables 39-42 and are discussed in Chapter VI. In this chapter, general trends of irrigation system alternative selection and specification subject to proposed district irrigation efficiencies, water costs, and environmental charges are discussed.

Specification of district irrigation efficiency levels

The specified overall efficiency for systems considered affects both total annual costs and the configuations of the systems. As the water supply to the Salem Irrigation District was restricted for gravity-supplied irrigation systems, the total annual cost of the optimal system combinations increased, as shown in Figure 27. From Table 39 in Chapter VI, it can be seen that a system supplied by a gravity distribution system has an efficiency of 13 percent, a total annual cost of $30 per acre, and requires a total system maximum flow rate of 230.9 cfs. All distribution system sections are unlined channels, and the application system on each soil type is subirrigation. At a specified efficiency of 50 percent, the total annual cost for the system is $63

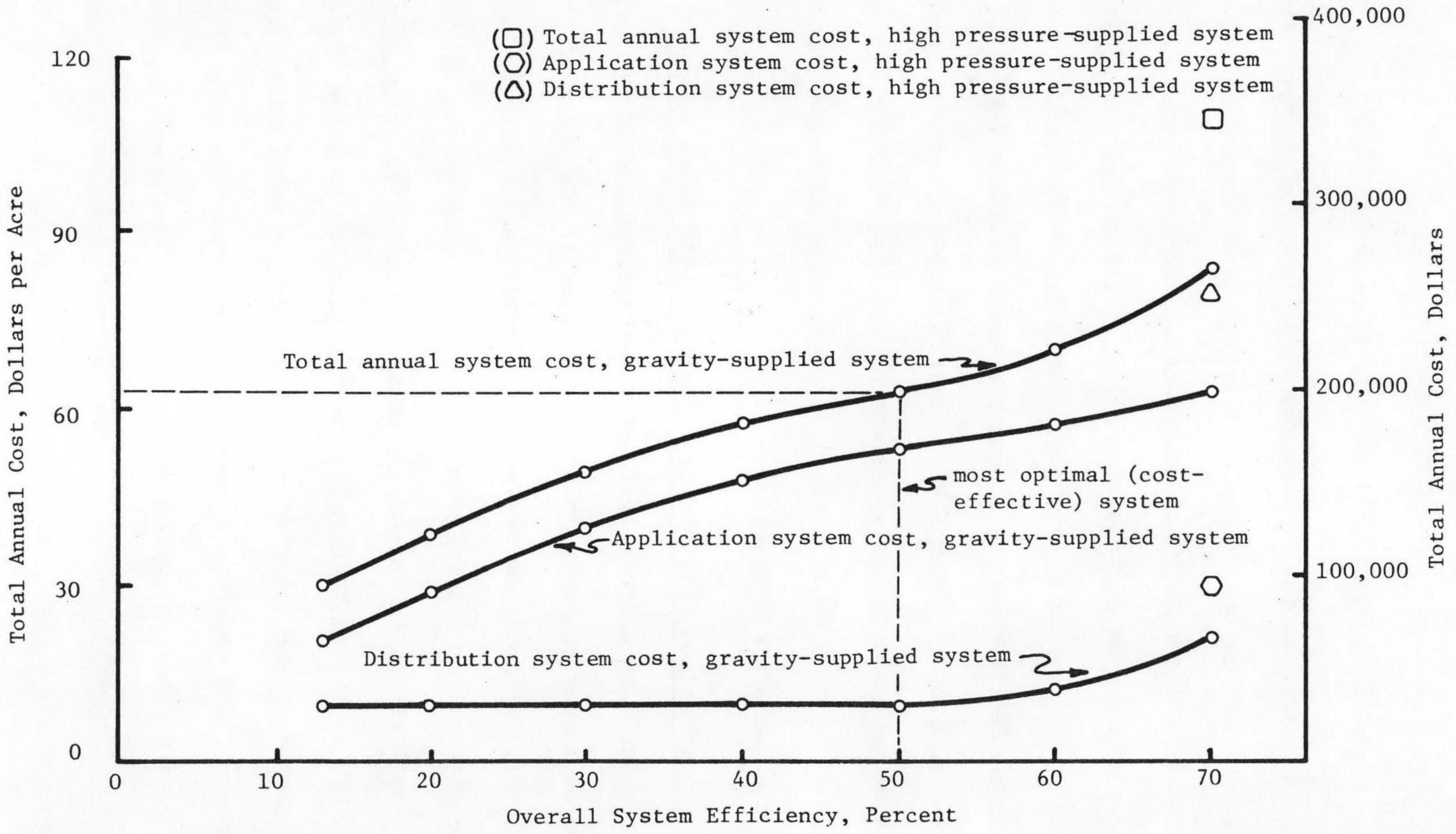


Figure 27. Annual irrigation system costs of gravity and high-pressure-supplied irrigation systems at various specified system efficiencies, Salem Irrigation District, 1977.

per acre; and the maximum required flow rate is 60.4 cfs. The distribution system was specified as all unlined channel, with all application systems upgraded to more efficient and costly practices. Sprinkler systems were specified for potatoes on all soil types and for all crops grown on the Hayeston soil class, a high infiltration rate soil. Unimproved and improved border irrigation systems were selected as the least cost systems at this efficiency level for grain and alfalfa crops on Annis, Withers, and Blackfoot soil classes. The major differences between unimproved and improved gravity systems were more extensive-land-leveling operations and increased water management with shorter irrigation set times on the improved gravity irrigated fields. Soils and distribution system routes for the Salem District are shown in Figures 5, 6, and 7 in Chapter IV. Irrigation application systems evaluated and optimized are summarized in Tables 12-17 for the various soil types.

According to Figure 27, money is best spent in rehabilitation of a subirrigation-unlined channel system by investing the first $33 per acre in updating of on-farm systems. This is due to the magnitude of efficiency increase experienced by the conversion to gravity and sprinkler systems. Percentages of various application systems selected for specified efficiency levels are listed in Table 43. Unimproved and improved gravity are the predominant systems at efficiencies of 30-50 percent. If the water flow rate into the total system is further restricted, then sprinkler systems are designated for most crop-soil

Table 43. Percentage of Salem Irrigation District irrigated with alternative application systems and required flow rates for specified system efficiency levels of gravity-supplied systems.

Sys. Eff. (%)	Dist. Sys. Cost ($/ac)	App. Sys. Cost ($/ac)	Sys. Flow Rate (cfs/ac)	Percent of district under different application systems[1]					
				SUB	UNG	IMG	HMP&SRP	SSP	CPP
13	9.46	20.61	.0730	100	--	--	--	--	--
20	9.46	28.91	.0477	47	45	--	8	--	--
30	9.46	39.84	.0318	4	76	--	16	--	4
40	9.46	47.55	.0239	--	55	22	11	--	12
50	9.46	53.50	.0191	--	22	30	36	--	12
60	12.51	57.41	.0159	--	16	21	51	--	12
70	21.08	63.04	.0136	--	--	10	70	--	20

[1] System abreviations and application efficiencies are defined in Tables 14-17.

combinations. Costs rise sharply as the specified efficiency approaches 60 and 70 percent. This sharp increase is caused by increased distribution system costs. Changes specified in the gravity distribution system can be seen in Table 39. Some distribution sections are lined to decrease seepage losses at the 60 percent efficiency levels, and gravity pipe is required in many sections to achieve a 70 percent system irrigation efficiency.

As system efficiency and the percentage of sprinkler systems in a system increase, the energy demand of the system also increases. The average energy consumed by on-farm sprinkler systems and small pumping plants of various system efficiency levels can be seen in Figure 28. Included in this figure is the energy demand of a system comprised entirely of sprinkler systems supplied by a large pumping plant-high pressure pipe system. The higher energy demand of this system indicates a lower pumping efficiency for the large pumping-high pressure system. The costs of this system are also shown in Figure 27. Application system costs are low because power and pumping costs have been included in the distribution system cost. Since the total annual cost of this system and the energy demanded are greater than for gravity-supplied systems at all efficiencies, this system would be an unfavorable alternative in rehabilitation of the Salem Irrigation District.

As the system flow rate is restrained, energy requirements increase for the gravity-supplied system and labor requirements often decrease

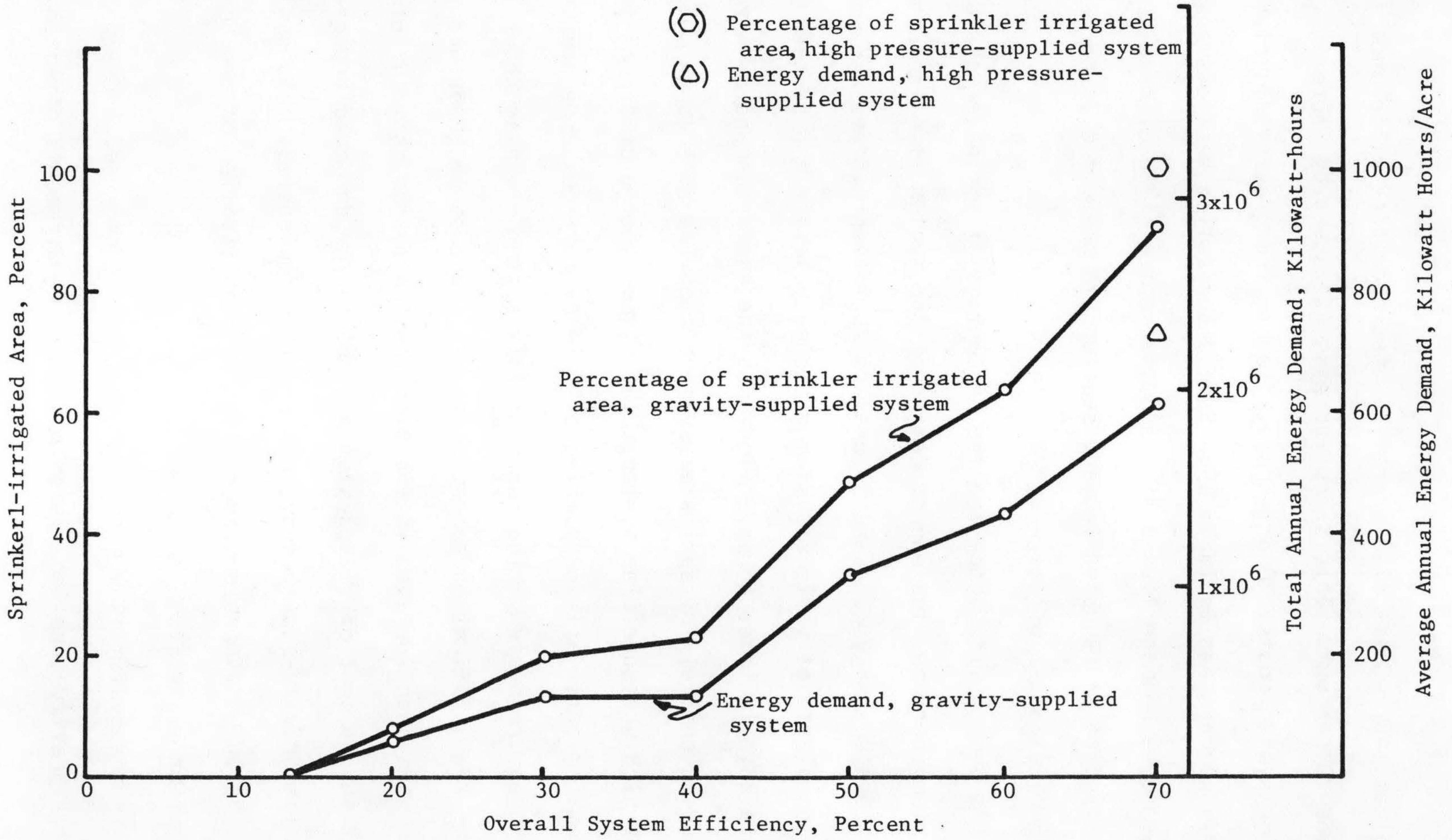


Figure 28. Sprinkler irrigated area and energy demand of gravity and high-pressure-supplied irrigation systems at specified system efficiencies, Salem Irrigation District, 1977.

due to conversion to sprinkler systems. The labor cost involved in management of subirrigation and surface systems is replaced by increased capital and energy costs of sprinkler systems. Capital costs may be substituted for labor costs in sprinkler system selection, as in the case of selection of side-roll rather than handmove systems. In this study, the total annual cost of a side-roll sprinkler system was comparable to that of a hand-move system for all soil types. The selection of a side-roll system may be most favorable in areas of high labor costs or shortages in labor availability. A comparison of annual costs of the various on-farm systems evaluated, including pumping and power costs, can be found in Tables 14-17.

The value of each dollar per unit area invested in an irrigation system is often important in determining the optimum degree of systems rehabilitation to plan for a particular district. Figures 29 and 30 can be useful in determining the appropriate target system efficiency to be achieved with each additional dollar per acre invested annually in a system. From Figure 29 it can be seen that the increase in system efficiency obtained for each additional dollar per acre annually invested increases until a value of $33 per acre has been invested. This value is in addition to the $30 per acre required to operate present subirrigation systems.

It is interesting to note annual costs incurred by completely replacing the present unlined distribution system with a lined channel or gravity pipe system. Data plotted in Figure 31 show the total system

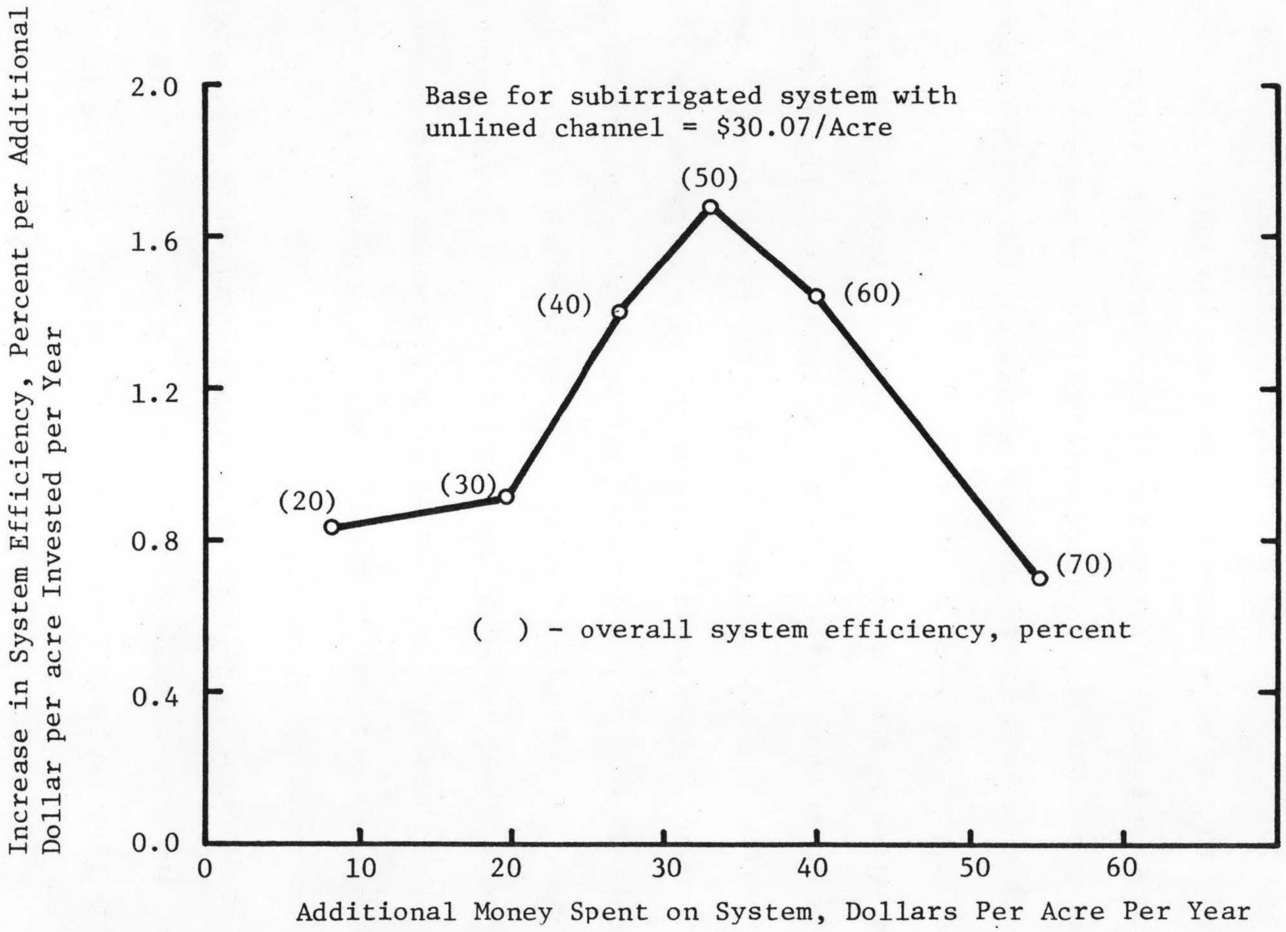


Figure 29. Maximum possible increase in system efficiency per additional dollar annually invested, Salem Irrigation District, 1977.

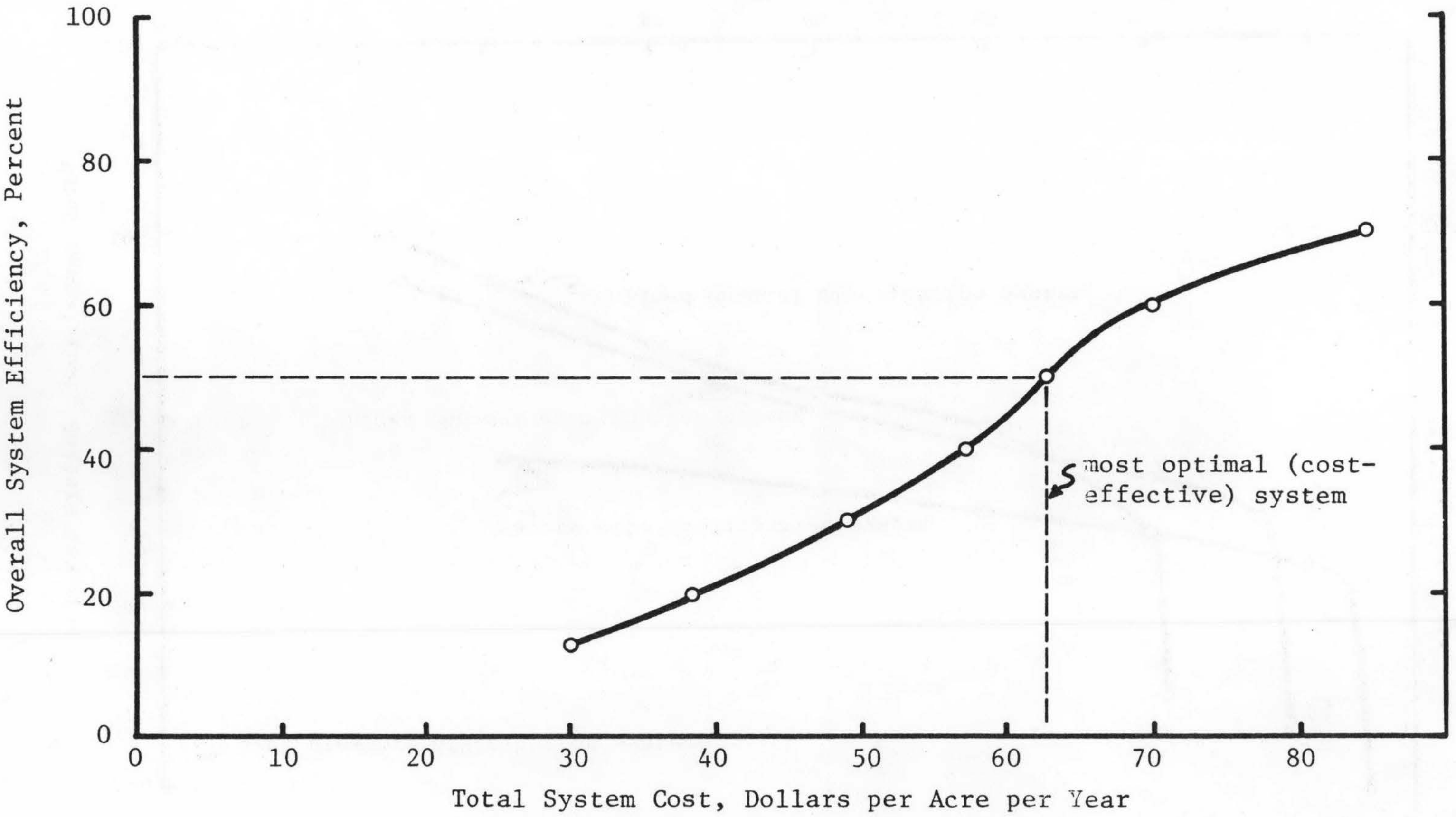


Figure 30. Overall system water-use efficiency versus dollars invested into system, Salem Irrigation District.

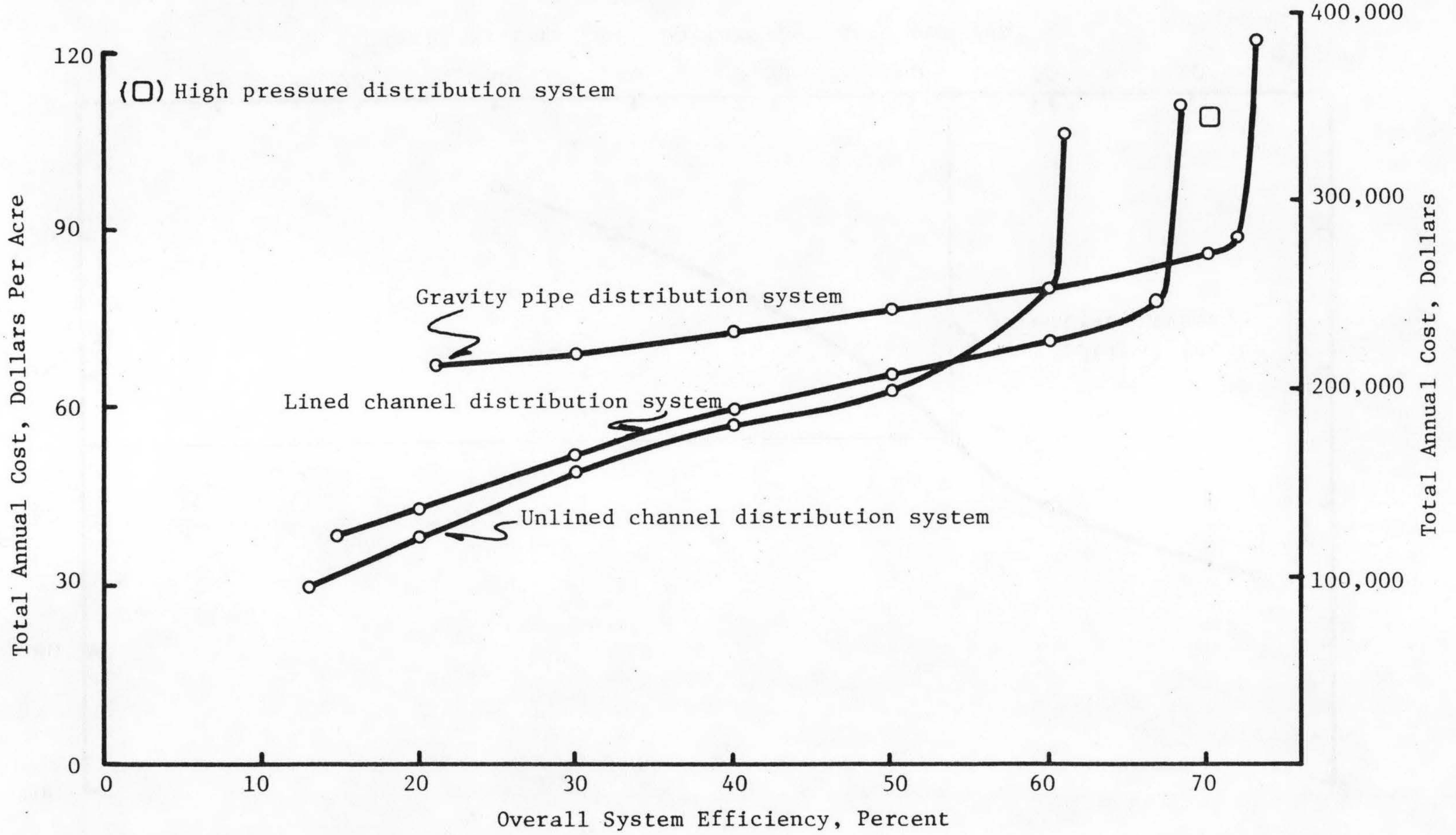


Figure 31. Total annual costs for unlined channel, lined channel, gravity pipe, and high pressure pipe - supplied irrigation systems in relation to system efficiency, Salem Irrigation District, 1977.

annual costs for application systems optimized at set efficiency levels for each distribution system alternative. The sharp increase in annual cost at higher efficiency levels results when the most efficient application systems, solid-set and center pivot, are incorporated into the overall design. No increase in system efficiency beyond the end point of each cost curve is possible.

The increase in money spent in the Salem Irrigation District to rehabilitate the present system can represent the value of any water saved by a reduction in the amount of water diverted. This is only true, however, if no increases in crop yields are realized by upgrading the systems, or if no higher valued crops can be raised in the district with increased water control and management.

Effects of Changes in Water Costs

In many areas of the western United States, costs for water charged to users are increasing due to higher distribution system costs or inter-basin transfers. It is important to systems operators and management to have available information regarding the most economical system component combinations possible in their district for various water changes assessed. The parametric programming option in a linear-programming routine can be valuable in optimizing system combinations subject to increasing water costs. Results of systems optimization at various water cost charges are shown in Table 41 for gravity-supplied system in the Salem Irrigation District. It can be seen that all changes in the system occur on the farm for water costs less than $9 per acrefoot. If the cost for water in the Salem Irrigation District were increased to $15 per acre-foot, half of the distribution system would require lining to keep total system costs at minimum levels. Potatoes and pasture crops would be best irrigated with sprinkler systems on the Annis, Withers, and Blackfoot soil types, and grain and alfalfa would require border methods. The Hayeston soil class would be most economically irrigated with center pivot systems on all crops.

Relationships between annual system cost, system efficiency, and water requirements are shown graphically in Figure 32 and 33 for various water costs. The annual cost of the gravity-supplied system, including the water costs, increases at a substantial rate as the cost of water increases from $0 to $6 per acre-foot. At greater water cost charges, the annual system cost increases in a linear fashion. The overall efficiency of the least cost system at a charge of $15 per acre-foot is 58 percent. The percentages of the Salem Irrigation District irrigated with various application systems at possible water charges are shown in Table 44 for the gravity-supplied system.

A charge of $15 per acre-foot for water in a high-pressure-supplied system has very little effect upon the system configuration or efficiency level. The annual cost of owning and operating the system is seen in Figure 33 to increase linearly with the value of water.

Effects of Changes in Deep Percolation Charges

The method and results of theoretically charging penalties for deep percolation and surface runoff in the Salem Irrigation District were

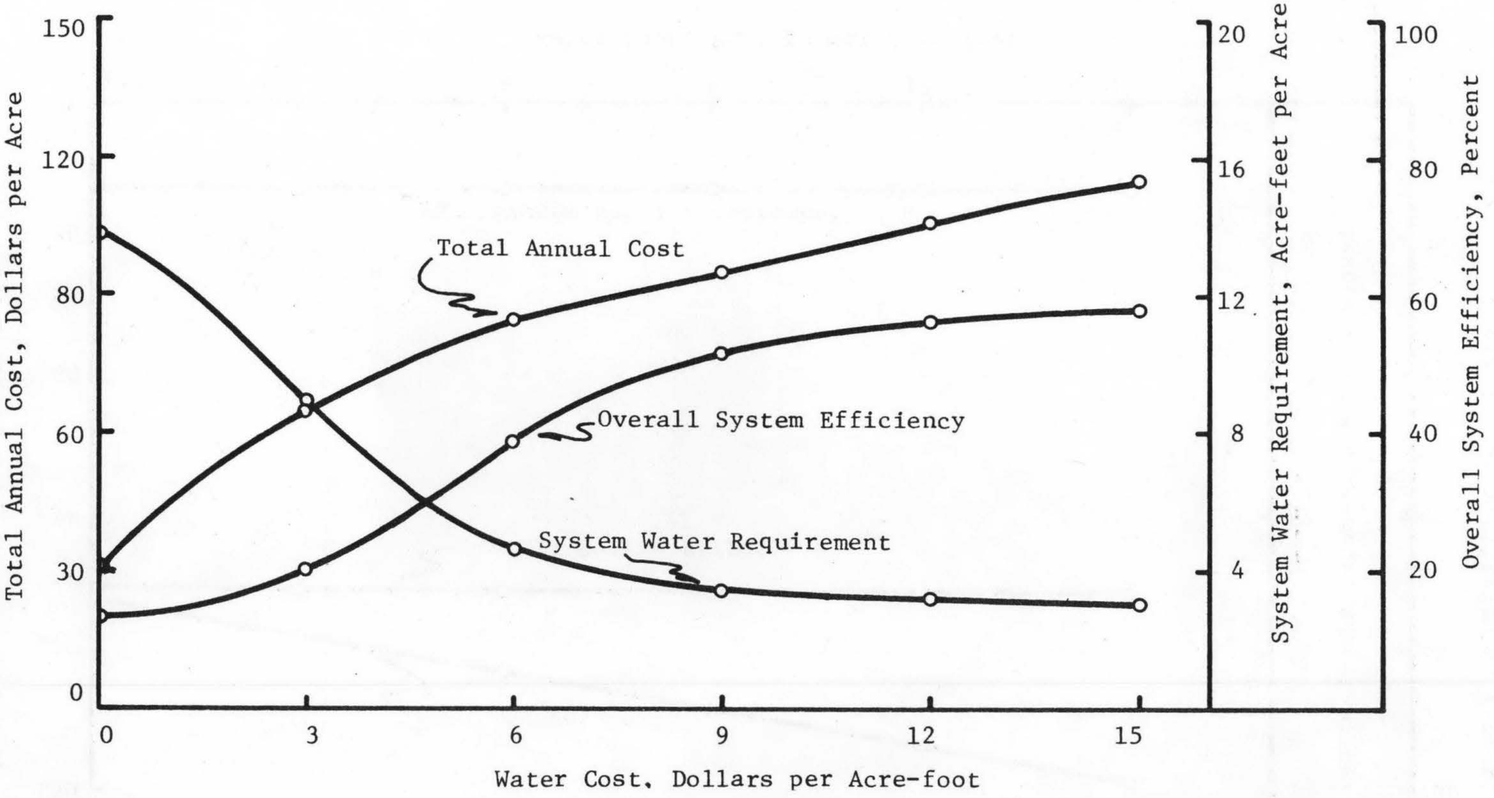


Figure 32. Overall system annual cost, efficiency, and annual water requirements versus water cost for optimal gravity-supplied irrigation systems, Salem Irrigation District, 1977.

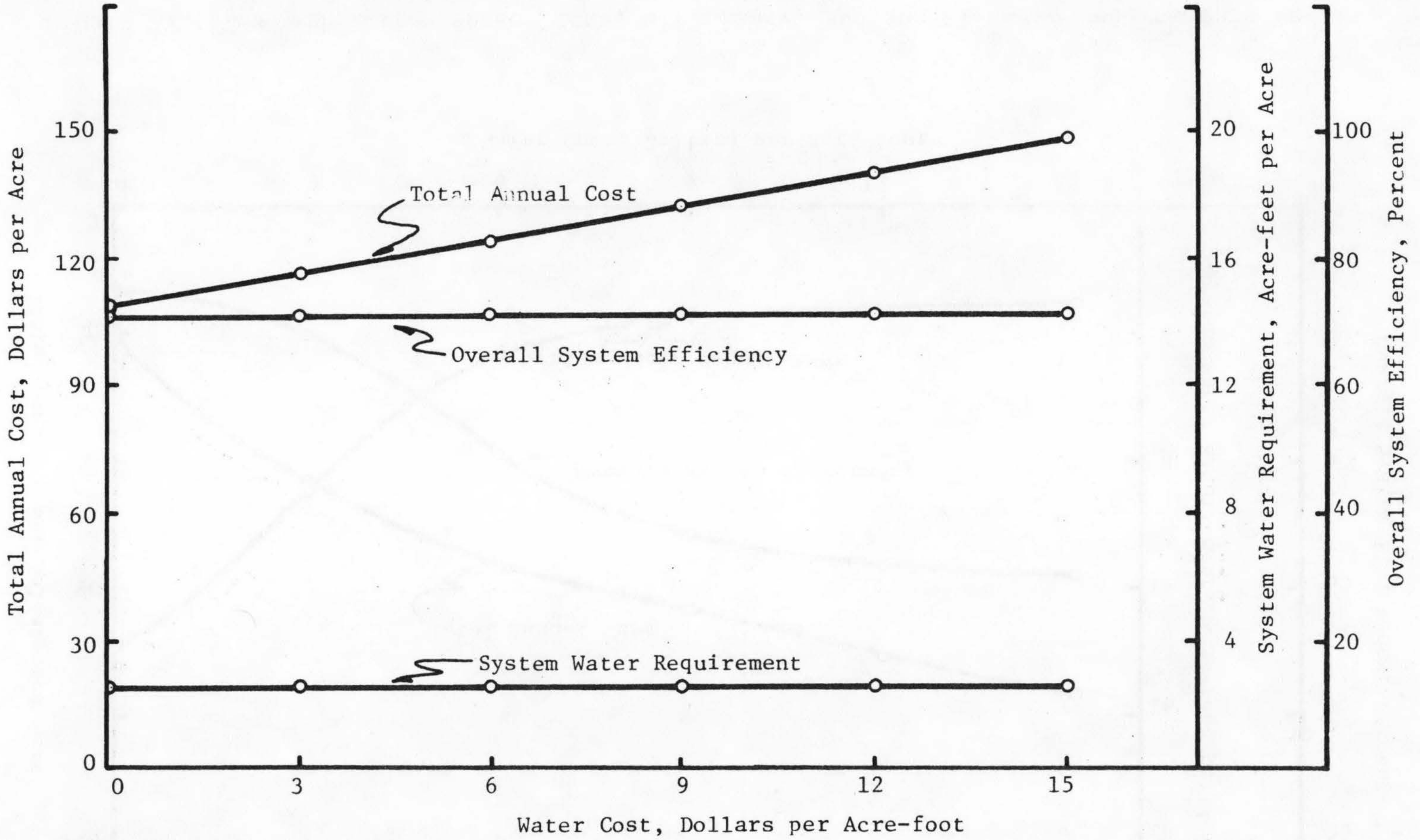


Figure 33. Total system annual cost, efficiency, and annual water requirement versus water cost for a high pressure-supplied irrigation system, Salem Irrigation District, 1977.

Table 44. Percentage of Salem Irrigation District irrigated with alternative application systems and water-use efficiencies for various water costs for gravity-supplied systems.

Water Cost ($/AF)	Dist. Sys. ($/ac)	App. Sys. ($/ac)	Sys. Eff. (%)	Percent of district under different application systems[1]					
				SUB	UNG	IMG	HMP&SRP	SSP	CPP
0	9.46	20.61[2]	13.1	100	--	--	--	--	--
3	9.46	56.02	20.3	40	52	--	8	--	--
6	9.46	74.64	38.9	--	55	22	11	--	12
9	10.36	85.05	51.8	--	22	30	36	--	12
12	10.36	95.17	56.0	--	12	33	43	--	12
15	11.95	103.00	58.3	--	12	33	43	--	12

[1] System abreviations and application efficiencies are defined in Tables 14-17.

[2] Application system cost includes cost of water and pumping costs.

discussed in Chapter VI. Deep percolation can be beneficial to groundwater recharge, although under most border, furrow, and sprinkler systems, deep percolation of water leaches valuable nutrients to depths below crop root zones.

When charges for beneficial and non-beneficial deep percolation were levied against the gravity-supplied system in the study area, subirrigation always remained as the most viable irrigation system alternative. This result is due to the lack of any real evidence of nutrient losses from subirrigated fields and the absence of surface runoff from this irrigation method. A charge for non-beneficial deep percolation caused only negligible effects upon the high pressure system, also. Hand-move systems were replaced by center pivot systems on the higher infiltration rate soil.

The effects of environmental charges on various systems can be important in analyzing the impacts of soil erosion, degradation of surface and groundwater, and soil nutrient losses on the feasibility and favorability of a particular system combination.

Summary of Results

Results presented in this report are those obtained specifically for the Salem Irrigation District. All prices and costs used were adjusted as closely as possible to second quarter 1976 prices and costs. Dollar values attached to the many different system components and alternatives are of many different forms such as capital costs, labor costs, energy costs, management and operation costs, and other costs for some rather intangible items.

Emphasis must be placed upon the fact that the methodology used in this model and the results obtained are intended to be used as planning tools and not as final designs. The physical values used are necessary input parameters if realistic results are to be obtained from the analytical model. The results presented indicate what types of system components would best meet a given set of conditions. These results can be used to develop specific designs for system components with the cost of the resultant design for the entire system being nearly the same as the cost obtained from the analytical model results.

Many of the results and system configuration trends summarized for the Salem Irrigation District in this report can be extended to other areas of the Teton River flood plain and subirrigated areas along the Egin Bench west of Henry's Fork of the Snake River. Component costs, farm sizes, soil types, and management practices of these areas are quite similar.

According to results from this study, the best method of rehabilitation of the Salem Irrigation District for greater water-use efficiencies would be to maintain the existing distribution system with the possible lining of some canal sections. Most farms could be converted to sprinkler irrigation systems, with improved gravity methods used on the deeper, more level soils in the eastern portion of the district. Utilization of this rehabilitation and conversion scheme could result in an overall district irrigation efficiency of approximately 60 percent. Annual costs of irrigation, including power and distribution system costs, would total about $70 per acre. Use of sprinkler systems on most farms would eliminate the need for extensive land leveling costs, and would be compatible with sprinkler systems already in use in the district. Pressurized water could be furnished by on-farm pumping units. All application systems evaluated in this study, except subirrigation and unimproved gravity systems, are assumed to be well-managed and maintained systems.

Although crop yield variations between various alternative systems were not evaluated in this study, increased crop uniformity and growth rates should be experienced with more properly designed and managed systems. Greater utilization and control of soil nutrients and fertilizers is possible with more efficient systems if irrigation scheduling is used. High value cash crops could be grown under sprinkler irrigation if the short growing season is not a major hinderance. Present cropping patterns of the Sugar City area were assumed for all systems in this study.

Costs of energy for all sprinkler and pumping systems were assumed to escalate at 9 percent per year over the life of these systems. As the lives of the on-farm pumping systems were estimated to be 15 years, no predictions of energy price increases after this time period were made. Alternative energy sources with low generation costs, such as low head hydroelectric production, may be economically feasible at that time.

This optimization procedure may prove to be valuable in planning of irrigation systems for the upper Snake River area if uses for water other than irrigation are developed in the future. The value of water to irrigation districts and optimum system renovation at these values can be determined.

This procedure could be used in water development projects to evaluate the need and cost for consolidation of the numerous irrigation districts along the Teton River flood plain and the elimination of some canal systems. Costs of consolidation would most probably be less per unit area of land than costs of constructing systems evaluated exclusively for the Salem Irrigation District. This would be made possible by more efficient systems design due to the larger land areas served, and would be especially apparent in the design of high pressure and large pumping systems.

Model Limitations and Assumptions

One of the objectives of this model is to obtain a least cost irrigation system which would comply with physical, social, legal, and environmental constraints. In formulating the mathematical model, two major objectives were considered: (a) an objective function to be optimized (i.e., minimization of cost), and (b) fulfillment of constraints or system restrictions. Since linear programming is a mathematical model, constraints imposed by the problem must be translated into mathematical form. Physical constraints can be handled easily by the model as it is rather easy to assign numerical values to the system. An example is to impose the size of area to be irrigated for a specific crop or to set a maximum rate of water that can enter the system. Legal constraints can be satisfied by specifying the decreed water rights of the district. Social constraints could be considered in the model by limiting the amount of water lost to deep percolation or surface runoff, or by restricting the use of a particular system component.

While this model is designed to accomodate various social and environmental constraints, it should be pointed out that they must be equated with a dollar value to satisfy the objective function optimized. Furthermore, by using a linear model to optimize irrigation systems, all costs and physical descriptions of system components must be expressed in linear form. This expression may result in some error, depending upon the properties of the components in relation to the flow rate of water conveyed or applied.

Sizes and uniformity along the various distribution sections must be generalized to keep the total model in relatively simple form. Soil types must also be generalized to allow application system operation characteristics to be defined and estimated.

If increases in crop yields achieved by upgrading on-farm systems could be accurately estimated, then a cost-benefit analysis could be performed for each system combination. Crop price forecasts would be necessary to compare long term benefits of the various irrigation systems.

Since all soil-crop-application system combinations are optimized independent of each other, some inconsistencies, such as subirrigation systems mixed with sprinkler systems, can be specified by the optimization procedure. This problem can be alleviated by optimizing on the basis of soil-application system combinations only. The number of application systems columns and soil-crop rows in the linear-programming matrix will be decreased, and all crops on a soil type would be optimized for the same irrigation method(s). Trends in the selection of particular soil-crop-application systems at various water costs and efficiencies could not be individually studied and defined in this case.

Many cost and design algorithms used in the distribution system cost evaluation routines were developed by the United States Bureau of Reclamation (USBR). Many of these equations describing costs of individual components have been revised during this project. Computer routines using acutal USBR cost estimation procedures are utilized and discussed by Galinato et al. (1977).

Reasonably attainable interest rates should be used in all cost routines to compute annual system costs, as a small variation in the rate of interest charged may result in large variations in annual costs of some systems.

A large digital computer with a FORTRAN IV compiler and 180,000 bytes of virtual storage is necessary to operate most of the computer programs discussed in this report. Procurement of a linear-programming routine design to operate on the specific computer utilized is also essential for use of this model. An integer-programming routine could possibly be used to replace the dynamic-programming routine developed during this study, and a non-linear program could facilitate more accurate modelling of a system's physical and environmental parameters.

REFERENCES

Abbett, R.W. 1956. American civil engineering book. John Wiley and Son, Inc., New York. pages 17-31.

Ackoff, R.L., and M.W. Sasieni. 1968. Fundamentals of operation research. John Wiley and Sons, Inc., New York.

Batty, J.C., S.N. Hamad, and J. Keller. 1975. Energy inputs to irrigation. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 101:293-307.

Bellman, R. 1957. Dynamic programming. Princeton University Press, Princeton, New Jersey.

Beveridge, G.S.G. and R.S. Schechter. 1970. Optimization: theory and practice. McGraw-Hill, New York.

Brockway, C.E. and D.L. Reese. 1973. Operation and Maintenance costs on irrigation distribution systems. Final report, College of Engineering, University of Idaho, Moscow, Idaho.

Buras, N. 1972. Scientific allocation of water resources. American Elsevier, New York.

Busch, J.R. 1974. Methodology for obtaining least cost irrigation system specifications. Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.

Christiansen, J.E. 1942. Hydraulics of sprinkling systems of irrigation. Transactions of the American Society of Civil Engineers 107:221-239.

Claiborn, B.A. 1975. Predicting attainable irrigation efficiencies in the upper Snake River region. M.S. Thesis, Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.

Dantzig, G.B. 1973. Linear programming and extensions. Princeton University Press, Princeton, New Jersey.

deNeufville, R. and J.H. Stafford. 1971. Systems analysis for engineers and managers. McGraw-Hill, New York.

Engineering News Record. Construction Weekly. McGraw-Hill, Inc. 1221 Avenue of the Americas, New York, New York, 10020.

Eyer, J.M. 1965. Pumping plant operation and maintenance costs. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 91:37-58.

Freeman, B.G. and D.F. Lard. 1970. A users guide to linear programming and the IBM MPS-360 computer routine. Departmental Technical Report Number 70-2, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas.

Galinato, G.D. 1974. Evaluation of irrigation systems in the Snake River Fan, Jefferson County, Idaho. Unpublished M.S. Thesis, University of Idaho, Moscow, Idaho.

Galinato, G.D., J.R. Busch and C.E. Brockway. Optimizing irrigation system design. Research Technical Completion Report, Water Resources Research Institute, University of Idaho, Moscow, Idaho.

Hadley, G. 1962. Linear Programming. Addison-Wesley, Reading, Massachusetts.

Hall, W.A. and J.A. Dracup. 1970. Water resources systems engineering. McGraw-Hill, New York.

Hammond, J. 1978. A program to promote irrigation conservation in Idaho. State of Idaho Department of Water Resources, Improved Water Use Efficiency Project: #535 Final Report, p. 18-20.

International Business Machines Corporation. 1969a. Mathematical programming system/360, Version 2, linear and separable programming -- users manual. While Plains, New York.

International Business Machines Corporation. 1969b. Mathematical programming system/360, application description manual. White Plains, New York.

International Business Machines Corporation. 1969c. Mathematical programming system/360, version 2, control language user's manual. White Plains, New York.

Israelson, O.W. and V.E. Hansen. 1962. Irrigation principles and practices. John Wiley and Sons, Inc., New York.

Jensen, M.E. and O.W. Howe. 1965. Performance and design of border checks on a sandy soil. American Society of Agricultural Engineers, Transactions 8(1):141-145.

Jensen, M.E., D.C.N. Robb, and E. Franzoy. 1970. Scheduling irrigations using climate-crop-soil data. Journal of Irrigation and Drainage Division, American Society of Civil Engineers 96:25-38.

Katopodes, N.D. and T. Skrelkoff. 1977. Dimensionless Solutions of border-irrigation advance. Journal of Irrigation and Drainage Division, American Society of Civil Engineers 103:401-417.

Keller, J. 1976. Energy economics in pipe and system selection. Paper presented at the 1976 Sprinkler Irrigation Association Technical Conference, Kansas City, Missouri, February 22-24.

Kruse, E.G. and D.F. Heermann. 1977. Implications of irrigation system efficiencies. Journal of Soil and Water Conservation 32(6):265-270.

Madison Soil and Water Conservation District. 1977. Madison County atlas and plat book. Rockford Map Publishers, Inc., Rockford, Illinois.

Milligan, J.H. 1971. General theory of the allocation model, in Appendix A, Application of operations research techniques for allocation of water resources in Utah. Utah Water Research Laboratory, Utah State University, Logan, Utah, pages 63-66.

Pair, C.H., D.C. Larsen, and R.A. Kohl. 1973. Center-pivot sprinkler systems. Cooperative Extension Service, College of Agriculture, University of Idaho. Bulletin No. 192, 4 pages.

Pearson, G.F. 1974. Life-cycle costing in an energy crisis era. Professional Engineer 44(7):26-29.

Schreiber, D.L. 1968. Optimization techniques for water resource systems. Open-file Report No. 6. State of Washington Water Research Center, Washington State University, Pullman, Washington.

Stark, R.M. and R.M. Nicholls. 1972. Mathematical foundations for design: civil engineering systems. McGraw-Hill, New York.

Strelkoff, T. 1977. Algebraic computation of flow in border irrigation. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 103:357-377.

Sutter, R.J. and G.L. Corey. 1970. Consumptive irrigation requirements for crops in Idaho. College of Agriculture Bulletin 516, University of Idaho, Moscow, Idaho.

U.S. Department of Agriculture, Soil Conservation Service. 1960. Irrigation guide for northeastern Colorado. Denver, Colorado.

U.S. Department of Agriculture, Soil Conservation Service. 1970. Irrigation guide for Southern and Southeastern Idaho. Boise, Idaho.

U.S. Department of Agriculture, Soil Conservation Service, 1974. Border irrigation, SCS National Engineering Handbook, section 15. U.S. Government Printing Office, Washington, D.C.

U.S. Department of the Interior, Bureau of Reclamation. 1977. Groundwater studies of the Henry's Fork-Teton River Area, Idaho. Pacific Northwest Region, Boise, Idaho.

U.S. Department of the Interior, Bureau of Reclamation. 1977. Irrigation operation and maintenance cost trends. Engineering and Research Center, Division of Water Operation and Maintenance, Bureau of Reclamation, Denver, Colorado.

Vaziri, C.M., H.G. Collins, and W.N. Reynolds. 1973. Furrow irrigation criteria for Hawaiian sugarcane. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, 99:1-14.

Wilke, O.C., and E.T. Smerdon. 1968. A hydrodynamic determination of cutback stream sizes for irrigation furrows. American Society of Agricultural Engineers, Transactions 11:634-637.

APPENDIX A

Page

Soils Description

SOILS DESCRIPTION[1]

Blackfoot Silt Loam

This soil is very deep and moderately well drained. It usually occurs on river terraces.

In a typical profile the surface layer is silt loam 10 inches thick; the upper substratum is silt loam 6 inches thick; the lower substratum is stratified silty clay loam, silt loam and sandy loam extending to depths of over 60 inches. The soil is calcareous throughout the mildly or moderately alkaline solum.

Permeability is moderate (0.2 to 0.6 inches/hour). Available water holding capacity (that available for plant use) is at least 2¼ inches per foot of soil depth. Organic matter content is moderately low (less than 1½ percent). A seasonal high water table fluctuates between 4 and 6 feet - usually for brief periods and can be affected by drainage.

Bannock Loam

These are moderately deep soils (20 to 40 inches), but with no restrictions on root zone for most plants. Below the surface area they are gravels or gravelly sand.

Soluble calcium salts are present throughout the profile. Water intake rate is 1 to 1.5 inches per hour and capacity for retention for

---

[1] Information obtained from USDA Soil Conservation Service.

plant use is about 1 to 1.25 inches per foot of depth.

Organic matter content is less than 0.5 percent.

Annis Silty Clay Loam

These soils are 60 inches or more deep on slopes of 0 to 1 percent. They are formed from mixed stream deposited materials on flood plains.

In a typical profile the surface layer is silty clay loam 7 inches thick. It is moderately affected by salts (can be sodium or calcium). The pH ranges from 7.9 to 8.4. The underlying layer and subsoil are silt loam 14 inches thick. The substratum is silty clay loam to a depth of 49 inches and silt loam to a depth of 60 inches.

Intake rates may be somewhat slow; permeability is 0.2 to 0.6 inches/hour. Effective rooting depth is 60 inches or more (depending upon the crop). Water available to plants is very high (about 2½ inches/foot of soil depth). Surface runoff is slow and erosion hazard is slight. Organic matter content is moderately low.

Withers Clay Loam

These soils are 40 inches or more deep on slopes of 0 to 1 percent. They formed from mixed stream deposited materials on flood plains.

The surface layer is 27" of silty clay loam or clay loam. The substratum is mottled gravelly loamy sand about 10 inches think over sand and gravel. Some areas have stratified silty clay loam, silt loam or clay loam in the lower 10 inches. Included in this unit are small areas of shallow or deep soils and areas with varied surface textures.

Permeability is moderately rapid (1.0 to 1.5 inches/hour). Available water holding capacity is about 1.9 inches per foot of soil depth. Effective rooting depth is 40 inches (depending upon the crop). Organic matter is moderately low.

Hayeston Variant Coarse Sandy Loam

This soil is moderately deep (20 to 40 inches) to sand and gravel. It formed in river washed or river deposited materials.

This soil is in Land Capability Class IIIs-3 which means that the soil (texture and depth) is the limiting productive factor. Growing soil building crops such as grass-legumes and management practices which build organic matter content are important to good management.

In a typical profile the surface layer is sandy loam 23 inches thick; the upper substratum is very gravelly sandly loam 5 inches thick; the lower substratum is sand and gravel to depths of over 60 inches.

Water intake and permeability ratio is moderately rapid (perhaps 2 inches/hour). Available water holding capacity is about 2 inches/foot. Effective rooting depth is 60 inches or more. Organic matter content is low - less than 1/2 percent.

Labenzo Silt Loam

This soil is moderately deep to gravel. In a typical soil profile the surface layer is silt loam 13 inches thick. The underlying layers are silt loam and loamy sand to a depth of 34 inches over sand and gravel. Soluble calcium salts are present throughout.

Effective rooting depth is 60 inches or more. The intake rate is more than .5 inches/hour. Water holding capacity is moderate to high (2.3 to 2.5 inches per foot of soil). Surface runoff is very slow and the hazard of erosion is slight.

Organic matter content in the surface layer is moderately low.

Haplaquolls, Miscellaneous

The soils of this unit are deep or moderately deep over sand, or sand and gravel, and are poorly or very poorly drained. They have a water table at or near the surface in the spring and summer months.

Textures of the upper part of the profile are usually clay, silty clay or silty clay loam, although coarser textures are also present in some areas. The material below 20 to 30 inches is usually stratified sand and soil material. Areas of Annis and Withers soils are included.

Because of the drainage, these areas are used mostly for native pasture or wildlife habitat. The general slope is less than 1 percent with potholes creating a channeled effect. Available water holding capacity is 4 to 8.5 inches.

APPENDIX B

DOCUMENTED LISTING OF COMPUTER PROGRAMS

APPENDIX B (continued)

Note: All computer programs were written to utilize the subroutine INPUT supported as a library program by Computer Services, University of Idaho, and included in this appendix. The subroutine INPUT allows free-form input of numeric data. Only numeric data are read from data input cards. Alphanumeric data are ignored.

```
C           DATA SET WIRFARM     AT LEVEL 063 AS OF 03/09/78
C            FARM PROGRAM      FOR COMPUTING APPLICATION SYSTEM COSTS
C               FOR ON-FARM IRRIGATION SYSTEMS AND OPERATIONS
C
C/    LIST,NONE
C
C  THIS PROGRAM DETERMINES ANNUAL COST OF ON-FARM IRRIGATION SYSTEMS
C
      COMMON TRAM(20),NCMB,FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50),TITLE(17), TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),PW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     &XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20)
      DATA COD7/3HEND/
C
   10 FORMAT(/,' THIS PROGRAM COMPUTES IRRIGATION SYSTEM COST'/)
   11 FORMAT(1H1,////////,T30,'OUTPUT OF PROGRAM---FCOST (FARM COST)')
   12 FORMAT(/,' TYPE NUMBER OF LAND SUBCLASS TO BE PROCESSED'/)
   14 FORMAT(/,' >>>>AT THIS POINT, DATA ARE FOR SPECIFIC SOIL TYPE <<'
     '//' TYPE THE FF DATA FOR SOIL TYPE NUMBER----',I2,/
     '' 1-AVERAGE FARM SIZE, ACRES'/
     '' 2-AVERAGE FIELD SLOPE, FT/FT'/
     '' 3-INTAKE FAMILY, SCS CLASSIFICATION'/)
   16 FORMAT(/,' THIS PROGRAM IS TERMINATED SUCCESSFULLY'///
     ''  OUTPUT OF THIS PROGRAM IS  OBTAINED AT THE'//
     '' TERMINAL - DATA 100 LINE PRINTER'/
     '//' GOODLUCK........BYE........'/)
C
C                  <--------------------READ CARD-----------
C  READ THE NUMBER OF LAND/SOIL CLASSES
C         NSOIL = NO. OF SOIL TYPEES TO BE PROCESSED
      WRITE(9,10)
      WRITE(6,11)
    5 WRITE(9,12)
C
      CALL INPUT(A,NS)
C
      NSOIL = A(1)
      IF(NSOIL.EQ.0)GO TO 4
      DO 2 K= 1,NSOIL
C
C                <------------------------------READ CARD-----------
C  READ AVERAGE FARM SIZE FOR EACH SOIL TYPE
C     ALSO-SLOPE,INTAKE FAMILY AND FIELD LENGTH
      WRITE(9,14)K
C
      CALL INPUT(A,NF)
      SIZE(K) = A(1)
      SL = A(2)
      FAM = A(3)
C
      CALL CROP(K)
      IF(TYP1.EQ.COD7)GO TO 4
C
    2 CONTINUE
      IF(TYP1.NE.COD7)GO TO 5
C
    4 CONTINUE
      WRITE(9,16)
C
      STOP
      END
C
      SUBROUTINE CROP (K)
C/    LIST,NONE
      REAL IRTOTC
      COMMON TRAMC(20),NCMB,      FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50), TITLE(17), TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     &XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20),XLNTF,RN(20)
      DIMENSION DLNTF(20),DLNT(20)
      DATA COD1,COD2,COD3,COD4,COD6 /4HGRAV,4HHAND,4HSIDE,4HCENT,4HSOLI/
      DATA COD5,COD7/4HREWO,3HEND/
C
C
C''''' THIS SUBROUTINE READS CROP AND SOILS DATA
C      COMPUTES ALSO WEIGHTED ANNUAL COST FOR SPECIFIC ALTERNATIVE
C
   50 FORMAT(/,' TYPE TOTAL NUMBER OF CROPS TO BE PROCESSED:'/)
   52 FORMAT(/,' TYPE NAME OF CROP NUMBER----',I2/)
   54 FORMAT(/,' TYPE THE FF DATA FOR CROP....',5A4/
     '' 1-WATER HOLDING CAPACITY, IN/FT'/
     '' 2-ROOT ZONE DEPTH, FT'/
```

```
     '' 4-TOTAL ANNUAL ET REQ., INCHES'/
     '' 5-MAXIMUM ET REQ., INCHES PER DAY'/
     '' 6-PERCENTAGE OF CROP GROWN'/)
   56 FORMAT(/,' TYPE IRRIGATION SYSTEM TO BE PROCESSED:'/
     '' USE THE FF CODE--'/
     ''...   GRAVITY    ..FOR FURROW, OR BOPDER IRRIGATION'/
     ''...   HAND MOVE ..FOR HAND MOVE SPRINKLER SYSTEM'/
     ''...   SIDE ROLL ..FOR WHEEL MOVE SPRINKLER SYSTEM'/
     ''...   CENTER PIVOT .. FOR SELF PROFELLED SPRINKLER SYSTEM'/
     ''...   SOLID SET .. FOR SOLID SET SPPINKLER SYSTEM'/)
   58 FORMAT(/,' IS THERE ANYMORE IRRIGATION SYSTEM TO PROCESS -----'/
     ''  UNDER SOIL TYPE NUMBER----',I3,' \\\\\\'//
     ''  IF ... NO TYPE..   REWORK'/
     ''  IF ...YES, TYPE... GRAVITY SYSTEM OR'/
     ''                    HAND MOVE OR'/
     ''                    SIDE ROLL OR'/
     ''                    CENTER PIVOT'/
     ''                   SOLID SET'/
     ''  IF END OF JOB...TYPE ..    END'/)
   60 FORMAT(/'TYPE THE MANNINGS ROUGHNESS COEFFICIENT FOR THIS CROP',/
     ''   SCS VALUES ARE AS FOLLOWS:'/
     ''       .04---BARE EARTH'/
     ''       .10---SMALL GRAIN-DRILLED'/
     ''       .15---ALFALFA,SMALL GRAIN-BROADCAST'/
     ''       .25---DENSE SOD,SMALL GRAIN-DRILLED ACROSS BORDER'/
     ''  0.0 MAY BE INSERTED IF BORDER IRRIGATION IS NOT CONSIDERED'/
     ''   FOR THIS CROP'/)
C
C                    <-------------------READ CARD-----------
      J=0
      WRITE(9,50)
      CALL INPUT(A,NC)
      NCMB = A(1)
C-----NCMB = TOTAL NUMBER OF CROPS TO BE PROCESSED
C
      DO 2 L = 1,NCMB
C                    <-------------------READ CARD-----------
C     READ HEADING FOR EACH CROP COMBINATION
      WRITE(9,52) L
      READ(5,4)(HEAD(L,I),I=1,20)
      WRITE(9,4)(HEAD(L,I),I=1,20)
    4 FORMAT(20A4)
C
C                    <-------------------READ CARD-----------
C     READ CROP-SOIL-WATER PARAMETERS
C        WHC = WATER HOLDIND CAPACITY
C        RZD = ROOT ZONE DEPTH IN FEET
C        PCT = PERCENT OF TOTAL AVAIL MOIST USEABLE AS  R.A.M.
C        ETTOTC= TOTAL ANNUAL ET REQUIREMENT IN INCHES
C        ETMAX = MAXIMUM ET RATE IN INCHES PER DAY
C        CROPD = PERCENTAGE OF CROP GROWN
      WRITE(9,54)(HEAD(L,IL),IL=1,5)
      CALL INPUT(A,ND)
      WHC = A(1)
      RZD = A(2)
      PCT = A(3)
      ETTOTC(L) = A(4)
      ETMAX = A(5)
      CROPD(L)= A(6)/100.
      RZDR(L) = RZD
C-----COMPUTE TOTAL READILY AVAILABLE MOISTURE
C
      TRAMC(L ) = RZD * WHC * PCT /100.
C
C-----COMPUTE TOTAL NUMBER OF IRRIGATION PER YEAR ASSUMING THAT TOTAL
C     READILY AVAILABLE MOISTURE  IS  SUPPLIED EACH IRRIGATION
C
      TOT = ETTOTC(L )/TRAMC(L ) + 0.85
      KTOT = TOT
      IRTOTC(L ) = KTOT
C
C-----COMPUTE IRRIGATION FREQUENCY
C
      EFQ = TRAMC(L )/ETMAX + 0.3
      IFQ =EFQ
      FREQC(L ) = IFQ
      WRITE (9,60)
      CALL INPUT(A,NRN)
      RN(L) = A(1)
C
    2 CONTINUE
C                    <-------------------READ CARD-----------
C--READ AN ALTERNATIVE TO BE PROCESSED
      WRITE(9,56)
C
```

```
   14 READ(5,3)TYP1,TYP2,TYP3,TITLE
      WRITE(9,3)TYP1,TYP2,TYP3,TITLE
    3 FORMAT(3A4,17A4)
C
C--CODE USED:
C       'GRAVITY'  =FURROW,CORRUGATION OR BORDER IRRIGATION
C       'HAND MOVE'=HAND-MOVE SPRINKLER SYSTEM
C       'SIDE ROLL'=WHEEL-MOVE SPRINKLER SYSTEM
C       'CENTER PIVOT'=SELF-PROPELLED SPRINKLER SYSTEM
C
      IF(TYP1.EQ.COD5.OR.TYP1.EQ.COD7)GO TO 20
      IF(TYP1.NE.COD1)GO TO 6
C
C     PROCESS GRAVITY IRRIGATION
C
   80 WRITE(9,57)
   57 FORMAT(/,'  TYPE AVERAGE FIELD LENGTHS, FT,'/
     ''  FOR FURROW IRRIGATED FIELDS, AND BORDER IRRIGATED FIELDS IN '/
     ''  THIS PARTICULAR SOIL CLASS'/
     ''  ENTER AS MANY PAIRS OF RUN LENGTHS AS DESIRED FOR COMPUTATION'/
     ''  OF EFFICIENCIES.  (I.E., 1300.,1200.,   650.,600., ...)'/)
C
      CALL INPUT(A,NRL)
      DO 85 NR=2,NRL,2
      DLNTF(NR/2) = A(NR-1)
      DLNT(NR/2)  = A(NR)
   85 CONTINUE
      NRL=NRL/2
C
      DO 90 NR=1,NRL
      XLNTF = DLNTF(NR)
      XLNT  = DLNT(NR)
      NN = NR
C
C
      CALL SURFCE(K,NN)
C
C--COMPUTE WEIGHTED COST FOR ALL CROPS ON A FARM
C
   16 WTDC = 0.
      WEFF = 0.
      WDVOL = 0.
      WRVOL = 0.
      DO 8 M=1,NCMB
      WTDC = WTDC + CROPD(M)*TCOST(M)
      WEFF = WEFF + CROPD(M)*EFFA(M)
      WDVOL = WDVOL + CROPD(M)*DVOL(M)
      WRVOL = WRVOL + CROPD(M)*RVOL(M)
    8 CONTINUE
C
C
C
C     K=SUBSCRIPT FOR TYPE OF SOIL
C     J=SUBSCRIPT FOR ALTERNATIVE
C
      J=J+1
C
      COSW(K,J) = WTDC
      WRITE(6,13)K
   13 FORMAT(1H1,///,T20,'SOIL TYPE NUMBER------',I2)
C
      WRITE(6,12)COSW(K,J),WEFF,WDVOL,WRVOL
   12 FORMAT(     ////T20,'WEIGHTED COST FOR  THIS SOIL TYPE AND IRRIGAT
     'TION SYSTEM ALTERNATIVE---->>>',T97,F6.2,2X,'DOLLARS PER ACRE
     & '//T20,'WEIGHTED WATER APPLICATION EFFICIENCY-----------
     & ',T97,F6.2,2X,'PERCENT'//
     & T20,'WEIGHTED VOLUME OF DEEP PERCOLATION ------------',T97,
     & F6.4,2X,'AC-FT PER AC PER YR'//
     & T20,'WEIGHTED VOLUME OF SURFACE RUNOFF ------------',T97,
     & F6.4,2X,'AC-FT PER AC PER YR'/)
C
   90 CONTINUE
C
      WRITE(9,58) K
      GO TO 14
C
C     PROCESS SPRINKLER SYSTEM
C
    6 IF(TYP1.EQ.COD2)KODE=3
      IF(TYP1.EQ.COD3)KODE=4
      IF(TYP1.EQ.COD4)KODE=5
      IF(TYP1.EQ.COD6)KODE=6
C
      CALL SPNKLR(K,KODE)
C
```

```
C
      GO TO 16
C
   20 RETURN
      END
C
C--SUBROUTINE SURFACE WILL COMPUTE THE TOTAL ANNUAL COST ON A PER ACRE
C  BASIS FOR  ON-FARM GRAVITY SYSTEM
C
      SUBROUTINE SURFCE(KSOIL,NN)
C/    LIST,NONE
C
      REAL IRTOTC,LFC,LFCF
      COMMON TRAMC(20),NCMB,FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50), TITLE(17), TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     & XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20),XLNTF,RN(20)
      DIMENSION KODE(5),CSTD(20)
      DATA DCOD/3HYES/
C
   50 FORMAT(/,' TYPE THE FF DATA FOR GRAVITY IRRIG. SYSTEM'/
     ''......FOR EACH CROP...  THERE ARE', I2, ' CROPS TO  PROCESS'/)
   51 FORMAT(/,
     '' 1-GRAVITY SYSTEM CODE'/
     ''      (1) CODE FOR FURROW IRRIGATTION'/
     ''      (2) CODE FOR BORDER IRRIGATION'/
     '' 2-AVERAGE INFLOW RATE, GPM FOR FURROW; CFS FOR BORDER'/
     '' 3-FURROW SPACING, IN OR BORDER WIDTH, FT'/
     '' 4-AVERAGE TIME OF SET. IF NOT KNOWN, TYPE...  0.'/)
   53 FORMAT(/,' TYPE DATA FOR CROP NUMBER....'.I3/,
     ''               AND RUN LENGTH NUMBER...',I3/)
   54 FORMAT(/,' TYPE THE FF DATA :'/
     '' 1-COST OF CONSTRUCTING OPEN DITCH AND DRAIN, $/FT'/
     '' 2-COST OF LINING FARM DITCHES, $/FT'/
     '' 3-COST OF IRRIGATION STRUCTURES, FURROW, $/AC'/
     '' 4-COST OF IRRIGATION STRUCTURES. BORDER, $/AC'/
     '' 5-COST OF MISC. IRRIGATION EQUIP.FURROW, $/AC'/
     '' 6-COST OF MISC. IRRIGATION EQUIP.BORDER, $/AC'/
     '' 7-COST OF LEVELING, SMOOTHING OP GRADING FURROW FIELDS, $/AC'/
     '' 8-COST OF LEVELING, SMOOTHING OR GRADING BORDER FIELDS, $/AC'/)
   52 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-IRRIGATION LABOR, FURROW, HR/IRRIG/AC/1000 FT OF RUN'/
     '' 2-IRRIGATION LABOR, BORDER, HR/IRRIG/AC/1000 FT OF RUN'/
     '' 3-ADDITIONAL LABOR IF ANY. FURROW, HR/IRRIG/AC'/
     '' 4-ADDITIONAL LABOR IF ANY, BORDER, HR/IRRIG/AC'/
     '' 5-RATE OF LABOR. $/HR'/)
   56 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-LIFE OF IRRIGATION EQUIPMENT, FORROW, YEARS'/
     '' 2-LIFE OF IRRIGATION EQUIPMENT, BORDER, YEARS'/
     '' 3-SALVAGE VALUE, PERCENT OF CAPITAL COST'/
     '' 4-RATE OF INTEREST, PERCENT'/)
   58 FORMAT(/, ' TYPE THE FF DATA:'/
     '' 1-COST OF ANNUAL LAND PREPARATION (PLANING), $/AC'/
     '' 2-VALUE OF LAND LOST TO PRODUCTION, $/AC'/)
   60 FORMAT(/,' TYPE THE FF DATA:'/
     ' ' 1-ANNUAL MAINTENANCE COST. PERCENT OF INVESTMENT'/
     '' 2-TAX AND INSURANCE, PERCENT OF AVE INVESTMENT'/)
   62 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-VALUE OF WATER LOST TO SURFACE RUNOFF, $/AF'/
     '' 2-VALUE OF WATER LOST TO D.P., $/AF'/)
   64 FORMAT(/,' DO YOU CONSIDER SUB-SURFACE DRAINAGE \\\\\'/
     ''    (YES OR NO)'/)
   68 FORMAT(/,' TYPE THE FF SUB SURFACE DRAINAGE DATA:'/
     '' 1-DRAIN DEPTH, FT'/
     '' 2-DISTANCE BETWEEN DRAIN & BARRIER, FT'/
     '' 3-PERMEABILITY BET. ROOT ZONE AND BARRIER, FT/DAY'/
     '' 4-MAX. PERMISSIBLE W.T. HEIGTH ABOVE DRAIN, FT'/
     '' 5-SLOPE OF LATERAL DRAIN, FT/FT')
   70 FORMAT(/,' TYPE THE COST AND LAYING OF DRAIN PIPES,$/FT'/
     '' 1-A 4-INCH PIPE'/
     '' 2-A 6-INCH PIPE'/
     '' 3-AN 8-INCH PIPE'/)
   72 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-UNIT COST OF EXCAVATION, $/CY'/
     '' 2-UNIT COST OF BACKFILL. $.CY'/
     '' 3-UNIT COST OF GRAVEL ENVELOP, $/CY'/
     '' 4-CONTINGENCY COST. PERCENT'/)
C
C                   <-------------------------READ CARD-----------
C          CODE MUST BE READ IN THE SAME ORDER AS BEFORE
C         1 = CODE FOR FURROW IRRIGATION
C         2 = CODE FOR BORDER IRRIGATION
      WRITE(9,50)NCMB
C
```

```
      WRITE(9,51)
C
      DO 45 LX=1,NCMB
      WRITE(9,53)LX,NN
      CALL INPUT(A,LZ)
      KODE(LX) = A(1)
      QGDM(LX) = A(2)
      FWIDE (LX) = A(3)
      TM (LX) =  A(4)
   45 CONTINUE
      IF(NN.GT.1) GO TO 590
C
C          '  SETLF = LABOR REQUIRED FOR FURROW PER SET PER ACRE
C          '  SETL  = LABOR REQUIRED FOR BORDER PER SET PER ACRE
C          '  GRLF  = ADDITIONAL LABOR REQUIRED PER SET PER ACRE, FURROW
C          '  GRL   = ADDITIONAL LABOR REQUIRED PER SET PER ACRE, BORDER
C          '  RATL  = LABOR RATE IN $/HR
C
C      SETLF AND SETL ARE INPUT FOR A FIELD 1000 FEET IN LENGTH.
C      AS THE RUN LENGTH DECREASES, LABOR REQUIREMENT PER IRRIGATED ACRE
C      INCREASES
C
C
      WRITE(9,52)
C
      CALL INPUT(A,LB)
      SETLF = A(1)
      SETL  = A(2)
      GRLF  = A(3)
      GRL   = A(4)
      RATL  = A(5)
C                      <--------------------READ CARD-----------
C  READ--' CDIT = COST OF CONSTRUCTING FARM DITCHES AND DRAINS,$/FT
C        ' CLIN = COST OF LINING FARM DITCHES, $/FT
C        ' CSTR = COST OF IRRIGATION STRUCTURES(CHECKS,SIDHON TURES).$/A
C        ' COTH = COST OF MISC EQUIPMENT,$/AC
C        ' LFC  = COST OF LEVELING.GRADING,SMOOTHING, $/AC
      WRITE(9,54)
C
      CALL INPUT(A,NC)
      CDIT = A(1)
      CLIN = A(2)
      CSTRF= A(3)
      CSTR = A(4)
      COTHF= A(5)
      COTH = A(6)
      LFCF = A(7)
      LFC  = A(8)
C
C                      <--------------------READ CARD-----------
C  READ--'  ELFE = EXPECTED LIFE OF IRRIGATION EQUIPMENT
C        '  SVAL = SALVAGE VALUE AS A PERCENTAGE OF CAPITAL COST
C        '  RINT = INTEREST RATE IN PER CENT
      WRITE(9,56)
C
      CALL INPUT(A,LF)
      ELFEF= A(1)
      ELFE = A(2)
      SVAL = A(3)/100.
      RINT = A(4)/100.
C
C                      <--------------------READ CARD-----------
C  READ--' CPRED = COST OF LAND PREPARATION IN $/ACRE
C        ' CLOST = VALUE OF LAND LOST TO PRODUCTION, $/ACRE
      WRITE(9,58)
C
      CALL INPUT(A,NP)
      CPREP = A(1)
      CLOST = A(2)
C                      <--------------------READ CARD-----------
C  READ--' XMAINT = ANNUAL MAINTENANCE AS A PERCENT OF INVESTMENT
C        ' XOEP  = OTHER EXPENSES AS A PERCENT OF AVERAGE INVESTMENT
      WRITE(9,60)
C
      CALL INPUT(A,CM)
      XMAINT = A(1)/100.
      XOEP = A(2)/100.
C                      <--------------------READ CARD-----------
C  READ--' SRVAL = NET VALUE OF WATER LOST TO SURFACE RUNOFF,$/AC-FT
C        ' DPVAL = NET VALUE OF WATER LOST TO DEEP PERC,$/AC-FT
      WRITE(9,62)
C
      CALL INPUT(A,NS)
      SRVAL = A(1)
```

```
C
      WRITE(9,64)
      READ(5,65)DRCD
      WRITE(9,65)DRCD
   65 FORMAT(A3)
      IF(DRCD.NE.DCOD)GO TO 66
      WRITE(9,68)
      CALL INPUT(A,NDD)
      DEPDD = A(1)
      DBF = A(2)
      PERM = A(3)
      XMAX = A(4)
      SLOP = A(5)
      WRITE(9,70)
      CALL INPUT(A,NPP)
      C4 = A(1)
      C6 = A(2)
      C8 = A(3)
      WRITE(9,72)
      CALL INPUT(A,NCC)
      UEXD = A(1)
      UBKD = A(2)
      UGRAV = A(3)
      CONTG = A(4)/100.
   66 CONTINUE
C
C--SET LOOP FOR ALL CROPS AND SYSTEMS CONSIDERED
C
  590 CONTINUE
      FL= XLNT
      FLF=XLNTF
      LL=0
      WRITE(6,80) XLNT,XLNTF
   80 FORMAT(1H1,///5X,'RESULTS FOR SURFACE IRRIGATED FIELDS'/
     '///5X,'WITH BORDER RUNS =',F6.0,/
     '///5X,' AND FURROW RUNS =',F6.0,/)
      DO 5 L = 1,NCMB
      IF (KODE(L).EQ.1) GO TO 220
C--COMPUTE COSTS FOR BORDER SYSTEMS
C
C--COMPUTE LABOR COST
C
      CLAB = IRTOTC(L)*(SETL*1000./XLNT+GRL)*RATL
C--COMPUTE  TOTAL INVESTMENT COST
C
      CROPA = SIZE(KSOIL) * CROPD(L)
      TCLIN = CLIN * (CROPA/FL) * 43560.
      TCDIT = CDIT * (CROPA/FL) * 43560.
C
      XCAP = TCDIT + TCLIN +(CSTR + COTH   )*CROPA
      YCAP = TCLIN +(CSTR + COTH) * CROPA
      ACAP = XCAP/CROPA + LFC
C) * CROPA
C--USE SINKING FUND DEPRECIATION  PLUS INTEREST
C) * CROPA
      SFF = RINT/(((1.+RINT)**ELFE)-1.)
C
      DEP = (XCAP-SVAL*YCAP) * SFF / CROPA
      CIN = RINT * XCAP / CROPA
      XLFC = RINT * LFC
      CIN = CIN + XLFC
C
C--COMPUTE OTHER EXPENSES SUCH AS TAXES AND INSURANCE
C
      COEXP = XOEP *(XCAP+SVAL*XCAP)/2. /CROPA
C
C--COMPUTE MAINTENANCE AND REPAIR COST
C
      CMAINT = XMAINT *(XCAP+SVAL*XCAP)/2. / CROPA + CPREP
C
C--COMPUTE TOTAL COST
C
      SUBT = DEP + CIN + COEXP + CMAINT + CLAB
      XXLST = 30./XLNT
      TCOST(L)= SUBT + CLOST * XXLST
      GO TO 280
C
C--COMPUTE COSTS FOR FURROW SYSTEMS
C
C
C--COMPUTE LABOR COST
C
  220 CLAB = IRTOTC(L)*(SETLF*1000./XLNTF+GRLF)*RATL
C--COMPUTE  TOTAL INVESTMENT COST
C
```

```
      CROPA = SIZE(KSOIL) * CROPD(L)
      TCLIN = CLIN * (CROPA/FLF)* 43560.
      TCDIT = CDIT * (CROPA/FLF)* 43560.
C
      XCAP = TCDIT + TCLIN +(CSTRF+ COTHF )*CROPA
      YCAP = TCLIN +(CSTRF+ COTHF)* CROPA
      ACAP = XCAP/CROPA + LFCF
C) * CROPA
C--USE SINKING FUND DEPRECIATION  PLUS INTEREST
C) * CROPA
      SFF = RINT/(((1.+RINT)**FLFFF)-1.)
C
      DEP = (XCAP-SVAL*YCAP) * SFF / CROPA
      CIN = RINT * XCAP / CROPA
      XLFC = RINT * LFCF
      CIN = CIN + XLFC
C
C--COMPUTE OTHER EXPENSES SUCH AS TAXES AND INSURANCE
C
      COEXP = XOEP *(XCAP+SVAL*XCAP)/2. /CROPA
C
C--COMPUTE MAINTENANCE AND REPAIR COST
C
      CMAINT = XMAINT *(XCAP+SVAL*XCAP)/2. / CROPA + CPREP
C
C--COMPUTE TOTAL COST
C
      SUBT = DEP + CIN + COEXP + CMAINT + CLAB
      XXLST = 30./XLNTF
      TCOST(L)= SUBT + CLOST * XXLST
C
   280 ZZLST = CLOST * XXLST
C--WRITE RESULTS
C
      WRITE(6,10)TYP1,TYP2,TYP3,TITLE
   10 FORMAT(1H1,T21,'ANNUAL COST OF IRRIGATION---------',20A4 )
      WRITE(6,11)KSOIL
   11 FORMAT(T21,'SOIL TYPE NUMBER-----',I2,/)
      WRITE(6,20)(HEAD(L,JL),JL=1,20)
   20 FORMAT(T40,20A4,/)
C
      IF(KODE(L).EQ.1) WRITE(6.13) FLF,SETLF,GRLF,RATL,CDIT,CLIN,CSTRF,
     +COTHF,LFCF,CPREP,CLOST,IRTOTC(L),TRAMC(L),FREQC(L),SIZE(KSOIL),
     +CROPA,ACAP
      IF(KODE(L).EQ.2) WRITE(6.13) FL.SETL,GRL,RATL,CDIT.CLIN.CSTR.COTH,
     +LFC,CPREP.CLOST,IRTOTC(L).TRAMC(L).FREQC(L),SIZE(KSOIL),CROPA,ACAP
      WRITE(6,17) DEP,CIN.CLAB.CMAINT,COEXP,SUBT,ZZLST
C
   13 FORMAT(T20,'FARM DATA:'/
     '       T11,'FIELD LENGTH. FT                      ',T51,F5.0/
     '       T11,'LABOR REQUIRED. HR/AC/IRR             ',T51,F5.2/
     '       T11,'ADDITIONAL LABOR, HR/AC/IRR           ',T51,F5.2/
     '       T11,'LABOR RATE, $/HR                      ',T51,F5.2/
     '       T11,'COST OF CONST. FARM DITCH. $/FT       ',T51,F5.2/
     '       T11,'COST OF FARM DITCH LINING. $/FT       ',T51.F5.2/
     '       T11,'COST OF IRRIGATION STRUC., $/AC  ',T51,F5.2/
     '       T11,'COST OF MISC. EQUIPT.. $/AC,          ',T51,F5.2/
     '       T11,'COST OF LEVELING. GRADING, $/AC        ',T50,F6.2/
     '       T11,'COST OF LAND PREPARATION, $/AC        ',T51.F5.2/
     '       T11,'COST OF LAND LOST TO PRODUCTION, $/AC',T50,F6.2///
     '       T11,'NUMBER OF IRRIG./SEASON               ',T51,F5.0/
     '       T11,'DEPLETED RAM BETWEEN IRRIGATIONS,INCHES',T51.F5.2/
     '   T11,'FREQUENCY OF IRRIGATION AT PEAK USE,DAYS  ' T51,F5.0//
     '       T11,'FARM SIZE, ACRE                      'T51,F5.0/
     '       T11,'FIELD SIZE FOR THIS CROP, AC          'T51,F5.0 /
     '   T11.'TOTAL INVESTMENT, $/AC     ',T49,F7.0//
     '       T20,'OWNERSHIP COST ($/AC)'/)
   17 FORMAT(T11,'DEPRECIATION (SINKING FUND)           'T50.F6.2/
     '       T11,'INTEREST ON INITIAL INVESTMENT        'T50,F6.2//
     '       T11,'OPERATION AND MAINTENANCE COST ($/AC)'/
     '   T11,'LABOR COST     ',T50,F6.2/
     '       T11,'MAINTENANCE AND REPAIR                'T51,F5.2/
     '       T11,'TAXES AND INSURANCE                  'T51.F5.2//
     '       T20,'SUB TOTAL ....................    'T50,F6.2/
     '       T11,'COST OF LAND LOST TO PRODUCTION          'T51,F5.2/)
   75 FORMAT(/T11,'COST OF WATER LOST '.T50,F6.2/
    ' T11,'COST OF SUB-SURFACE DRAIN ($/AC)',T50,F6.2//
     '       T20,'TOTAL ANNUAL COST ($/AC/YR)...        'T50.F6.2/)
C--AT THIS POINT,  COMPUTE WATER APPLICATION AND WATER LOSSES
C
      IF(KODE(L).EQ.1)GO TO 77
      LL = LL + 1
      CALL BORDER(L.AC.BC.C.LL.NN.DH.DE)
      GO TO 79
   77 CALL FURROW(L.AC,BC.C)
```

```
   79 CONTINUE
C
C
      IF(DCOD.NE.DRCD)CSTD(L)=0.
      IF(DCOD.EQ.DRCD)CALL   SDRAIN(L,DEPDD,DRF,PERM,XMAX,SLOP,FL,
     'C4,C6,C8,UEXD,UBKD,UGRAV,CONTG,RINT,SFF,XMAINT,CROPA,CSTD)
C
C----COMPUTE COST OF WATER LOST
      COSWL =    (RVOL(L)*SRVAL + DVO-(L)*DPVAL)
C
      TCOST(L) = TCOST(L) + CSTD(L) + COSWL
      WRITE(6,75)COSWL,CSTD(L),TCOST(L)
      SLL = SL
C
      IF(KODE(L).EQ.2)GO TO 150
      WRITE(6,89)
   89 FORMAT(1H1,///,T21,'FURROW IRRIGATION EFFICIENCY ESTIMATES')
      WRITE(6,11)KSOIL
      WRITE(6,90)XLNTF,TRAMC(L),QGDM(L),FWIDE(L),SLL,TM(L),FAM,AC,
     'BC,C,EFFA(L),EFFD(L),DVOL(L),RVOL(L)
   90 FORMAT(T15,'LENGTH OF IRRIGATION RUN,FT ' ,T65,F5.0/
     '        T15,'DEPTH OF WATER APPLIED,IN     ',T66,F6.2/
     '        T15,'FURROW STREAM SIZE,GPM',T65,F5.0/
     '        T15,'FURROW SPACING,IN',T65,F5.0/
     '        T15,'FIELD SLOPE, FT/FT',T69,F6.5/
     '        T15,'TIME OF APPLICATION,MIN',T65,F5.0/
     '        T15,'INTAKE FAMILY BASED ON SCS',T65,F6.1/
     '        T15,'        A COEF =',F6.4/
     '        T15,'        B COEF =',F6.4/
     '        T15,'        C COEF =',F6.4/
     '        T15,'APPLICATION EFFICIENCY, PERCENT',T65,F5.0/
     '        T15,'DISTRIBUTION EFFICIENCY, PERCENT',T65,F5.0/
     '        T15,'VOLUME OF DEEP PERC, AC-FT/AC/YR',T66,F6.2/
     '        T15,'VOLUME OF RUNOFF, AC-FT/AC/YR',T66,F6.2/)
      GO TO 5
  150 WRITE(6,152)
      WRITE(6,11)KSOIL
C
  152 FORMAT(1H1,///,T21,' BORDER IRRIGATION EFFICIENCY ESTIMATES')
      WRITE(6,154)XLNT,DH,DE,QU(L),FWIDE(L),SLL,TM(L),
     'EFFA(L),EFFD(L),DVOL(L),RVOL(L)
  154 FORMAT(T15,'LENGTH OF IRRIGATION RUN, FT',T64,F5.0/
     '        T15,'DEPTH OF WATER APPLIED AT FIELD HEAD, IN',T65,F6.2/
     '        T15,'DEPTH OF WATER APPLIED AT FIELD END , IN',T65,F6.2/
     '        T15,'UNIT STREAM SIZE, CFS/FT',T67,F6.4/
     '        T15,'BORDER WIDTH, FT',T64,F5.0/
     '        T15,'FIELD SLOPE, FT/FT',T67,F6.4/
     '        T15,'TIME OF APPLICATION, MIN',T64,F5.0/
     '        T15,'APPLICATION EFFICIENCY, PERCENT',T64,F5.0/
     '        T15,'DISTRIBUTION EFFICIENCY, PERCENT',T64,F5.0/
     '        T15,'VOLUME OF DEEP PERC, AC-FT/AC/YR',T65,F6.2/
     '        T15,'VOLUME OF RUNOFF, AC-FT/AC/YR',T65,F6.2/)
C
C--GO TO NEXT CROP
    5 CONTINUE
C
C---ADD EXTRA COST FOR MAIN CANAL---COMPOSITE
      IF(CLIN.NE.0.)GO TO 16
      ADCST = FL * CDIT
      GO TO 18
   16 ADCST = FL * CLIN
   18 RETURN
      END

C---THIS SUBROUTINE COMPUTES APPLICATION EFFICIENCIES OF
C    BORDER IRRIGATION SYSTEMS....R.G.ALLEN...G.D.GALINATO....
C
      SUBROUTINE BORDER(L,AC,BC,C,LL,NN,DH,DE)
C/    LIST,NONE
C
      PEAL IRTOTC
      COMMON TRAMC(20),NCMB,FREQC(20),ETTOC(20),HEAD(7,20)
      COMMON A(50),TITLE(17),TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     & XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20),XLNTF,RN(20)
C
      DIMENSION TA(100),TTR(100),DPPH(100),DPTH(100)
      DIMENSION LAL(2),LG(2),CF(4,5),COFF(5,9,4),COEF1(90),COEF2(90)
      DIMENSION XI(10),XDS(10),TDS(4,10),TRS(10),TIN(10)
      EQUIVALENCE (COEF1(1),COEF(1,1,1)), (COEF2(1),COEF(1,1,3))
      DATA YS/3HYES/
```

```
       DATA COEF1/
      & -0.4150, 2.3160, 0.0924,-0.0455,-0.0079,
      & -0.2994, 2.1981. 0.1181,-0.0494,-0.0148,
      & -0.1468, 2.0824, 0.1333,-0.0090,-0.0006,
      &  0.0407, 1.9526, 0.1403,-0.0103,-0.0041,
      &  0.2987, 1.7926, 0.1221, 0.0004,-0.0019,
      &  0.5293, 1.6122, 0.1013, 0.0084,-0.0002,
      &  0.5849, 1.4689, 0.1509, 0.0419, 0.0043,
      &  0.5818, 1.4445, 0.1806, 0.0430, 0.0037,
      &  0.5825, 1.4489, 0.1794, 0.0388, 0.0033,
      & -0.4824, 2.9732, 0.3149,-0.1295,-0.0414,
      & -0.3600, 2.7319, 0.3469,-0.0548,-0.0225,
      & -0.2239, 2.5006, 0.4359, 0.0363,-0.0062,
      & -0.0068, 2.2471, 0.4526, 0.1211, 0.0153,
      &  0.2474, 2.1225, 0.4042, 0.0571,-0.0012,
      &  0.5693, 1.9495, 0.2585, 0.0054,-0.0058,
      &  0.5726, 1.7614, 0.4251, 0.1288, 0.0135,
      &  0.5847, 1.7385, 0.4384, 0.1193, 0.0111,
      &  0.5823, 1.7349, 0.4484, 0.1193, 0.0110/
       DATA COEF2/
      & -0.6769, 3.9867, 1.1193,-0.1685,-0.1404,
      & -0.5245, 3.4924, 1.2310, 0.2436, 0.0035,
      & -0.2962, 3.1432, 1.2328, 0.4197, 0.0608,
      & -0.0400, 2.9050, 1.2328, 0.4439, 0.0608,
      &  0.2539, 2.6001, 1.0028, 0.3401, 0.0424,
      &  0.4791, 2.3461, 0.9260, 0.3266, 0.0400,
      &  0.5835, 2.3119, 0.9534, 0.3031, 0.0325,
      &  0.6093, 2.2950, 0.9449, 0.2758, 0.0271,
      &  0.6482, 2.2491, 0.8792, 0.2468, 0.0236,
      & -0.6234, 6.7411, 5.6423, 2.1934, 0.2117,
      & -0.5195, 6.0496, 6.2052, 3.5753, 0.7379,
      & -0.2863, 5.5300, 5.4534, 2.8355, 0.5053,
      &  0.0297, 4.8251, 4.2143, 1.9799, 0.3144,
      &  0.4247, 4.0387, 3.0400, 1.3074, 0.1874,
      &  0.6862, 3.5188, 2.1300, 0.7616, 0.0916,
      &  0.8811, 3.4234, 1.9788, 0.6451, 0.0701,
      &  0.9393, 3.2551, 1.7330, 0.5178, 0.0517,
      &  0.9496, 3.2288, 1.6451, 0.4667, 0.0446/
C
C----DEFINITION OF VARIABLES
C       QCFS - BORDER STREAM SIZE
C       SL - FIELD SLOPE. PERCENT
C       XLNT - LENGTH OF EIIRGATION RUN, FEET
C       BWIDE - BORDER WIDTH
C       TM - TIME OF APPLICATION
C       FAM - INTAKE FAMILY ACCORDING TO SCS CLASSIFICATION
C       RN - MANNINGS ROUGHNESS COEFFICIENT FOR BORDER
C
        QCFS = QGDM(L)
        BWIDE = FWIDE(L)
C
    110 FORMAT(/,' ADDITIONAL INFORMATION ON BORDER IRRIGATION'//
       '' DO YOU HAVE ADVANCE AND RECESSION DATA \\\\\\'/
       '' (YES OR NO)'/)
    118 FORMAT(/.' TYPE LAG TIME AND ASSUMED EFFICIENCY FOR'/
       '' THIS SOIL TYPE.  --SEE BORDER IRRIGATION MANUAL, SCS'/)
    129 FORMAT(/,' TYPE MULTIPLIER AND EXPONENT OF INTAKE CURVE'/)
    130 FORMAT(/,' TYPE MULTIPLIER AND EXPONENT OF ADVANCE CURVE'/)
    132 FORMAT(/,' TYPE MULTIPLIER AND EXPONENT OF RECESSION CURVE'/)
    117 FORMAT(/,' TYPE:                                          '/
       '           5X,'1--IF THE FLOW RATE AND SET LENGTH ARE TO BE ',
       '              'ADJUSTED TO INCREASE EFFICIENCY.'/
       '           5X,'2--IF ONLY THE SET LENGTH IS TO BE ADJUSTED.'/
       '           5X,'3--IF NEITHER Q NOR SET LENGTH ARE TO BE ADJUSTED'/)
C
C---ASSIGN COEFFICIENTS FOR DIFFERENT INTAKE FAMILIES
C
        FAM = FAM - .00001
        IF(FAM.LE.0.1)GO TO 5
        IF(FAM.LE.0.3)GO TO 10
        IF(FAM.LE.0.5)GO TO 15
        IF(FAM.LE.1.0)GO TO 20
        IF(FAM.LE.1.5)GO TO 25
        IF(FAM.LE.2.0)GO TO 30
        IF(FAM.LE.3.0)GO TO 35
        IF(FAM.LE.4.0)GO TO 40
C
      5 AC = 0.0244
        BC = 0.6610
        GO TO 45
     10 AC = 0.0368
        BC = 0.7210
        GO TO 45
     15 AC = 0.0467
```

```
      GO TO 45
   20 AC = 0.0701
      BC = .7650
      GO TO 45
   25 AC = 0.0899
      BC = 0.7990
      GO TO 45
   30 AC = 0.1084
      BC = 0.8080
      GO TO 45
   35 AC = 0.1437
      BC = 0.8160
      GO TO 45
   40 AC = 0.1750
      BC = 0.8230
   45 C=0.275
      NOT=0
C
      IF(LL.EQ.1)WRITE(9,110)
      IF(LL.EQ.1)READ(5,112)ADV
      IF(LL.EQ.1)WRITE(9,112)ADV
      IF(ADV.EQ.YS)GO TO 114
C
  112 FORMAT(A3)
      IF(LL.NE.1.OR.NN.GT.1) GO TO 108
      WRITE(9,117)
      CALL INPUT(A,NONE)
      DIMP=A(1)+.0005
      NIMP=DIMP
  108 IF(TM(L).GT..005) GO TO 116
C
C----IF TIME OF APPLICATION IS NOT GIVEN-WILL COMPUTE LEAST TIME
C    SET TO APPLY THE REQUIRED DEPTH.. PROCEDURE IS BASED ON BORDER
C    IRRIGATION MANUAL, SCS.
       IF(LL.NE.1)GO TO 150
       IF(NN.GT.1)GO TO 150
C
      WRITE(9,118)
      CALL INPUT(A,NL)
      TLAG = A(1)
      EFFAS = A(2)
C----COMPUTE TIME REQUIRED TO APPLY NET DEPTH
  150 FL = TRAMC(L)
      TN = ((TRAMC(L) - C)/AC)**(1./BC)
C----COMPUTE UNIT Q
      UST = (XLNT*FL)/(7.2*(TN-TLAG)*EFFAS)
      QU(L) = UST
      TTA = TN-TLAG
      TM(L) = TTA
      QCFS = UST * BWIDE
      GO TO 120
C
  116 CONTINUE
      TLAG = 12.
      QU(L) =QCFS/BWIDE
      TTA = TM(L)
C
C---COMPUTE ADVANCE USING GENERALIZED DIMENSIONLESS SOLUTION
C    DEVELOPED BY N.D. KATOPODES AND THEODOR STRELKOFF, UCD.
C
C----COMPUTE NORMAL DEPTH USING MANNINGS EQUATION FOR OPEN CHANNEL FLOW
C
  120 Q0 = QU(L)
      CU = 1.486
      IF(SL.LE.0.) SL=0.00001
      YN = (Q0*RN(L)/(CU*SL**.5))**.600
C
C----CALCULATE DIMENSIONAL PARAMETERS USED IN COMPUTATION OF ADVANCE
      TS = (YN/(AC/(60.**BC*12.)))**(1./BC)
      XS = Q0/YN*TS
      P = SL*Q0*TS/YN**2
C
C----CALCULATE THE SQUARE OF THE FROUDE NUMBER AND TEST FOR ZERO INERTIA
      FN2 = Q0**2/(32.17*YN**3)
      IF(FN2.GT..05) WRITE(6,330) FN2
C----DETERMINE COEFFICIENTS OF THE 4TH DEGREE POLYNOMIAL REGRESSION
C    EQUATIONS DESCRIBING T* VS X* FOR THE FOUR CURVES
C    OF ALPHA AND NPL WHICH ENVELOPE BC AND P.
C
      LAL(1) = INT(BC*10.)
      LAL(2) = LAL(1)+1
      PLG = ALOG10(P*10.**6)
      LG(1) = INT(PLG)
      LG(2) = LG(1)+1
```

```
      DO 210 I=1,2
      LALPHA = LAL(I)-5
      DO 210 J=1,2
      NPL = LG(J)
      IF(NPL.GT.9) NPL=9
      IF(NPL.LT.1) NPL=1
      JC = JC+1
      DO 205 JP=1,5
  205 CF(JC,JP) = COEF(JP,NPL,LALPHA)
  210 CONTINUE
C
C----DIVIDE FIELD INTO 10 STATIONS AND CALCULATE DIMINSIONLESS DISTANCES
      XL = XLNT/10.
      XJ = 0.
      DO 220 I=1,10
      XJ = XJ+XL
      XI(I) = XJ
  220 XDS(I) = XJ/XS
C
C----COMPUTE DIMENSIONLESS ADVANCE TIMES OF EACH STATION FOR
C    EACH OF 4 SETS OF REGRESSED CURVES
      DO 250 JC=1,4
      DO 250 I=1,10
      TJ = CF(JC,1)
      DO 240 JP=2,5
  240 TJ = TJ+CF(JC,JP)*(ALOG(XDS(I)))**(JP-1)
  250 TDS(JC,I) = EXP(TJ)
C
C----DETERMINE INTERPOLATED VALUE OF TDS BETWEEN THE FOUR CURVES
      P1 = 10.**(LG(1)-6)
      P2 = 10.**(LG(2)-6)
      IF(LG(1).LT.1.OR.LG(2).GT.9) GO TO 260
      DP = (P-P1)/(P2-P1)
      GO TO 264
  260 DP = 0.
  264 DO 270 J=1,3,2
      DO 270 I=1,10
  270 TDS(J,I) = TDS(J,I)+DP*(TDS(J+1,I)-TDS(J,I))
      DP = (BC*10.-LAL(1))/(LAL(2)-LAL(1))
      DO 280 I=1,10
  280 TDS(1,I) = TDS(1,I)+DP*(TDS(3,I)-TDS(1,I))
C
C----TRANSFORM DIMENSIONLESS TIME INTO ACTUAL TIME IN MINUTES
      DO 290 I=1,10
      TA(I) = TDS(1,I)*TS/60.
  290 CONTINUE
C
C------COMPUTATION OF VOLUMES OF INFILTRATION FOR THE STATIONS,
C      AND RUNOFF FROM THE FIELD USING AN ALGEBRAIC COMPUTATION DERIVED
C      BY T. STRELKOFF,(UNIV. CALIF.,DAVIS), IN PROC. ASCE IR3 SEPT.1977
C
C----COMPUTE THE RECESSION CURVE
C----FIND THE AVERAGE INFILTRATION RATE IN THE FIELD AT BEGINNING OF
C    RECESSION
      TR = TTA+TLAG
      AIN = (AC*BC*TR**(BC-1))/20.
      DO 300 I=1,9
      IF((TR-TA(I)).LE.0.) GO TO 435
  300 AIN = AIN+(AC*BC*(TR-TA(I))**(BC-1))/10.
      IF((TR-TA(10)).LE.0.) GO TO 435
      AIN = AIN+(AC*BC*(TR-TA(10))**(BC-1))/20.
C
C----COMPUTE THE FLOW RATE OFF END OF FIELD AT BEGINNING
C    OF RECESSION
      Q1 = Q0-(AIN*XLNT/(60.*12.))
C----DETERMINE NORMAL DEPTH AT END OF FIELD
      YN = (Q1*RN(L)/(CU*SL**.5))**.600
C
C----CALCULATE SY, THE RATE OF CHANGE OF DEPTH WITH DISTANCE
      SY = YN/XLNT
      IF((SL-SY).LE.0.) GO TO 400
      IF(SY.LE.0.) GO TO 400
      AIN = AIN/(60.*12.)
C----CALCULATE COEFFICIENT FOR SOLUTION OF A NONLINEAR ORDINARY
C    DIFFERENTIAL EQUATION
      CD = CU*SL**.5*SY**(5./3.)/(RN(L)*AIN)
      CP = CD**1.5
C----DETERMINE TIME WATER FRONT RECEDES PAST STATIONS
      IF((CP*XLNT).LE.0.) GO TO 420
      RECL=0.
      IF((CP*XLNT).LE.1.) GO TO 310
      DO 305 K=1,15
      J=K-1
  305 RECL = RECL+(-1.)**J*(CP*XLNT)**((1.-2.*J)/3.)/((1.-2.*J)/3.)
```

```
      GO TO 315
  310 DO 312 K=1,15
      J=K-1
  312 RECL = RECL+(-1.)**J*(CP*XLNT)**((2.*J+3.)/3.)/((2.*J+3.)/3.)
  315 DO 320 II = 1,9
      RECD = 0.
      I=10-II
      IF((CP*XI(I)).LE.0.) GO TO 420
      IF((CP*XI(I)).LE.1.) GO TO 317
      DO 316 K=1,15
      J=K-1
  316 RECD = RECD+(-1.)**J*(CP*XI(I))**((1.-2.*J)/3.)/((1.-2.*J)/3.)
      RECD = RECD-4.71238
      TRS(II) = TR+SY/(AIN*CP)*(RECL-RECD)/60.
      GO TO 320
  317 DO 318 K=1,15
      J=K-1
  318 RECD = RECD+(-1.)**J*(CP*XI(I))**((2.*J+3.)/3.)/((2.*J+3.)/3.)
      TRS(II) = TR+SY/(AIN*CP)*(RECL-RECD)/60.
  320 CONTINUE
      TRS(10) = TR+SY/(AIN*CP)*RECL/60.
C----CALCULATE TOTAL INFILTRATION OF THE STATIONS AND FIND AVERAGE
  340 TINH = AC*TR**BC+C
      TAIN = TINH/20.
      DO 350 I=1,9
      TIN(I) = AC*(TRS(I)-TA(I))**BC+C
      TAIN = TAIN+TIN(I)/10.
  350 CONTINUE
      TIN(10) = AC*(TRS(10)-TA(10))**BC+C
      VIN = TAIN + TIN(10)/20.
C----DETERMINE THE TOTAL VOLUME OF WATER TO FLOW ONTO THE FIELD
      VON = TTA*Q0*60./XLNT*12.
C----DETERMINE TOTAL RUNOFF
      VSR = VON-VIN
C----CALCULATE DEEP PERCOLATION
      IF(TINH.LE.TRAMC(L).AND.TIN(10).LE.TRAMC(L)) GO TO 380
      TN = TRAMC(L)
      VDP = AMAX1((TINH-TN),0.)/18.
      DO 360 I=1,9
      VDP = VDP+AMAX1((TIN(I)-TN),0.)/9.
  360 CONTINUE
      VDP = VDP+AMAX1((TIN(10)-TN),0.)/18.
      GO TO 385
  380 VDP = 0.
C
C----CALCULATE APPLICATION EFFICIENCY AND DISTRIBUTION EFFICIENCY
  385 EFFA(L) = (VIN-VDP)/VON*100.
      EFFD(L) = AMIN1(TIN(10),TINH)/VIN*100.
C----CALCULATE SEASON LOSSES
      RVOL(L) = VSR*IRTOTC(L)/12.
      DVOL(L) = VDP*IRTOTC(L)/12.
C
      IF(NIMP.EQ.3) GO TO 200
      DIFIN = TIN(10)/TRAMC(L)
      IF(DIFIN.LT..85) GO TO 390
      IF(DIFIN.LT.1.1) GO TO 200
      IF(NQT.EQ.2) GO TO 200
      WRITE(6,441) TTA,EFFD(L),EFFA(L).QU(L).TINH,TIN(10)
  441 FORMAT(/5X,'THE SET TIME OF ',F10.3,' MINUTES IS TOO LONG.'/
     &5X,'DEEP PERCOLATION AT THE FIELD END IS OCCURRING. '/
     &5X,'    TIME WILL BE DECEASED BY 5. PERCENT.'/
     &5X,'DISTRIBUTION EFFICIENCY =',F5.1,' PERCENT'/
     &5X,'APPLICATION EFFICIENCY  =',F5.1.' PERCENT'/
     &5X,'UNIT FLOW RATE =',F6.4,' CFS.'//
     &5X,'INFILTRATION AT FIELD HEAD IS ',F8.4,' INCHES'/
     &5X,'INFILTRATION AT FIELD END  IS ',F8.4,' INCHES.'//)
      TTA = TTA/1.05
      TM(L) = TTA
      NQT=1
      GO TO 120
  390 CONTINUE
      WRITE(6,443) EFFD(L),EFFA(L).QU(L).TTA.TINH.TIN(10)
C
  443 FORMAT(/5X,'    THE END OF THE FIELD IS BEING UNDERIRRIGATED.'/
     &5X,'DISTRIBUTION EFFICIENCY =',F5.1,' PERCENT.'/
     &5X.'APPLICATION EFFICIENCY  =',F5.1.' PERCENT'/
     &5X,'UNIT FLOW RATE =',F6.4,' CFS'/
     &5X,'SET TIME = ',F10.2,' MINUTES.'/
     &5X.'INFILTRATION AT FIELD HEAD IS ',F8.4,' INCHES '//
     &5X,'INFILTRATION AT FIELD  END IS ',F8.4.' INCHES.'//
     &5X,'    Q AND TIME WILL BE INCREASED BY 10. PERCENT.'//)
      TTA = TTA*1.1
      TM(L) = TTA
```

```
  330 FORMAT(5X,'THE VALUE OF THE FROUDE NUMBER DESCRIBING THE FLOW OF'/
     &5X,'WATER ALONG THE FIELD IS HIGHER THAN ALLOWED FOR ACCURATE'/
     &5X,'ADVANCE PREDICTIONS USING THE ASSUMPTION OF ZERO INERTIA. '/
     &5X,'THE VALUE OF THE FROUDE NO.**2 IS',F6.2,' ,WHICH IS GREATER'/
     &5X,'THAN THE SUGGESTED VALUE OF .05'/)
  400 WRITE(6,410)
  410 FORMAT(5X,'THE RATE OF CHANGE OF NORMAL DEPTH AT THE END OF THE',
     &/5X,'FIELD AT T=TR IS GREATER THAN THE SLOPE OF THE FIELD,'/
     &5X,'OR SY IS LESS THAN OR EQUAL TO ZERO'/
     &5X,'EFFICIENCY IS SET AT 0.'/)
      GO TO 440
  420 WRITE(6,430)
  430 FORMAT(5X,'THE VALUE OF CP*XLNT OR CP*XDS(I) APPEARING IN THE',
     &/5X,' FORMULA DESCRIBING THE DIFFERENTIAL EQUATION'/
     &5X,' RECL IS LESS THAN OR EQUAL TO 0.'/
     &5X,'EFFICIENCY IS SET AT 0.'/)
      GO TO 440
  435 IF(NQT.EQ.0) GO TO 436
      NQT=2
      TTA=TTA*1.05
      TM(L)=TTA
      GO TO 120
  436 WRITE(6,442) TR,XI(I),TA(I)
  442 FORMAT(/5X,'RECESSION OF THE BORDER STREAM HAS BEEN DETERMINED'/
     '5X,'TO BEGIN BEFORE THE STREAM HAS ADVANCED ACROSS THE FIELD.'/
     '5X,'RECESSION TIME IS AT',F8.2,' MINUTES'/
     '5X,'THE STREAM HAS ADVANCED TO ',F7.1,' FEET AT',F8.2,' MINUTES')
  444 FORMAT(5X,
     '      'A LARGER FLOW RATE AND LONGER SET TIME WILL BE TRIED.'/)
  445 FORMAT(5X,'A LONGER SET TIME WIL BE TRIED.'/)
      IF(NIMP.EQ.1) WRITE(6,444)
      IF(NIMP.GT.1) WRITE(6,445)
      IF(NIMP.EQ.1) QU(L)=QU(L)*1.2
      TTA = TTA*1.2
      TM(L) = TTA
      GO TO 120
  440 EFFA(L)=0.
      EFFD(L)=0.
      RVOL(L)=0.
      DVOL(L)=0.
      GO TO 200
C
C----IF ADVANCE AND RECESSION DATA ARE AVAILABLE--ENTER DATA
C
  114 IF(LL.NE.1)GO TO 152
      WRITE(9,129)
      CALL INPUT(A,NI)
      DK= A(1)
      TD = A(2)
      WRITE(9,130)
      CALL INPUT(A,NAD)
      AK = A(1)
      AN = A(2)
      WRITE(9,132)
      CALL INPUT(A,NAR)
      RK = A(1)
      RNR = A(2)
C----ASSUME 50 FEET BETWEEN STATION
      DIST = 50.
      STA = XLNT/DIST
      NSTA = STA
      STA = NSTA
      DREM = XLNT-STA*DIST
      DO 131 KX=1,100
      X= KX
      NEND =KX
      DSTA = DIST*(X-1.)
      IF(DSTA.GE.XLNT)GO TO 133
      TA(KX) = (DSTA/AK)**(1./AN)
      TTR(KX) = (DSTA/RK)**(1./RNR)
  131 CONTINUE
  133 TA(NEND) = (XLNT/AK)**(1./AN)
      TTR(NEND) =(XLNT/RK)**(1./RNR)
  152 CONTINUE
C
      IF(TM(L).NE.0.)GO TO 138
C----COMPUTE SET TIME AND EFFICIENCY
      TM(L) = TA(NEND)-TTR(NEND)+(TRAMC(L)/DK)**(1./TD)
C
  138 DO 134 KN = 1,NEND
      DPPH(KN) = DK*((TM(L)-TA(KN)+TTR(KN))**TD)
      DPTH(KN) = DPPH(KN)-TRAMC(L)
  134 IF(DPTH(KN).LT.0.)DPTH(KN) =0.
```

```
      VPP = 0.
      VDP = 0.
      DO 136 KN = 2,NEND1
      VPP = VPP+((DPPH(KN-1)+DPPH(KN))/24.)*DIST
  136 VDP = VDP+((DPTH(KN-1)+DPTH(KN))/24.)*DIST
      VPP = VPP+((DPPH(NEND1)+DPPH(NEND))/24.) * DREM
      VDP = VDP+((DPTH(NEND1)+DPTH(NEND))/24.)* DREM
      UST = QCFS/BWIDE
      QU(L) = UST
      VSR = ((UST*TM(L)*60.)-VPP)*BWIDE/43560.
      VDP = VDP * BWIDE/43560.
      VAPP = UST * BWIDE * TM(L) * 60./43560.
C----COMPUTE EFFICIENCY
      EFFA(L) = 100. * (VAPP - VSR - VDP)/VAPP
C----VOLUME LOST OF DP
      DVOL(L) = VDP * IRTOTC(L)
C----VOLUME LOST SR
      RVOL(L) = VSR * IRTOTC(L)
      TINH=DPPH(1)
      TIN(10)=DPPH(NEND)
C
  200 CONTINUE
      DH=TINH
      DE=TIN(10)
      RETURN
      END
C  THIS SUBROUTINE COMPUTES SUBSURFACE DRAINAGE COST
C
C
      SUBROUTINE  SDRAIN(L,DEPD,DBF,PERM,XMAX,SLOP,FL,C4,C6,C8,UEXD,
     *UBKD,UGRAV,CONTG,RINT,SFF,XMAINT,CROPA,CSTD)
C/    LIST,NONE
      REAL IRTOTC
      COMMON TRAMC(20),NCBM,FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50),TITLE(17),TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     *XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20)
      DIMENSION CSTD(20),QP(10)
C
C---CONVERT D.P. TO CU FT PER SQ FT PER IRRIGATION
      QD = DVOL(L)/IRTOTC(L)/FREQC(L)
      DBF1 = DBF + DEPD - RZDR(L)
C---COMPUTE SPACING USING DONNAN*S EQUATION--FT
      DSPAC = (4.*PERM*(DBF1**2.-DBF**2.)/QD)**(1./2.)
C---FIND DRAIN DISCHARGE USING  USBR EQUATION
      DDB1 = DBF + XMAX/2.
      QLF = (2.*3.1416*PERM*XMAX*DDB1)/DSPAC
      QLF = QLF/ 86400.
C
C---ASSUMPTION* LENGTH OF LATERAL DRAIN = FIELD WIDTH
C                         MANNINGS N=.015
C
      NN = 0
      DO 20 LZ=4,8,2
      NN=NN+1
      XLD=LZ/12.
      AREP=(3.1416*XLD**2.)/4.
      HR=XLD/4.
      VL=(1.49*HR**(2./3.)*SLOP**(1./2.))/.015
      QP(NN) = AREP*VL
   20 CONTINUE
C
C---COMPUTE COST OF PIPES
      FWIDT = CROPA*43560./FL
      XL1=QP(1)/QLF
      IF(XL1.GE.FWIDT)GO TO 68
      XL2=FWIDT-XL1
      XL3=QP(2)/QLF
      IF(XL3.GE.XL2)GO TO 82
      XL4=XL2-XL3
      CPP=XL1*C4+XL3*C6+XL4*C8
      VOLP=(3.1416/(144.*4.*27.))*(4.**2.*XL1+6.**2.*XL3+8.**2.
     **XL4)
      GO TO 80
   68 CPP = FWIDT*C4
      VOLP = 3.1416*4.**2.*FWIDT/(144.*4.*27.)
      GO TO 80
   82 CPP = XL1*C4 + XL2*C6
      VOLP = (3.1416/(144.*4.*27.))*(4.**2.*XL1+6.**2.*XL2)
   80 CONTINUE
C---COMPUTE COST OF EXCVA. AND BACKFILL
C   ASSUME 8-FT DEPTH, 12 INCHES MIN WIDTH
```

```
      VODBF = VODEX - VOLP
      ERCD = VODEX * UEXD + VODBF * UBKD
      DNCST = CPP + ERCD + FWIDT*UGRAV
      DNCST = DNCST + DNCST*CONTG
      ADRAN = FWIDT*DSPAC/43560.
      DEPDD = DNCST * SFF/ADRAN
      CIND = DNCST * RINT/ADRAN
      CMAINT = XMAINT*DNCST/2./ADRAN
      CSTD(L) = DEPDD + CIND + CMAINT
C
      RETURN
      END
C
      SUBROUTINE SPNKLR(KSOIL,KODE)
C/    LIST,NONE
      REAL LLEN,LSPA,IRTOTC
      DIMENSION  SZE(20),XML(20).CMF(20),SP(20), TSET(20)
      COMMON TRAMC(20),NCMB,FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50), TITLE(17), TYP1,TYP2,TYP3
      COMMON IRTOTC(20).CROPD(20),SIZE(20).TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20).FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     ↰ XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20)
      DATA YSS/3HYES/
C
  100 FORMAT(/,' TYPE DATA FOR----',3A4,17A4/
     ''   FOR A CENTER PIVOT, LENGTH OF LATERAL = EFFECTIVE RADIUS'//
     ''   TYPE THE FF DATA:'/
     '' 1-LENGTH OF LATERAL, FT'/
     ''   FOR A CENTER PIVOT WITH A CORNER SYSTEM, ENTER LENGTH OF'/
     ''   LATERAL EQUAL TO 1298.5 ... AREA WILL THEN BE 152. ACRES'//
     '' 2-LATERAL SPACING, FT--ENTER 0. FOR CENTER PIVOT'/)
  101 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-TIME REQ TO SET ONE LATERAL-ON AND OFF'/
     '' 2-TIME FOR SET LENGTH IN HOURS...UP TO 11 VALUES'/
     ''     I.E... 8 HR SET, 10 HR SET...ETC'/)
  102 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-TIME REQ. TO MOVE LATERAL, MINUTES'/
     '' 2-TIME FOR SET LENGTH IN HOURS...UP TO 11 VALUES'/
     ''     I.E... 8 HR SET, 10 HR SET...ETC'/)
  104 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-OVERALL EFFICIENCY OF THE SYSTEM, PERCENT'/
     '' 2-OTHER LOSSES. PERCENT'/)
  106 FORMAT(/,' TYPE MAXIMUM ALLOWABLE INTAKE RATE OF SOIL, IPH'/)
  108 FORMAT(/,' TYPE THE FF LATERAL LINE DATA:'/
     '' 1-ORIGINAL COST OF ONE LATERAL, $'/
     ''    (COST INCLUDES PIPE, SPRINKLER HEADS, RISERS, ETC)'/
     '' 2-LIFE OF SYSTEM, YEARS '/
     '' 3-INTEREST RATE, PERCENT'/
     '' 4-TAX AND INSURANCE EXPENSES, PERCENT OF AVE. INVESTMENT'/
     '' 5-SALVAGE VALUE. PERCENT OF ORIGINAL INVESTMENT'/
     '' 6-MAINTENANCE COST, PERCENT OF ORIG. INVESTMENT'/
     '' 7-CONTINGENCY COST, PERCENT'/)
  111 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-SIZE OF LATERAL USED. INCHES'/
     '' 2-UNIT COST OF EXCAVATION--FOR MAINLINE, $/CY'/
     '' 3-UNIT COST OF BACKFILL. $/CY'/)
  110 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-LABOR RATE (MOVING LATERAL), $/HR'/
     '' 2-TRANSPORT TIME BETWEEN IRRIGATION. HR'/)
  112 FORMAT(/,' TYPE VALUE OF WATER LOST TO D.P., $/AF'/)
  114 FORMAT(/,' TYPE THE FF DATA FOR THE MAINLINE:'/
     '' 1-PIPE SIZE. INCHES'/
     '' 2-LENGTH OF PIPE WITH THIS SIZE. FT. ON ENTIRE FARM'/
     '' 3-COST OF MAINLINE (PIPE AND ACCESS.), $/FT'/
     ''-----TYPE AS MANY SIZES AS NEEDED'/)
  116 FORMAT(/,' TYPE THE FF MAINLINE DATA:'/
     '' 1-LIFE OF EQUIPMENT, YEARS'/
     '' 2-INTEREST RATE, PERCENT'/
     '' 3-SALVAGE VALUE, PERCENT'/
     '' 4-TAX AND INSURANCE, PERCENT OF AVERAGE INVEST.'/
     '' 5-MAINTENANCE COST, PERCENT OF ORIGINAL INVESTMENT'/
     ')
  118 FORMAT(/,' TYPE VALUE OF LAND TO PRODUCTION, $/AC'/)
C
C                      <--------------------READ CARD-----------
      WRITE(9,100)TYP1,TYP2,TYP3,TITLE
C
C   READ IN LATERAL LENGTH AND LATERAL SPACING
C         LLEN = LENGTH OF LATERAL IN FEET
C         LSPA = LATERAL SPACING IN FEET
      CALL INPUT(A,NL)
      LLEN = A(1)
      LSPA = A(2)
```

```
      IF(KODE.EQ.6 )WRITE(9,101)
      IF(KODE.NE.6)WRITE(9,102)
C   READ IN AVERAGE TIME REQUIRED PER LATERAL MOVE AND
C   SET LENGTH TIME ALTERNATIVES
C         TMOV = TIME REQUIRED TO MOVE LATERAL IN MINUTES
C         TSET = TIMES FOR SET LENGTHS IN HOURS
C         NOTE:  TSET MAY CONTAIN UP TO 11 VALUES STARTING WITH
C                   THE SMALLEST VALUE
C                TSET MUST INCLUDE REQUIRED MOVING AND
C                   OTHER DOWN TIME
C                TMOVE MUST BE THE FIRST VALUE STORED ON THE CARD
C
      CALL INPUT(SP,N)
      TMOV = SP(1)
      DO 4 NK=2,N
      NK1=NK-1
    4 TSET(NK1) = SP(NK)
C
C
C                   <--------------------READ CARD-----------
C   INPUT THE OVER-ALL EFFICIENCY OF THE SYSTEM AND THE
C   PERCENTAGE OF WATER LOST TO EVAPORATION BEFORE COMING
C   IN CONTACT WITH THE SOIL OR CROP CANOPY
C        OAEFF = OVER-ALL EFFICIENCY IN PERCENT
C        OLOSS = OTHER LOSSES IN PERCENT
      WRITE(9,104)
      CALL INPUT(A,NE)
      OAEFF = A(1)
      OLOSS = A(2)
C
      WRITE(9,106)
C                   <--------------------READ CARD-----------
      CALL INPUT(A,NR)
C
C   INPUT THE MAXIMUM ALLOWABLE INTAKE RATE FOR SPRINKLER IRRIGATION
C         RIMAX = MAXIMUM ALLOWABLE INTAKE RATE IN INCHES PER HOUR
      RIMAX = A(1)
C
C                   <--------------------READ CARD-----------
C
C   INPUT THE EXPECTED LIFE OF THE SYSTEM AND THE INTEREST RATE
C   AND OTHER EXPENSES SUCH AS TAXES AND INSURANCE
C         CNEW = ORIGINAL COST
C         TLIFE = LIFE OF SYSTEM IN YEARS
C         RINT = INTEREST RATE IN PERCENT
C         OEXP = OTHER EXPENSES IN PERCENT OF AVERAGE INVESTMENT
C         SVAL = SALVAGE VALUE AS A PERCENT OF ORIGINAL INVESTMENT
C       XMTL = MAINTENANCE COST AS PERCENT OF ORIGINAL INVESTMENT
C        CONTG = CONTINGENCY COST, PERCENT
      WRITE(9,108)
      CALL INPUT(A,NE)
      XCNEW = A(1)
      TLIFE = A(2)
      RINT = A(3)
      OEXP = A(4)
      SVAL = A(5)/100.
      XMTL = A(6)
      CONTG = A(7)/100.
      RINT = RINT/100.
      XMTL = XMTL/100.
C
      OEXP = OEXP/100.
C
      IF(KODE.EQ.3.OR.KODE.EQ.4.OR.KODE.FQ.5)GO TO 115
      WRITE(9,109)
  109 FORMAT(/,' IS THE LATERAL LINE BURIED \\\'/
     '' (YES OR NO)'/)
      READ(5,113)XLYES
      WRITE(9,113)XLYES
  113 FORMAT(A3)
      IF(XLYES.NE.YSS)GO TO 115
      WRITE(9,111)
      CALL INPUT(A,JXX)
      SZLAT = A(1)
      UEXC = A(2)
      UBKF =A(3)
  115 WRITE(9,110)
C                   <--------------------READ CARD-----------
      CALL INPUT(A,NT)
C   INPUT LABOR RATE FOR MOVING LATERALS AND TRANSPORT TIME
C   BETWEEN IRRIGATIONS
C         RLABOR = LABOR RATE IN $/HOUR
C         TTRAN  = TRANSPORT TIME IN HOURS
```

```
C
C                   <--------------------READ CARD-----------
C
C   INPUT THE COST OF WATER AT THE POINT OF DELIVERY AND THE
C   INPUT THE NET VALUE OF WATER LOST TO DEEP PERCOLATION
C         DPVAL = VALUE OF WATER TO DP IN $/ACRE-FOOT
      WRITE(9,112)
      CALL INPUT(A,ND)
      DPVAL= A(1)
C
C                   <--------------------READ CARD-----------
C
C   INPUT MAINLINE DATA
C         AML = AREA THE MAINLINE SERVES IN ACRES
C         CML = COST OF MAINLINE IN DOLLARS TOTAL OR DOLLARS PER FOOT
C         XML = LENGTH OF MAINLINE IN FEET
C         NOTE: IF THE COST IS GIVEN AS TOTAL COST THE VALUE FOR XML
C               MUST BE OMITTED
C     READ THE SIZE,LENGTH AND CORRESPONDING COST IN $/FOOT OF MAIN LINE
      AML = SIZE(KSOIL)
      WRITE(9,114)
C
      CALL INPUT(SP,NM)
C
      DO 210 KX =3,NM,3
      SZE(KX/3) = SP(KX-2)
      XML(KX/3) = SP(KX-1)
      CMF(KX/3) = SP(KX)
  210 CONTINUE
C
C--COST OF MAINLINE
C
      WRITE(9,117)
  117 FORMAT(/,' IS THE MAINLINE BURIED  ---'/
     '' (YES OR NO)'/)
      READ(5,113)XMYES
      WRITE(9,113)XMYES
      IF(XMYES.NE.YSS)GO TO 119
      WRITE(9,121)
  121 FORMAT(/,' TYPE THE FOLLOWING UNIT COST DATA'/
     '' (1) UNIT COST OF EXCAVATION, MAINLINE, $/CY'/
     '' (2) UNIT COST OF BACKFILL, MAINLINE, $/CY'/)
      CALL INPUT (A,NYX)
      UEXCM = A(1)
      UBKFM = A(2)
C
  119 TLM = 0.
C
      NM = NM/3
      CML=0.
      DO 212 KJ=1,NM
      IF(XMYES.NE.YSS)GO TO 209
      VOMEX = XML(KJ) * .426
      VOMBK = VOMEX - 3.1416*SZE(KJ)**2.*XML(KJ)/(144.*4.*27.)
      ERCM = VOMEX * UEXCM + VOMBK*UBKFM
      CML = CML + ERCM
  209 CML = CML + XML(KJ)*CMF(KJ)
      TLM = TLM + XML(KJ)
  212 CONTINUE
      CML = CML + CML * CONTG
C
      WRITE(9,116)
C                   <--------------------READ CARD-----------
      CALL INPUT(A,NE)
      TIML = A(1)
      TINT = A(2)/100.
      TSAL = A(3)/100.
      TOEX = A(4)/100
      XMTM = A(5)/100.
C
      WRITE(9,118)
C                   <--------------------READ CARD-----------
      CALL INPUT(A,NV)
      VLAND = A(1)
C
C--SET LOOP FOR ALL CROPS CONSIDERED
C
      DO 98 L=1,NCMB
C
      CNEW = XCNEW
      IF(KODE.EQ.5)GO TO 71
C
C   DETERMINE APPLICATION RATES
      KT=1
   11 AR = TRAMC(L)/(TSET(KT)-TMOV/60.)
      IF(RIMAX-AR)12,14,14
```

```
   12 KT =KT+1
      IF(KT-N)11,13,13
   13 WRITE(6,201)
  201 FORMAT(3X,'APPLICATION RATE IS EXCESSIVE FOR ALLOWABLE TIMES')
      GO TO 98
C
C   DETERMINE AREA COVERED BY EACH SET
   14 AREA = LLEN*LSPA/43560.
      IF(KODE.EQ.6)GO TO 70
C
C   DETERMINE TOTAL AREA COVERED BY EACH LATERAL IN ACRES
      TOTA = AREA*(24./TSET(KT))*(FREQC(L)-TTRAN/24.)
C
C   MINIMUM NUMBER OF LATERALS PER FARM IS TWO IF > 79 ACRES
      IF(AML.LE.79.) GO TO 61
      ITNL = AML/TOTA + 1
      IF(ITNL.LT.2) ITNL=2
      FLAT=ITNL
      TOTA = AML/ITNL
      GO TO 65
   61 FLAT=AML/TOTA
   65 CONTINUE
C   RECALCULATE THE SET TIME LENGTH FOR NEW TOTAL AREA
      TSETN=AREA*(FREQC(L)-TTRAN/24.)*24./TOTA
      KB=0
      DO 62 KA=1,NK1
      KB=KB+1
      IF(TSETN.LE.TSET(KA)-.01) GO TO 63
   62 CONTINUE
   63 KT=KB-1
C
C
C   DETERMINE LABOR REQUIREMENTS FOR LATERAL MOVING
      CLAB= IRTOTC(L)*(24./TSET(KT)*FREQC(L)*(TMOV/60.)*RLABOR)
      CLAB=CLAB/FLAT
C
C   COMPUTE COSTS OF TRANSPORTING BETWEEN IRRIGATIONS
      CTRAN = IRTOTC(L)*(TTRAN*RLABOR)
      XLAB = (CLAB + CTRAN) / TOTA
      XLAB1 = XLAB/RLABOR
C
C  COMPUTE DEPRECIATION AND INTEREST FOR LATERAL LINE
C  COST OF LATERAL LINE INCLUDES PIPE,SPRINKLER HEADS,RISERS,ETC.
C*USE SINKING FUND DEPRECIATION PLUS INTEREST ON ORIG. INVESTMENT
      GO TO 72
   70 TOTA = AREA
C       VOL OF EXC - USE USBR QNT ESTIMATE--1967
      IF(XLYES.NE.YSS)ERCLAT = 0.
      IF(XLYES.NE.YSS)GO TO 123
      VOLEX = LLEN * .426
      VOLBK = VOLEX - 3.1416*SZLAT**2.*LLEN/(144.*4.*27.)
      ERCLAT = VOLEX *UEXC + VOLBK*UBKF
      WRITE(6,76)VOLEX,VOLBK,ERCLAT,CNEW
   76 FORMAT(4F15.0)
C
  123 CNEW = (CNEW+ ERCLAT)
      XLAB1 = (TMOV/60. * IRTOTC(L)   )/TOTA
      XLAB = XLAB1 * RLABOR
      ITNL = SIZE(KSOIL)/TOTA + 1.
      FLAT=ITNL
      IF(SIZE(KSOIL).LT.80.) FLAT=SIZE(KSOIL)/TOTA
      GO TO 72
   71 TOTA = 3.1416 * LLEN ** 2. /43560.
      XLAB=0.
      IF(LLEN.GE.1298.1.AND.LLEN.LE.1298.9) TOTA=152.
      FLAT = 1.
   72 CNEW = CNEW + CNEW*CONTG
C
      SFFL= RINT/((((1.+RINT)**TLIFE)-1.)
      DEPL=(CNEW- SVAL*CNEW)* SFFL / TOTA
      CINL= RINT * CNEW / TOTA
C
C   COMPUTE TAXES AND INSURANCE
      COEXP  =((CNEW-SVAL *CNEW)/2.+SVAL *CNEW)*OEXP / TOTA
C
C   COMPUTE ANNUAL MAINTENANCE COSTS AS PERCENT  OF TOTAL INVESTMENT
      CMAINT = XMTL*CNEW / TOTA
C
C   COMPUTE THE VALUE OF WATER LOST TO DEEP PERCOLATION
      CDP = (ETTOTC(L)/12.)*(1-(OAEFF)/100.)*DPVAL
      DEEP =(ETTOTC(L)/12.)*(1-(OAEFF)/100.)
      EFFA(L) = OAEFF
      DVOL(L) = DEEP
      RVOL(L) = 0.
C
```

```
C
C--COMPUTE DEPRECIATION AND INTEREST FOR MAINLINE
C
      SFFM= TINT/(((1.+TINT)**TIML)-1.)
      DEPM=(CML -TSAL *CML)* SFFM / AML
      CINM= TINT * CML / AML
C
C
      TIS = CNEW/TOTA + CML/AML
C   COMPUTE ANNUAL MAINTENANCE COST AS PERCENT  OF ORIGINAL INVESTMENT
      TMAINT = XMTM*CML / AML
C
C   COMPUTE TAXES AND INSURANCE
      TOTHER=((CML- TSAL*CML)/2.+ TSAL*CML)*TOEX / AML
C
C--COMPUTE ANNUAL COST PER ACRE OF MAINLINE AND LATERAL
C
      TCOST(L)=(XLAB + DEPL + CINL + COEXP + CMAINT )
     &   + ( DEPM + CINM + TMAINT + TOTHER)
C
      AMAINT = CMAINT  + TMAINT
      AEXP = COEXP + TOTHER
C  PRINT RESULT
      WRITE(6,10)TYP1,TYP2,TYP3,TITLE
   10 FORMAT(1H1,T20,'ANNUAL COST OF IRRIGATION-------',20A4)
      WRITE(6,7)KSOIL
    7 FORMAT(T20,'SOIL TYPE NUMBER-----',I2,/)
C
      WRITE(6,60)(HEAD(L,JL),JL=1,20)
   60 FORMAT(T40,20A4./)
C
C
C--COMPUTE THE FLOW RATE PER LATERAL
C
      GPML=TRAMC(L)*LLEN*LSPA/12*7.48/(TSET(KT)-TMOV/60.)/60.
      IF(KODE.EQ.5)GPML=TRAMC(L)/12.*TOTA*43560.*7.48/(FREQC(L)*24.*60.)
C
      WRITE(6,19)LLEN,SIZE(KSOIL).IRTOTC(L),FREQC(L),GPML,RLABOR,FLAT,
     &LLEN,LSPA,TMOV,TSET(KT),TTRAN,TOTA.CNEW,RIMAX,XLAB1
      WRITE(6,25) DEEP,OAEFF
      WRITE(6,20) AML,TLM
C
      DO 42 K =1,NM
   42 WRITE(6,33)SZE(K),XML(K),CMF(K)
C
      WRITE(6,16)CML,TIS,DEPL,DEPM,CINL.CINM,XLAB,AMAINT,AEXP,
     ' TCOST(L)
C
   33 FORMAT(T17,F3.0,T32,F5.0.T50,F5.2)
C
   19 FORMAT(T20,'FARM DATA:'//
     &       T11,'FIELD LENGTH, FT                       ',T51,F5.0/
     &       T11,'FARM SIZE, ACRES                       ',T51,F5.0/
     &       T11,'NO. OF IRRIGATION                      ',T51,F5.0/
     &       T11,'FREQUENCY OF IRRIGATION, DAYS          ',T51,F5.0/
     &       T11,'GPM/LATERAL                           ',T51,F5.0/
     &       T11,'LABOR RATE, $/HR                       ',T51,F5.2//
     &       T11,'NUMBER OF LATERALS / FARM               ',T51,F5.1/
     &       T11,'LENGTH OF LATERAL, FEET               ',T51,F5.0/
     &       T11,'LATERAL SPACING, FEET                  ',T51.F5.0/
     &       T11,'TIME TO MOVE LATERAL, MIN/SET          ',T51,F5.0/
     &       T11,'TIME OF SETTING, HRS                   ',T51.F5.0/
     &       T11,'TRANSPORT TIME PER ROTATION,HRS        ',T51,F5.0/
     &       T11,'AREA COVERED BY EACH LATERAL, ACRES    ',T50,F6.2//
     &       T11,'COST PER LATERAL LINE, $             ',T50,F6.0/
     &       T11,'ALLOWABLE INTAKE RATE, IN/HR           ',T51,F5.2/
     &       T11,'TOTAL LABOR, HR/AC/YR                  ',T50,F6.0//)
   25 FORMAT(    T11,'DEEP PERCOLATION,AF/ACRE       ',T50,F6.4/
     &       T11,'APPLICATION EFFICIENCY,PERCENT      ',T51,F5.2/)
   20 FORMAT(T20,'MAINLINE DATA:'//
     &       T11,'TOTAL AREA SERVED BY MAINLINE, ACRES ',T51.F5.0/
     &       T11,'TOTAL LENGTH OF MAINLINE, FEET       ',T51.F5.0//
     &       T14,'DIAMETER(IN)',T31,'LENGTH(FT)',T46,'COST ($/FT)' )
C
   16 FORMAT( /,T11,'TOTAL COST OF MAINLINE, $                 ',T50,F6.0/
     'T11,'TOTAL INVESTMENT ($/AC)',T50.F6.0//
     &       T14,'ANNUAL COST:',T56,'$/AC'//
     &       T11,'DEPRECIATION'/
     &       T15,'LATERAL                                ',T53,F7.2/
     &       T15,'MAINLINE                               ',T53.F7.2/
     &       T11,'INTEREST ON INVESTMENT'/
     &       T15,'LATERAL                                ',T53.F7.2/
     &       T15,'MAINLINE                               ',T53,F7.2/
     &       T11,'LABOR COST                             ',T53.F7.2/
     &       T11,'MAINTENANCE COST                       ',T53,F7.2/
```

```
     &         T11,'TAXES AND INSURANCE                         ',T53,F7.2//
     &         T26,'T O T A L                                   ',T53,F7.2 //
     &         T11,'NOTE:  TOTAL ANNUAL COST DOES NOT INCLUDE PUMP UNIT AN
     &D RESERVOIRS')
C
C--GO TO NEXT CROP
C
   98 CONTINUE
C
C--ADD EXTRA COST FOR MAIN PIPELINE --IF THERE IS ANY
C
      ADCST = 0.
C
      RETURN
      END

C       SUBROUTINE FURROW......CALLED BY MAIN WRDFARM
      SUBROUTINE FURROW (L,AC,BC,C)
C/    LIST,NONE
C
C---THIS SUBROUTINE COMPUTES APPLICATION EFFICIENCY OF FURROW IRRIGATION
C   THE  METHOD USED HERE IS BASED ON  USDA SOIL CONSERVATION SERVICE
C   FURROW IRRIGATION DESIGN CRITERIA,WEST TECHNICAL SERVICE CENTER,
C   PORTLAND,OREGON
C
      REAL IRTOTC
      COMMON TRAMC(20),NCMB,FREQC(20),ETTOTC(20),HEAD(7,20)
      COMMON A(50),TITLE(17),TYP1,TYP2,TYP3
      COMMON IRTOTC(20),CROPD(20),SIZE(20),TCOST(20),COSW(20,20),ADCST
      COMMON QGDM(20),FWIDE(20),BW(20),TM(20),QU(20),RATIO(20),SL,FAM,
     *       XLNT,EFFA(20),EFFD(20),DVOL(20),RVOL(20),RZDR(20),XLNTF
C
C
C-----DEFINITION OF VARIABLES
C
C     QGPM = FURROW STREAM SIZE,GPM
C     SL   = FIELD SLOPE,
C     XLNTF= LENGTH OF IRRIGATION RUN, FEET, OF THE FURROWS
C     XMAD = NET IRRIGATION APPLICATION
C     FWIDE= FURROW SPACING
C     TM   = TIME OF APPLICATION
C     FAM  =INTAKE FAMILY ACCORDING TO SCS CLASSIFICATION
C
C   ASSIGN COEFICIENTS FOR DIFFERENT INTAKE FAMILIES
C
      FAM =FAM - .00001
      QGPM = QGDM(L)
      IF(FAM.LE.0.1)GO TO 5
      IF(FAM.LE.0.3)GO TO 10
      IF(FAM.LE.0.5)GO TO 15
      IF(FAM.LE.1.0)GO TO 20
      IF(FAM.LE.1.5)GO TO 25
      IF(FAM.LE.2.0)GO TO 30
      IF(FAM.LE.3.0)GO TO 35
      IF(FAM.LE.4.0)GO TO 40
C
    5 AC = 0.0244
      BC = 0.6610
      GO TO 45
   10 AC = 0.0368
      BC = 0.7210
      GO TO 45
   15 AC = 0.0467
      BC = 0.7560
      GO TO 45
   20 AC = 0.0701
      BC = 0.7850
      GO TO 45
   25 AC = .0899
      BC = 0.7990
      GO TO 45
   30 AC = 0.1084
      BC = 0.808
      GO TO 45
   35 AC = 0.1437
      BC = 0.816
      GO TO 45
   40 AC = 0.1750
      BC = 0.823
C
   45 C = 0.275
C
      IF(TM(L).NE.0.)GO TO 50
C
C--IF TIME OF APPLICATION IS NOT GIVEN--WILL COMPUTE LEAST TIME SET TO
```

```
C  APPLY THE REQUIRED DEPTH
      XMAD = TRAMC(L)
      FL = XMAD
C     FL IS THE DEPTH OF WATER TO BE APPLIED AT THE END OF RUN
C     COMPUTE TOP WIDTH OF WATER SURFACE
C
      TOP= 0.189072*(QGPM*.04/(SL**(1./2.)))**0.448+0.42028
      XLONG = 0.
C
C
C-----COMPUTE FC-FACTOR FOR CONVERTING VOLUME OF INTAKE TO INCHES
C
C
      FC =12./(TOP+2./3.*(FWIDE(L)/12.-TOP))
      FLVOL = 0.
  105 T1 = 0.
C
C--COMPUTE T2-TIME REQUIRED TO REPLENISH REQ.DEPTH OF WATER AT XL1
C--         XL1 IS THE LENGTH IN WHICH 100% OF DEPTH IS REPLENISHED
C     START XLN1 AT XLNTF-1---FEET
C
      XLN1 = XLNTF - XLONG
      DO 55 KC=1,2000
      T1 = T1 + 5.
C
      FSMAL = (AC*T1**BC+C)*TOP/(1.6041*QGPM*T1)
      TRF1 =( FSMAL * QGPM *T1/(7.481*2.7182818**(FSMAL*XLN1)))*FC
      IF(TRF1.LE.FL)GO TO 55
      T1=T1-5.
      GO TO 60
   55 CONTINUE
   60 DO 65 KY=1,10
      T1 = T1 + 1.
      FSMAL = (AC*T1**BC+C)*TOP/(1.6041*QGPM*T1)
      TRF1 =( FSMAL * QGPM *T1/(7.481*2.7182818**(FSMAL*XLN1)))*FC
      IF(TRF1.GE.FL)GO TO 70
   65 CONTINUE
C
C-----THIS IS THE LEAST TIME NEEDED TO APPLY REQ.DEPTH
C
   70 T1 = T1 - 1.
C--COMPUTE EQUIV.DEPTH OF WATER INFILTRATED AT  THE END OF RUN--XLNTF
      FL1 = (FSMAL*QGPM*T1/(7.481*2.7182818**(FSMAL*XLN1)))*FC
C  BASED ON APPLICATION TIME->T1
C
      FL2 = TRF1
C--COMPUTE VOLUME IN FEET ON A UNIT WIDTH BASIS
C
      VIN = (QGPM * T1/7.481)/(FWIDE(L)/12.)
C
C--COMPUTE INTAKE VOLUME AT LENGTH-XLN1
      FOL1 = (QGPM*T1/7.481)*(1.-1./2.7182818**(FSMAL*XLN1))*FC
C--COMPUTE INTAKE VOLUME AT LENGTH-XLNTF
      FOL2 = (QGPM*T1/7.481)*(1.-1./2.7182818**(FSMAL*XLNTF))*FC
C
C--COMPUTE DEEP PERCOLATION AT LENGTH-XLNT(DUMMY FIGURE)
      FLV2=(FSMAL*XLNTF*T1*QGPM/7.481)*(1./2.7182818**(FSMAL*XLNTF))*FC
      VPD = (FOL2-FLV2)/12.
C--COMPUTE ACTUAL RUNOFF VOLUME
C
      VSR = VIN - FOL2/12.
C
C--COMPUTE ACTUAL DEEP PERCOLATION
      FLV1=(FSMAL*XLN1*T1*QGPM/7.481)*(1./2.7182818**(FSMAL*XLN1))*FC
      VDP = (FOL1 - FLV1)/12.
C
      EFVOL = (VIN - VDP - VSR)
      IF(FLVOL.EQ.0.) FLVOL=FLV1
      XMIN = EFVOL/FLVOL * 100.
      IF(XMIN.LE.95.)GO TO 80
      XLONG = XLONG + 1.
      AEFF = EFVOL/VIN*100.
C
C--COMPUTE EFFICIENCY
      IF(XLN1.LE.1.)GO TO 80
      GO TO 105
   80 IF(VDP.LT.0.) VDP = -.0001
      AEFF = ((VIN - VDP - VSR)/VIN) * 100.
      EFFA(L) = AEFF
C--COMPUTE DISTRIBUTION EFF
C  D EFF = MIN DEPTH INFIL. DIVIDED BY AVE DEPTH
C
      DFL2 = (FSMAL*QGPM*T1/(7.481*2.7182818**(FSMAL*XLNTF)))*12.
      DEFF= DFL2/ ((DFL2+ (AC*T1**BC+C))/2.) * 100.
```

```
C--CONVERT VOLUME TO PER ACRE BASIS PER YEAR (IN FEET)
      VDPA = VDP * IRTOTC(L) /(FWIDE(L)*XLNTF/12.)
      VSRA = VSR * IRTOTC(L) /(FWIDE(L)*XLNTF/12.)
C--RECOMPUTE RUNOFF AND DEPERC TO MATCH EFFICIENCIES  (AF/ACRE)
      VDPA = (TRAMC(L)*(1.-DEFF/100.)/(DEFF/100.)/12.*IRTOTC(L))
      VSRA=VIN/XLNTF*IRTOTC(L)*(1.-AEFF/100.)-VDPA
      DVOL(L)=VDPA
      RVOL(L)=VSRA
      TM(L) =T1
C
      GO TO 75
C
C---TIME OPTION...IF TIME IS GIVEN, WILL COMPUTE EFF DIRECTLY
   50 T1=TM(L)
      TOP= 0.189072*(QGPM*.04/(SL**(1./2.)))**0.448+0.42028
      FC=12./(TOP+2./3.*(FWIDE(L)/12.-TOP))
      FSMAL=(AC*T1**BC+C) * TOP/(1.6041*QGPM*T1)
      VIN = QGPM*T1/7.481/(FWIDE(L)/12.)
      FOL=(QGPM*T1/7.481)*(1.-1./2.7182818**(FSMAL*XLNTF))*FC
      X = -ALOG(TRAMC(L)/(1.6041*FSMAL*QGPM*T1))/FSMAL
      IF(X.LE.0.) X = 0.
      FOX = QGPM*T1/7.481*(1.-1./2.7182818**(FSMAL*X))*FC
      VSR = VIN - FOL/12.
      VDP = FOX/12. - TRAMC(L)*FWIDE(L)*X/144.
      IF(VDP.LE.0.) VDP=0.
      GO TO 80
C
   75 CONTINUE
C
C
      RETURN
      END
```

```
C         DATA SET WIRCANM    AT LEVEL 013 AS OF 03/09/78
C     MAIN PROGRAM  CANAL  ......   COMPUTES COSTS OF IRRIGATION CANALS
C           .....G.D.GALINATO...R.G.ALLEN.....
C
      DIMENSION A(50)
      COMMON UEXC, UEXST. UEXSI. UEXPT, UERC, UERST, UERSI. UERPT.
     &UBACK, UBFST. UBFSI, UBFPT,UPREP, UCOMP, UCOMB,  CLN, CNSTR,
     &CNSIP, USTEL. UCEM, UHAUL
      COMMON WAGE,EQUIP, AREA, IHAUL1. IHAUL2,WAGEM,STELIN.CEMINX
      COMMON CAN.TITLE(17)
C
   10 FORMAT(/,' THIS PROGRAM COMPUTES COST OF OPEN CHANNEL '//)
      WRITE(9,10)
   12 FORMAT(' TYPE UNIT COST OF EXCAVATION FOR THE FF ITEMS:'/
     '' 1-COMMON, CANAL, $/CY'/
     '' 2-COMMON, STRUCTURE, $/CY'/
     '' 3-COMMON, SIPHON, $/CY'/
     '' 4-COMMON, PIPE TRENCH, $/CY'/
     '' 5-ROCK, CANAL. $/CY'/
     '' 6-ROCK, STRUCTURES, $/CY'/
     '' 7-ROCK, SIPHON. $/CY'/
     '' 8-ROCK, PIPE TRENCH, $/CY'/)
   14 FORMAT(/,' TYPE THE FF UNIT COSTS'/
     '' 1-BACKFILL,RELATIVELY COMPACTED, CANAL, $/CY'/
     '' 2-BACKFILL, STRUCTURES. $/CY'/
     '' 3-BACKFILL, SIPHON, $/CY'/
     '' 4-BACKFILL, PIPE TRENCH. $/CY'/
     '' 5-BED PREPARATION, CANAL LINING, $/CY'/
     '' 6-COMPACTING EMBANKMENT, $/CY'/
     '' 7-COMPACTING BACKFILL,(STRUCTURES,TRENCHES),$/CY'/
     '' 8-OVERHAUL, $/YD-MI'///)
   16 FORMAT(/,' TYPE THE FF UNIT COSTS:'/
     '' 1-CONCRETE IN CANAL LINING, $/CY'/
     '' 2-CONCRETE IN STRUCTURES,$/CY'/
     '' 3-CONCRETE IN SIPHON, $/CY'/
     '' 4-STEEL, $/LB'/
     '' 5-CEMENT, $/CWT'/)
   18 FORMAT(/,' TYPE THE FF DATA'/
     '' 1-HOURLY WAGE RATE FOR PIPE LAYER'/
     '' 2-EQUIPMENT INDEX, BASE YEAR IS 1976'/
     '' 3-AREA FACTOR'/
     '' 4-HAUL DISTANCE OF PIPE FOR UP TO 150 FT HEAD'/
     '' 5-HAUL DISTANCE OF PIPE OVER 150 FEET HEAD'/
     '' 6-HOURLY WAGE RATE FOR MINER'/
     '' 7-STRUCTURAL STEEL INDEX. BASE YEAR IS 1976'/
     '' 8-CEMENT INDEX, BASE YEAR IS 1976'/)
      WRITE(9,12)
      CALL INPUT(A,NX)
      UEXC = A(1)
      UEXST = A(2)
      UEXSI = A(3)
      UEXPT = A(4)
      UERC = A(5)
      UERST = A(6)
      UERSI = A(7)
      UERPT = A(8)
      WRITE(9,14)
      CALL INPUT(A,N1)
      UBACK = A(1)
      UBFST = A( 2)
      UBFSI = A( 3)
      UBFPT = A( 4)
      UPREP = A( 5)
      UCOMP = A( 6)
      UCOMB = A( 7)
      UHAUL = A(8)
      WRITE(9,16)
      CALL INPUT(A.N2)
      CLN = A( 1)
      CNSTR = A( 2)
      CNSIP = A( 3)
      USTEL = A( 4)
      UCEM =A( 5)
      WRITE(9,18)
      CALL INPUT(A,N3)
      WAGE = A( 1)
C---CONVERT TO BASE YEAR 1967.  GIVEN BASE IS 1976.
      EQUIP = A( 2) *1.93/1.0
      AREA = A( 3)
      IHAUL1= A( 4)
      IHAUL2 = A( 5)
      WAGEM = A( 6)
C---CONVERT TO BASE 1967.  GIVEN BASE YEAR IS 1976.
      STELIN = A( 7) *2.23/1.02
```

```
      WRITE(9,21)
   21 FORMAT(//5X,'ENTER ''1.'' IF THE PROGRAM IS TO ESTIMATE COSTS OF'/
     '' REHABILITATING AN EXISTING CHANNEL (LINING AN UNLINED).'/
     ''      ENTER ''0.'' TO ESTIMATE COSTS OF EXCAVATING A CHANNEL'/
     ''        IN NATURAL TERRAIN.'/)
      CALL INPUT(A,N5)
      IF(A(1).LT..5) GO TO 40
      WRITE(6,201)
  201 FORMAT(1H1,////////////////.T10.'OUTPUT OF THE PROGRAM--RECHAN--COS
     'T OF LINING AND RESHAPING AN EXISTING CHANNEL (+ STRUCTURES).'/)
      WRITE (9,28)
   28 FORMAT(//////5X,' THIS PROGRAM ASSUMES THE EXISTING CHANNEL IS '/
     ''COMPOSED OF EARTH, WITH UNIFORM BOTTOM SLOPE AND PRISMATIC DATA'/
     ''IT IS ASSUMED THAT THERE IS TO BE NO ROCK EXCAVATION IN THE '/
     ''RESHAPING PROCESS'/)
      CALL RECHAN
      GO TO 999
   40 WRITE(6,200)
  200 FORMAT(1H1,////////////////.T40,'OUTPUT OF THE PROGRAM--DITCST--COS
     $T OF OPEN CHANNEL'/)
      CALL DITCST
  999 WRITE(9,20)
   20 FORMAT(//,' THIS PROGRAM IS TERMINATED SUCCESSFULLY'///
     '' OUTPUT OF THIS PROGRAM IS OBTAINED AT THE '//
     '' TERMINAL - DATA 100 LINE PRINTER
     '  '////'GOODLUCK---------BYE......'/)
C
      STOP
      END
C     SUBROUTINE DITCST...CALLED BY CANAL (MAIN PROGRAM)
C-----READ UNIT COST INPUT
C
C
      SUBROUTINE DITCST
C/    LIST,NONE
C
C
C----THIS PROGRAM COMPUTES COST OF OPEN CHANNEL
C
C
      COMMON UEXC, UEXST, UEXSI. UEXPT, UERC, UERST, UERSI, UERPT.
     +UBACK, UBFST, UBFSI, UBFPT. UPREP, UCOMP, UCOMB, CLN. CNSTR.
     +CNSIP, USTEL. UCEM
      COMMON WAGE,EQUIP.AREA,IHAUL1,IHAUL2,WAGEM,STELIN,CEMINX
      COMMON CAN,TITLE(17)
C
      DIMENSION A(50), CTANN(500).QX(500)
      DIMENSION TNO(50), TSZ(50)
      DIMENSION XSTAAH(100),XS1(100),XF(100).C79(100),C80(100),
     +IP(100),XZ(100)
      DIMENSION CXN(10).LXD(10).CXQ(10)
      DATA CN1,CN2/4HEND ,4HSKIP/
      KXQ = 0
      NNT = 0
  255 FORMAT('1',///)
  500 FORMAT(/,' TYPE THE FF INFORMATION:'/
     '' ''READ---LINED CANAL''...THEN REACH IDENTIFIER>>IF LINED CANAL'/
     '' ''READ---UNLINED CANAL''...IF CANAL IS NOT LINED')
  502 FORMAT(/,' TYPE THE FF DATA COMMON TO ALL REACHES'/
     '' 1-PERCENT CONTINGENCY COST. CANAL OR LATERAL STRUCTURES'/
     '' 2-PERCENT CONTINGENCY COST , EARTHWORK'/
     '' 3-PERCENT CONTINGENCY COST, ROW'/
     '' 4-PERCENT CONTINGENCY COST. CANAL LINING'/
     '' 5-CANAL STRUCTURES COST INDEX, BASE IS 1976'/
     '' 6-CODE FOR LINING MATERIAL USED :'/
     ''                                  (0) NO LINING'/
     ''                                  (1) UNREINFORCED PORTLAND CEM'/
     ''                                  (2) REINFORCED PORTLAND CEM'/
     ''                                  (3) ASPHALTIC CONCRETE'/
     ''                                  (4) SHOTCRETE'/)
  504 FORMAT(/,' TYPE CHANNEL PROPERTIES'/
     '' 1-SIDE SLOPE OF CANAL'/
     '' 2-MANNINGS ROUGHNESS COEF'/
     '' 3-MAXIMUM ALLOWABLE VELOCITY, FPS'/
     '' 4-MINIMUM CHANNEL DEPTH, FT'/)
  506 FORMAT(/,' TYPE BRIDGE DATA'/
     '' 1-WIDTH OF COUNTY BRIDGE. FT'/
     '' 2-UNIT COST FOR COUNTY BRIDGE, $/SQ FT'/
     '' 3-WIDTH OF FARM BRIDGE. FT'/
     '' 4-UNIT COST OF FARM BRIDGE, $/SQ FT'/)
  508 FORMAT(/,' TYPE THE FF DATA'/
     '' 1-LIFE OF PROJECT, YEARS'/
     '' 2-ANNUAL INTEREST RATE. PERCENT'/
     '' 3-SALVAGE VALUE AS A PERCENT OF ORIGINAL COST'/)
  510 FORMAT(/,' TYPE THE FF DATA:'/
```

```
     '' 1-VALUE OF WATER LOST FROM CANAL SECTION, $/AF'/
     '' 2-NO OF DAYS CANAL IS OPERATING 75 PERCENT OF PEAK LOAD'/
     '' 3-OTHER OPERATIONAL LOSSES AS A PERCENT OF ''Q'' '/)
 512 FORMAT(/,' >>AT THIS POINT, DATA ARE FOR SPECIFIC REACH ONLY<<'/
     '/,' TYPE THE FF DATA FOR THIS REACH:'/
     '' 1-SEEPAGE COEF, MORITZ EQUATION'/
     '' 2-PERCENT OF ROCK EXCAVATION'/
     '' 3-ADDITIONAL ROW, FT'/
     '' 4-VALUE OF ROW, $/AC'/
     '' 5-AREA FOR SEVERANCE PAYMENT, AC'/
     '' 6-UNIT COSTS FOR SEVERANCE PAY, $/AC'/)
 514 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-LENGTH OF REACH, FT'/
     '' 2-ELEVATION OF OUTLET, FT'/
     '' 3-ELEVATION OF INLET, FT'/
     :)
 516 FORMAT(/,' TYPE NUMBER AND CORRESPONDING SIZES OF T.O., CFS'/
 518 FORMAT(/,' TYPE NUMBER OF STRUCTURES:'/
     ''          (1) RECTANGULAR INCLINED DROP'/
     ''          (2) CONCRETE CHECK, W/O APRON'/
     ''          (3) MODIFIED PARSHALL FLUME'/
     ''          (4) COUNTY BRIDGE'/
     ''          (5) FARM BRIDGE'/
     ''          (6) SIPHON'/
     ''          (7) TUNNEL'/
     ''          (8) RECTANGULAR INCLINED DROP, DROP>3. FT'/
     ''        NOTE: STRUCTURE #1 IS ASSUMED TO BE LOCATED AT THE OUTLET'/
     ''              OF THE DESIGN REACH...IF CHECKS ARE TO BE INCLUDED'/
     ''              ALONG THE CHANNEL, THIS ROUTINE WILL PLACE ONE'/
     ''              AT THE END OF THE REACH FIRST.'///)
 520 FORMAT(/,' TYPE DATA FOR SIPHON'/
     '' 1-HEAD LOSS DESIRED, FT/1000 FT'/
     '' 2-MAXIMUM VELOCITY IN PIPE, FPS'/
     '' 3-LENGTH OF PIPE, UPSTREAM SLOPE, FT'/
     '' 4-LENGTH OF PIPE, BOTTOM SLOPE, FT'/
     '' 5-LENGTH OF PIPE, DOWNSTREAM SLOPE, FT'/
     '' 6-TRANSITION LOSS COEF'/
     '' 7-PIPE SLOPE, UPSTREAM, FT/FT'/
     '' 8-PIPE SLOPE, BOTTOM, FT/FT'/
     '' 9-PIPE SLOPE, DOWNSTREAM, FT/FT'/
     ''10-WIDTH OF R-O-W, FT'/)
 522 FORMAT(/,' TYPE DATA FOR TUNNEL'/
     '' 1-HEAD LOSS DESIRED, FT/1000 FT'/
     '' 2-DESIRED VELOCITY ON TUNNEL, FPS'/
     '' 3-ELEVATION OF JOB, FEET'/
     '' 4-LENGTH OF TUNNEL, FT'/
     '' 5-NO. OF HEADINGS TO BE USED'/)
 524 FORMAT(/,' TYPE DATA FOR EARTHWORK--PRISM DATA'/
     '' 1-ROCK CUT SLOPE'/
     '' 2-UPPER CUT BANK SLOPE'/
     '' 3-FILL CUT SLOPE'/
     '' 4-UPPER BANK WIDTH, FT'/
     '' 5-LOWER BANK WIDTH, FT'/
     '' 6-COMPACTED EMBANKMENT WIDTH, FT'/
     '' 7-COMPACTMENT FACTOR'/
     '' 8-FILL COMPACTMENT FACTOR'/
     '' 9-PERCENT ROCK TO BE USED IN FILL'/
     '' 10-DEPTH OF CUT ADJUSTMENT---->ENTER 0.'/
     '' 11-COMPUTED EMBANKMENT CODE----> 0.'/)
 526 FORMAT(/,' TYPE DATA FOR TERRAIN CARD'/
     '' 1-STATION, FEET'/
     '' 2-GROUND SLOPE, FT/FT'/
     '' 3-CENTER LINE CUT, FT'/
     '' 4-ROCK CENTER LINE CUT, FT'/
     '' 5-STA CODE (9) WHEN STA IS THE SAME AS THE PREVIOUS ONE'/
     ''            (0) OTHERWISE'/
     '' 6-PRISM CODE (9) WHEN NEXT DATA IS A PRISM DATA'/
     ''               (0) OTHERWISE'/
     '' 7-END CODE (9)  WHEN NO TERRAIN DATA FOLLOWS'/
     ''            (0)  MORE TERRAIN DATA FOLLOWS'///
     ''---------START TYPING TERRAIN DATA---------'/
     ')
 528 FORMAT( ' TYPE MORE TERRAIN DATA'
     ')
 530 FORMAT(/,' ---------END OF TERRAIN DATA---------'/)
 532 FORMAT(/,' TYPE MINIMUM Q(CFS), MAXIMUM A(CFS) AND *Q* INTERVAL'/)
 534 FORMAT(/,' ARE THERE SOME MORE REACH TO PROCESS---------'/
     '' IF ''NO'' TYPE.... ''END DATA'' '/
     '' IF ''YES'' TYPE.... ''SKIP---LINED CANAL'' OR'/
     ''                     ''SKIP---UNLINED CANAL'' '//)
C
      WRITE(9,500)
    1 CONTINUE
      READ(5,150) CON,CAN,TITLE
      WRITE(9,150)CON,CAN,TITLE
```

```
  150 FORMAT (A4,3X,A4,17A4)
      IF (CON.EQ.CN1) GO TO 98
      IF (CON.EQ.CN2) GO TO 3
C---READ CONTINGENCIES AND COST INDEX
C
C
C       , CTGST = PERCENT CONTINGENCY COST FOR CANAL OR LATERAL STRUCTS.
C       , CTGER = PERCENT CONTINGENCY COST FOR EARTHWORK
C       , CTGRW = PERCENT CONTINGENCY COST FOR RIGHT OF WAY, ETC.
C       , CTGLN = PERCENT CONTINGENCY COST FOR CANAL LINING
C       , CIDX  = COST INDEX FOR CANAL/LATERAL STRUCTURES WITH A BASE
C                 YEAR IN  JAN 1976
C       , LCODE = CODE FOR LINING MATERIALS
C
      WRITE(9,502)
C
      CALL INPUT(A,NC)
C
      CTGST = A(1)
      CTGER = A(2)
      CTGRW = A(3)
      CTGLN = A(4)
      CIDX  = A(5)
      LCODE = A(6)
C
C---- READ IN CHANNEL PROPERTIES
C
C         Z = SIDE-SLOPE OF CHANNEL
C         RN = MANNINGS ROUGHNESS COEFFICIENT
C         VMX = MAXIMUM ALLOWABLE VELOCITY
C         YMN = MINIMUM CHANNEL DEPTH IN FEET
      WRITE(9,504)
C
      CALL INPUT(A,NP)
C
      Z   = A(1)
      RN  = A(2)
      VMX = A(3)
      YMN = A(4)
C
C-----READ BRIDGE DATA
      WRITE(9,506)
C
      CALL INPUT(A,NB)
C
C       , BRDW = WIDTH OF COUNTY BRIDGE
C       , CBRD = UNIT COST FOR COUNTY BRIDGE ($/SQ.FT)
C       , BFDW = WIDTH OF FARM BRIDGE
C       , CBFD = UNIT COST FOR COUNTY BRIDGE ($/SQ.FT)
C
      BRDW = A(1)
      CBRD = A(2)
      BFDW = A(3)
      CBFD = A(4)
      WRITE(9,508)
C
      CALL INPUT(A,NR)
C
C       , TLFE = LIFE OF PROJECT
C       , RINT = ANNUAL INTEREST RATE IN PERCENT
C       , SVAL = SALVAGE VALUE AS A PERCENT OF THE ORIGINAL COST
C
      TLFE = A(1)
      RINT = A(2)/ 100.
      SVAL = A(3)
C
C   READ IN DATA PERTAINING TO OPERATIONAL WASTE
C         DPV = VALUE OF WATER LOST FROM CANAL SECTION IN $/ACRE-FOOT
C         DPT = NUMBER OF DAYS CANAL IS CARRYING 75  OF PEAK DEMAND
C            (BASED ON BUREAU GUIDELINE OF CAP = 120-150  AVE DEMAND)
      WRITE(9,510)
      CALL INPUT(A,NO)
C
C       , PLOS = OTHER OPERATIONAL LOSSES AS A PERCENT OF Q
C
      DPV  = A(1)
      DPT  = A(2)
      PLOS = A(3)
C
C-----READ SEEPAGE,EXCAVATION & ROW DATA
C
C----BRANCH TO ANOTHER REACH
C
    3 CONTINUE
      WRITE(9,512)
```

```
C
      CALL INPUT(A,NS)
C
C       ' CMZ  = SEEPAGE COEFFICIENT 'C' IN MORITZ EQUATION
C       ' PERK = PERCENT OF ROCK EXCAVATION
C       ' RWID = ADDITIONAL WIDTH FOR RIGHT OF WAY,FT
C       ' RVAL = VALUE OF ROW, $/AC
C       ' ASER = AREA FOR SEVERANCE PAYMENT,AC
C       ' UCSEV = UNIT COST SEVERANCE PAYMENT,$/AC
C
      CMZ   = A(1)
      PERK  = A(2)
      RWID  = A(3)
      RVAL  = A(4)
      ASER  = A(5)
      UCSEV = A(6)
      WRITE(9,514)
C
      CALL INPUT(A,NL)
C
      SLEN = A(1)
      ELO  = A(2)
      ELI  = A(3)
C
C     READ THE NUMBER AND CORRESPONDING SIZE OF TURNOUTS--USE CHO
      WRITE(9,516)
C
      CALL INPUT(A,NT)
C
      DO 10 K=2,NT,2
      TNO(K/2)=A(K-1)
   10 TSZ(K/2)=A(K)
      NT = NT/2
C
C
C---READ DATA FOR DRAINAGE CROSSINGS
      WRITE(9,617)
  617 FORMAT(/,' TYPE DATA FOR DRAINAGE CROSSINGS'/
     '' 1-NUMBER OF CROSSINGS'/
     '' 2-DIAMETER, INCHES'/
     '' 3-APPROXIMATE CAPACITY, CFS'/
     '' ---IF NO DRAINAGE CROSSING,  ENTER  0. 0. 0. '/)
      CALL INPUT(A,NCX)
      DO 620 K=3,NCX,3
      CXN(K/3) = A(K-2)
      LXD(K/3) = A(K-1)
      CXQ(K/3) = A(K)
  620 CONTINUE
      NCX = NCX/3
C     READ OTHER STRUCTURES
      WRITE(9,518)
C
      CALL INPUT(A,NS)
C
C       ' XDRP = NUMBER OF DROPS
C       ' XCMB = NUMBER OF CHECKS
C       ' XMFL = NUMBER OF MODIFIED PARSHALL FLUME
C       ' XBRD = NUMBER OF PUBLIC BRIDGE
C       ' XBFD = NUMBER OF FARM BRIDGE
C       ' XSIP = NUMBER OF SIPHON (LIMIT TO ONE PER REACH)
C       ' XTUN = NUMBER OF TUNNEL (LIMIT TO ONE PER REACH)
C
C
      XDRP = A(1)
      XCMB = A(2)
      XMFL = A(3)
      XBRD = A(4)
      XBFD = A(5)
      XSIP = A(6)
      XTUN = A(7)
      XDRP3= A(8)
      IF(XSIP.EQ.0.) GO TO 110
C
C---READ INFO FOR SIPHON
      WRITE(9,520)
C
      CALL INPUT(A,NN)
      HD = A(1)
      VPIP = A(2)
      XL2 = A(3)
      XL3 = A(4)
      XL4 = A(5)
      C = A(6)
      SX = A(7)
      SY = A(8)
```

```
      SZ = A(9)
      RXWID = A(10)
C
  110 IF(XTUN.EQ.0.) GO TO 112
C---READ INFO FOR TUNNEL
      WRITE(9,522)
      CALL INPUT(A,NTN)
C        ' HDTUN - MAX HEAD LOSS DESIRED
C        ' VTUN - MAX DESIRED VELOCITY IN TUNNEL
C        ' ELEV - ELEVATION OF JOB IN FEET
C       LENTUN - LENGTH OF TUNNEL IN FEET
C        ' NPORT - NUMBER OF HEADINGS TO BE USED
C
      HDTUN = A(1)
      VTUN = A(2)
      ELEV = A(3)
      LENTUN = A(4)
      NPORT = A(5)
C
  112 CONTINUE
C
C---INPUT ONE PRISM CARD FOR EACH REACH
C   READ PRISM CARD
      WRITE(9,524)
C
      CALL INPUT(A,NO)
      S3 = A(1)
      S4 = A(2)
      S5 = A(3)
      WL = A(4)
      WR = A(5)
      WC = A(6)
      C1 = A(7)
      C2 = A(8)
      PCT = A(9)
      CLCNG = A(10)
      ICEMB = A(11)
C
C---READ TERRAIN CARD
C
      KM = 0
      WRITE(9,526)
  553 KM = KM + 1
      IF(KM.GT.1)WRITE(9,528)
      CALL INPUT(A,NS)
      XSTAAH(KM) = A(1)
      XS1(KM) = A(2)
      XZ(KM) = A(3)
      XF(KM) = A(4)
      C79(KM) = A(5)
      C80(KM) = A(6)
      IP(KM) = A(7)
      IF (IP(KM).EQ.0)GO TO 553
      WRITE(9,530)
C
C    COMPUTE CANAL EARTHWORK USING USBR PROGRAM---BR031
C
      WRITE(9,532)
C
      CALL INPUT(A,NM)
C
      MINQ = A(1)
      MAXQ = A(2)
      KNTQ = A(3)
C
      WRITE(9,566)
  566 FORMAT(/,' >>>>>>>END OF DATA FOR THIS REACH<<<<<<<'///)
C
C   COMPUTE COSTS FOR A RANGE OF DISCHARGES
C
      KX = 0
      WRITE(6,760)CAN, TITLE
      WRITE(6,793)
  793 FORMAT( //,4X,'Q',8X,'COST OF',7X,'COST OF',9X,'COST OF',7X,'COST
     &OF',8X,'TOTAL CONST.',4X,'ANNUAL EQUI',5X,'CONVEYANCE',/2X,'(CFS)'
     &,5X,'STRUCTURE',5X,'EARTHWORK',8X,'LINING',6X,'RIGHT OF/WAY',8X,
     ''COST',11X,' COST ',8X,'EFFICIENCY',/)
C
  760 FORMAT(1H1,//,T5,A4,17A4,/)
C
      TSRT = 0.
      LTS = 0
C
      DO 49 KQ=MINQ,MAXQ,KNTQ
```

```
      Q = KQ
C---- DETERMINE  BH RATIO
C
      IF(LCODE.NE.0) GO TO 202
C
C     COMPUTE BH RATIO FOR UNLINED CANAL-VARIABLE
C     USE  BR CRITERIA   10 CFS = 2:1 ;  10,000 CFS = 8:1 RATIO
C
      BH = .0006 * Q + 2.
C
      GO TO 204
C
C     COMPUTE BH RATIO FOR LINED CANAL
C     USE BR CRITERIA
C
  202 IF( Q.LE.200.) BH = 3.
      IF( Q.GT.200.AND. Q.LE.1000.) BH = 1.2
      IF( Q.GT.1000.) BH = 1.7
C
  204 CONTINUE
C
C
C
C   DETERMINE HYDRAULIC GRADIENT
   11 SLP =(ELI-ELO)/SLEN
      IF(SLP.LE.0.)GO TO 98
C   DETERMINE BOTTOM WIDTH AND WATER DEPTH FOR GIVEN B:H RATIO
      Y=((Q*RN/(1.49*(SLP**0.5)))**0.375)*((2*(1.+Z*Z)**0.5+BH)**0.25)/
     &((Z+BH)**0.625)
      YS = Y
      IF(Y.LT.YMN) YS=YMN
      BW = BH*YS
C
C----- TOP WIDTH
C
      XLN = BW  + (2. * YS * Z)
C
C--------WETTED PERIMETER
C
      WPER = BW + 2.* YS * ((1.+Z**2.0)**(1./ 2.))
C
C   CHECK VELOCITY AGAINST MAX ALLOWABLE VELOCITY
      V =(1.49/RN)*((Z*Y*Y+BW*Y)/(BW+2*Y*((1.+Z*Z)**0.5)))**0.66667
     &    *(SLP**0.5)
      IF(V.LE.VMX) GO TO 32
C   INSERT DROP OR COMBINATION STRUCTURE IF VELOCITY > VMX
      IF(XTO.EQ.0..AND.XDRP.EQ.0.) XDRP = 1.
      IF(XTO.GT.0..AND.XCMB.EQ.0.)GO TO 833
      GO TO 933
  833 XCMB = 1.
      XTO = XTO - 1.
  933 ELO = ELO +1.
      GO TO 11
C
C
   32 CONTINUE
C
C-----CALCULATE COST OF EACH STRUCTURE
C
C-----COST OF TURNOUTS >>> USE CONSTANT HEAD ORIFICE  (CHO)
C
      TOCST = 0
      DO 200 K=1,NT
C     GAP---COST INDEX FOR STEEL GATES AND PIPE (CMP). BASE=1976
      GAP=1.0
      QQ=TSZ(K)
      TOCST = TOCST+TNO(K)*(UEXST*13.64*QQ**.4326+UBFST*12.26*QQ**.3421
     &       + UCOMB*11.35*QQ**.3583+CNSTR*1.00*QQ**.4572
     &       + USTEL*99.27*QQ**.4143 +GAP*247.3*QQ**.3910)
  200 CONTINUE
      TOCST = TOCST * CIDX
C-----COST OF DROPS>>>USE RECTANGULAR INCLINED DROPS
C
C     DROP AND CHECK EQUATIONS REGRESSED FOR 5.< Q < 100. CFS AND
C                                $150. < COST CONCRETE < $200.
C
      TCDRP = XDRP*(UEXST*1.42*Q**.7716+CNSTR*.973*Q**.5456
     &         +USTEL*64.71*Q**.4756)
C
      TCDRP3=XDRP3*(UEXST*1.42*Q**.7716+CNSTR*.973*Q**.5456
     &         +USTEL*64.71*Q**.4756)*1.3
C
      TCDRP = TCDRP+TCDRP3
C-----COST OF CHECKS>>>USE CHECK WITHOUT DROP AND WITH APRON
C
```

```
      TCMB = XCMB*(UEXST*.83*Q**.8675+CNSTR*.36*Q**.7084
     &       + USTEL*21.45*Q**.7180)
C
C
C-----COST OF HEADWORKS/MEASURING STRUCTURE
C     FOR SMALL FLOWS >>>> USE  CHO*S
C     FOR LARGER FLOWS >>>> USE  MODIFIED PARSHALL FLUMES
C
      IF(Q.GT.65.)GO TO 222
      GAP=1.0
      QQ=TSZ(K)
      TCMFL = XMFL *       (UEXST*13.64*QQ**.4326+UBFST*12.26*QQ**.3421
     &       + UCOMB*11.35*QQ**.3583+CNSTR*1.00*QQ**.4572
     &       + USTEL*99.27*QQ**.4143 +GAP*247.3*QQ**.3910)
      GO TO 224
  222 TCMFL = XMFL*2687.*Q**.531*CIDX
  224 CONTINUE
C
C---- COST OF PUBLIC BRIDGE
C     UNIT COST IS IN $/SQ FT OF BRIDGE
C     COMPUTE FIRST THE REQUIRED LENGTH OF SPAN
C     TOTAL LENGTH =  WS WIDTH  +  ADD.WIDTH FOR FOOTING
C
      TWID = BW + 2.*YFB * Z
C
      TXBRD = XBRD * TWID *  BRDW * CBRD
C
C-----COST OF FARM BRIDGE
C
      TXBFD = XBFD * TWID *  BFDW * CBFD
C
C
      CTS = TOCST + TCDRP + TCMB + TCMFL + TXBRD + TXBFD
C
C
C
C-----COMPUTE HEIGHT OF BANK ABOVE WS FOR OPEN CHANNEL
C-----BASED ON BR CURVE
C
      IF( Q.LE.15.) FBC =1.2
      IF( Q.GT.15.AND.Q.LE.1000.) FBC=.56 * Q ** .2745
      IF( Q.GT.1000.) FBC = 1.1 * Q ** .1795
C
C     THEN COMPUTE TOTAL DEPTH
C
  612 YFB = Y + FBC
      IF(LCODE.EQ.0)GO TO 226
C-----COMPUTE HEIGHT OF LINING ABOVE  W.S.
C
      IF(Q.LE.40.) HLNG = 0.5
      IF(Q.GT.40.AND.Q.LE.400.) HLNG = 0.1 * Q ** 0.419
      IF(Q.GT.400.) HLNG = 0.275 * Q ** 0.25
C
C-----COMPUTE TOTAL HEIGHT OF LINING
C
      YLN = Y + HLNG
C
C
C
C
C-----COMPUTE THICKNESS OF HARDSUPFACE LINING
C-----BASED ON BR CURVES : THICKNESS DEPENDS ON  Q  & TYPE OF MATERIAL
C
      GO TO(210,212,214,216),LCODE
C
C-----UNREINFORCED PORTLAND CEMENT CONCRETE
C
  210 IF(Q.LE.200.)THLN= 2.2
      IF(Q.GT.200..AND.Q.LE.500.)  THLN = 2.5
      IF(Q.GT.500..AND.Q.LE.1500.) THLN = 3.1
      IF(Q.GT.1500..AND.Q.LE.3500.)THLN = 3.5
      IF(Q.GT.3500.)THLN= 4.0
      GO TO 218
C
C-----REINFORCED PORTLAND CEMENT CONCRETE
C
  212 IF(Q.LE.500.)THLN=3.5
      IF(Q.GT.500..AND.Q.LE.2000.)THLN = 4.0
      IF(Q.GT.2000.) THLN = 4.5
      GO TO 218
C
C-----ASPHALTIC CONCRETE
C
  214 IF(Q.LE.200.)THLN=2.15
      IF(Q.GT.200..AND.Q.LE.1500.)THLN = 3.2
```

```
      IF(Q.GT.1500.) THLN = 4.0
      GO TO 218
C
C-----SHOTCRETE
C
  216 IF(Q.LE.100.)THLN=1.25
      IF(Q.GT.100..AND.Q.LE.200.)THLN = 1.5
      IF(Q.GT.200..AND.Q.LE.400.)THLN = 2.75
      IF(Q.GT.400..AND.Q.LE.510.)THLN = 3.15
      IF(Q.GT.510.) WRITE(6,220)
  220 FORMAT(/,T10,'SORRY---NO SHOTCRETE ABOVE 510 CFS',/)
C
  218 CONTINUE
C
C     COMPUTE CONCRETE QUANTITIES FOR LINING MATERIAL
C     THIS COMPUTATION IS BASED ON  BR PROCEDURE;
C     WHERE SIDE SLOPE = 1.5 : 1
C
      THLN = THLN /12.
      VOL =(BW*THLN + 4*.302775*THLN**2. + 1.8027756*YLN*THLN*2.  +
     1 8.*THLN*2./12.) * SLEN/ 27.
C
C-----COMPUTE LINING COSTS
      CTL = VOL * CLN
      CTL = CTL + (CTL* CTGLN/100.)
  226 CONTINUE
C
C   CALCULATE CROSS-SECTIONAL AREA OF EXCAVATION
      ZREA = YFB*(BW + Z*YFB)
      AW = Q/V
C---COMPUTE COST OF SIPHON
C
  347 FORMAT( //,T30,'ESTIMATED COST OF STRUCTURES
     ' '//T45,'Q = ',I5,' CFS'/)
      IF(XSIP.EQ.0.)GO TO 310
C
C---COMPUTE APPROXIMATE DIAMETER OF SIPHON
C
      DIASIP = AINT( (4.*Q/(3.141592*VPIP))**(1./2.) * 12.)
      DIASIP = DIASIP/12.
      CALL SIPHON(Q,BW,YS,YFB,FBC,AW,V,PXWID,DIASIP,VPIP,
     +XL2,XL3,XL4,C,SX,SY,SZ,TSIP,KQ,MAXQ)
      GO TO 312
  310 TSIP = 0.
  312 CONTINUE
  348 FORMAT(/,T20,'ESTIMATED COST OF SIPHON...........................
     '',T80,F10.0)
C
      CTS = CTS + TSIP
C
      IF(XTUN.EQ.0.)GO TO 326
      DIATUN = AINT((4.*Q/(3.141592*VTUN))**(1./2.)*12.)
      DIATUN = DIATUN/12.
      CALL TUNNEL(WAGEM,STELIN,CEMINX,EQUIP,ELEV,DIATUN,
     $LENTUN,NPORT,ICOST)
      CSTUN = ICOST
      IF(KQ.NE.MAXQ) GO TO 328
      TLENG = LENTUN
      XPORT = NPORT
      WRITE(6,330)VTUN,DIATUN,TLENG,ELEV,XPORT
  330 FORMAT( /,T30,'TUNNEL COST ESTIMATE '//
     +T20,'MAXIMUM DESIRED VELOCITY IN TUNNEL.',T55,F9.2/
     +T20,'DIAMETER OF TUNNEL,FEET.............',T55,F9.2/
     +T20,'LENGTH OF TUNNEL,FEET...............',T53,F11.2/
     +T20,'ELEVATION OF TUNNEL,FEET............',T53,F11.2/
     +T20,'NUMBER OF HEADINGS..................',T55,F9.2/)
      GO TO 328
  326 CSTUN = 0.
  328 CTS = CTS + CSTUN
C
C
  349 FORMAT(/,T20,'ESTIMATED COST OF TUNNEL...........................
     '',T80,F10.0)
  350 FORMAT(/,T20,'ESTIMATED COST OF DROPS..........................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF CONCRETE CHECKS................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF MODIFIED P. FLUME..............
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF TURNOUTS.......................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF COUNTY BRIDGE..................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF FARM BRIDGE....................
```

```
     '/,T20,'ESTIMATED COST OF DRAINAGE CROSSINGS...........
     '',T80,F10.0/
     '/,T30,'CONTINGENCIES (', I3 ,' )....................
     '',T80,F10.0/
     '/,T20,'TOTAL COST OF STRUCTURES FOR THIS REACH...........
     '',T80,F10.0/)
C
C-----COMPUTE EARTHWORK COST
C
C-----TOTAL/ROCK/COMMON EXCAVATION
C
      CALL EARTH(BW,YFB.Y,Z,S3,S4,S5,WL.WP.WC,C1,C2,PCT,
     +CLCNG,ICEMB,CAN.TITLE,
     +XSTAAH,XS1,XZ,XF,C79,C80.IP,AVEROW.
     +TCOM,TROC,TFIL.TCEM.KM,KQ.MAXQ)
C
      IF(TROC.EQ.0.)TROC = TCOM * PERK/100.
C
C
      CTEX = TCOM * UEXC + TROC * UERC
C
C
      TCOMP = TCEM * UCOMP
C
C-----BACKFILL - USE 10  OF  TEXC
C
      TBACK = TFIL * UBACK
C
C-----PREPARING FOUNDATION - FOR LINED CANAL ONLY
C
      TPREP = ((TCOM + TROC) * 20./100.) * UPREP
      IF(LCODE.EQ.0)TPREP = 0.
C
C-----TOTAL COST OF EARTHWORK
C
      CTX =  CTEX + TCOMP + TBACK + TPREP
C
C-----ADD  CONTINGENCIES
C
      FCER = CTX +(CTX* CTGER/100.)
C
C
C---COMPUTE COST OF DRAINAGE CROSSINGS
      TDRA = 0.
C----ASSUME TYPE A COVER - 5 FEET
      ICOV = 1
      LHEAD = 25
      DO 625 NXZ = 1,NCX
      IF(LXD(NXZ).EQ.0)GO TO 625
      CALL PIPER(WAGE,EQUIP,AREA,IHAUL1.IHAUL2,LXD(NXZ),ICOV.IHEAD,
     *LHEAD,COST)
      TBAR = COST*AVEROW
C---ADD COST OF EARTHWORK-ASSUME EVEN GROUND SLOPE
      DIA = LXD(NXZ)
      IF(DIA.LE.6.) WT = 2.0
      IF(DIA.GT.6.AND.DIA.LE.18.) WT = .083*DIA + 2.00
      IF(DIA.GT.18.AND.DIA.LE.24.) WT = .083*DIA + 3.33
      IF(DIA.GT.24.) WT = .097*DIA + 3.0
      TOP = 4.
C---COMPUTE DEPTH OF EXCAVATION
      DEP = DIA + TOP
      XVOL = DEP * WT * AVEROW
      TEXC = XVOL * UEXC
C---BACKFILL COST
      BCST = XVOL * .50 * UBACK
C---COMPACTING BACKFILL COST
      CPCST = XVOL * .50 * UCOMP
C---TOTAL EARTHWORK
      TERT = TEXC + BCST + CPCST
C---UNLISTED ITEMS 5
      TERT = TERT + TERT * .05
C---TRANSITION COST
      CTRAN = 39. * CXQ(NXZ)**0.963 * CXN(NXZ)*CIDX
C---TOTAL COST OF CROSSINGS
      TDRA = TDRA + CTRAN + TBAR + TERT
  625 CONTINUE
      CTS = CTS + TDRA
C
C---ADD CONTINGENCIES TO STRUCTURES
      FCTNG = CTS * CTGST / 100.
      FCSTR = CTS + FCTNG
      ICON = CTGST
      IF(KQ.EQ.MAXQ)WRITE(6,760)CAN,TITLE
      IF(KQ.EQ.MAXQ)WRITE(6,347) KQ
```

```
      IF(KQ.EQ.MAXQ)WRITE(6.349)CSTUN
      IF(KQ.EQ.MAXQ)WPITE(6.350)TCDRP,TCMB,TCMFL,TOCST,
     * TXBRD,TXBFD,TDRA,ICON,FCTNG.FCSTR
C
C-----COMPUTE RIGHT OF WAY AND RELATED COSTS
C
C-----RIGHT OF WAY  COST
      AVEROW = AVEROW + RWID
C
      CROW = AVEROW * SLEN * RVAL/43560.
C
C-----SEVERANCE COST
C
      CSEV  =  ASER * UCSEV
C
C
C-----TOTAL COST
C
      TCROW = CROW + CSEV
C
C-----ADD CONTINGENCIES
C
      FCROW = TCROW + (TCROW * CTGRW/100.)
C
C-----COMPUTE TOTAL  FIFLD COST
C
      TFCONS =  FCSTR + FCER  + TCROW + CTL + TDRA
C
C-----COMPUTE ANNUAL COST EQUIVALENT
C
C
      CANN  =     TFCONS * (RINT * (1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.
     &)    -   SVAL * .01*(FCSTR + CTL)*PINT/(((RINT+1.)**TLFE)-1.)
C
C
C-----COMPUTE SEEPAGE LOSSES
C     USE *MORITZ* EQUATION
C     THE MORITZ EQUATION COMPUTES SEEPAGE LOSSES IN
C     CUBIC FEET PER SECOND PER MILE OF CANAL
C
      SEEP = 0.2*CMZ*((Q/V)**0.5)*SLEN/5280.
C
C---  CONSIDER OTHER LOSSES,IF THERE ARE ANY.
C     THESE MAY BE DUE TO OPERATIONAL LOSSES,SPILLS,ETC.
C
      OTLOS = Q * PLOS/100.
C
C---- CONVEYANCE EFFICIENCY
C
      EFF  = (Q - (SEEP + OTLOS))*100./Q
C
C---- COMPUTE VOLUME OF WATER LOST FOR THE SEASON
C     BASED ON NUMBER OF DAYS CANAL IS CARRYING 75  OF PEAK LOAD
C
      DPVOL = SEEP * 1.98 * DPT
C---COMPUTE AVERAGE SEEPAGE-AC-FT/CFS OF FLOW
      SRAT = DPVOL/Q
      TSRT = TSRT + SRAT
      LTS = LTS + 1
C
C---- COMPUTE VALUE OF WATER DUE TO SEEPAGE
C
      CTDP = DPVOL * DPV
C
C-----COMPUTE TOTAL VOLUME OF WATER LOST IN ONE DAY
C
      DAYSEP = (SEEP + OTLOS) * 1.98
C
      CTANN(KX) = CANN + CTDP
C
C
C   WRITE OUT RESULTS
      IF(KQ.EQ.MAXQ)WRITE(6,797)
  797 FORMAT(//,T30,'COST SUMMARY FOR THIS #Q# ')
C
      IF(KQ.EQ.MAXQ)WRITE(6,793)
C
      WRITE(6,401)Q,FCSTR,FCEP,CTL,TCROW,TFCONS,CTANN(KX),          EFF
  401 FORMAT(2X,F5.0.2X,4F14.0,F18.0,2F14.1)
C
      QX(KX) = KQ
C
   49 CONTINUE
C
```

```
   70 WRITE(6,260)          EFF
  260 FORMAT(///,      10X,'CONVEYANCE EFFICIENCY =' ,F5.1,' ')
      ZTZ = LTS
C
      XRTS = TSRT/ZTZ
      WRITE(6,261)XRTS
  261 FORMAT(/,10X,'AVERAGE CANAL SEEPAGE (AF-FT/CFS OF FLOW) = ',
     ' F8.4,/)
C
C
C   DETERMINE LINEAR REGRESSION COEFFICIENTS FOR THE DATA OBTAINED
      IF(CTANN(1).NE.0.)GO TO 670
      WRITE(6,677)
  677 FORMAT(T10,///,' ------------------  NO STRUCTURES ADDED --HENCE,
     &O ANNUAL FIXED COSTS FOR THIS SECTION ------------------'//)
      GO TO 675
  670 CONTINUE
      CALL REGLIN (QX,CTANN,KX,AC,BC,R)
  675 CONTINUE
      WRITE(9,534)
C---GO TO ANOTHER REACH
C
      GO TO 1
C
   98 RETURN
      END
C    SUBROUTINE EARTH.....CALLED BY MAIN PROG   WRDCANAL....
      SUBROUTINE EARTH(B,D,E,S2,S3,S4,S5,WL,WR,WC,C1,C2,
     +PCT,CLCNG,ICEMB,CAN,TITLE,
     +YSTAAH,YS1,YZ,YF,YC79,YC80,IPY,AVEROW,
     +TCOM,TROC,TFIL,TCEM,KM,KQ,MAXQ)
C/    LIST,NONE
C
C
C
C----THIS IS A MODIFIED VERSION OF U.S.B.R. PROGRAM #BR028#
C    THIS PROGRAM COMPUTES CANAL EARTHWORK VOLUMES
C
C
      DIMENSION XSTAAH(100),XS1(100),XZ(100),XF(100),C79(100),
     +C80(100),IP(100),XCOMM(100),XROCK(100),XFILL(100),XCEM(100)
      DIMENSION XBLST(100),KISTA(100),KJSTA(100),YCOM(100),
     +YROC(100),YCEM(100),YFILL(100),YBAL(100),YROW(100),ZX(100)
      DIMENSION YSTAAH(100),YS1(100),YZ(100),YF(100),YC79(100),
     +YC80(100),TITLE(17),
     +IPY(100)
C
      DIMENSION ZCOMM(100),ZROCK(100),ZFILL(100),ZCEM(100)
      AMAX=0.
C
C----DEFINTION OF VARIABLES
C
C----PRISM CARD INFORMATION
C   B---BOTTOM WIDTH
C   D---TOTAL DEPTH
C   E---HEIGHT OF COMPACTED EMBANKMENT--ASSME AT WATER DEPTH
C   S2--INSIDE BANK SLOPE H:V. EX.,1:.5*1,ENTER 1.5
C   S3--ROCK CUT SLOPE
C   S4--UPPER CUT BANK SLOPE
C   S5--FILL BANK CUT SLOPE
C   WL--UPPER BANK WIDTH--ASSUME WIDTH OF RIGTH OF WAY FOR RAOD
C   WR--LOWER BANK WIDTH--ASSUME WIDTH OF RIGHT OF WAY FOR ROAD
C   C1--COMPACTMENT FACTOR
C   C2--FILL COMPACTMENT FACTOR
C   PCT-PERCENT ROCK TO BE USED IN FILL
C   CLCNG-DEPTH OF CUT ADJUSTMENT
C   ICEMB-COMPACTED EMBANKMENT CODE. IF 1.-QUANT. WIL BE CONSIDERED FILL
C
C------ T E R R A I N   C A R D
C
C---STAAH----STATION STATION
C---S1---GROUND SLOPE
C   Z----CENTER LINE CUT
C   F----ROCK CENTER LINE CUT
C   COL79-CODE USED, 9---WHEN STA IS THE SAME AS THE PREVIOUS STA.
C   COL80-CODE USED, 9---WHEN NEXT CARD IS A PRISM CARD
C   IPLOT-CODE USED, 1---IF A MASS DIAGRAM IS DESIRED
C
C
      AMIN=0.
      LOC=1
C
C
```

```
      TCOM = 0.
      TROC = 0.
      TFIL = 0.
      TCEM = 0.
      TROW = 0.
      TKROW = 0.
C
C
C
      T=0.
      XDIST = 0.
      STABK=0.
      COMM1=0.
      ROCK1=0.
      FILL1=0.
      CEMB1=0.
      N=50
      Z=Z+CLCNG
      XMILE = 5280.
C
C---ASSIGN TERRAIN CARD VALUE<------------------------------------
C
      NQ = 1
C
  122 TBAL = 0.
      XCRE = 0.
      NN = 1
      NZ = NQ
C
      DO 111 KX = NZ,KM
      XSTAAH(NN) = YSTAAH(KX)
      XS1(NN) = YS1(KX)
      XS1(NN) = YS1(KX)
      XZ(NN) = YZ(KX)
      XF(NN) = YF(KX)
      C79(NN) = YC79(KX)
      C80(NN) = YC80(KX)
      IP(NN) = IPY(KX)
      NQ = NQ + 1
C
C
      IF(XSTAAH(NN).GE.XMILE) GO TO 113
      IF(IP(NN).NE.0)GO TO 113
      IF(C80(NN).NE.0.)GO TO 113
      NN = NN + 1
  111 CONTINUE
C
  113 CONTINUE
C
C
  117 DO 129 J=1,NN
C
      STAAH = XSTAAH(J)
      S1 = XS1(J)
      F = XF(J)
      COL79 = C79(J)
      Z = XZ(J) + XCRE
      ZX(J) = Z
      IPLOT = IP(J)
      COL80 = C80(J)
C
C
C
      IF(F)5014,5015,5014
 5014 F=F+CLCNG
 5015 IF(S1-S3)5011,5011,5012
 5011 WRITE(6,5013) STAAH
 5013 FORMAT(1H ,'GROUND X-SLOPE IS EQUAL TO OR EXCEEDS ROCK CUT SLOPE',
     1F7.0)
      GO TO 396
 5012 IF(Z-F)1001,851,1001
 1001 IF(S1-S4)850,850,851
  850 WRITE(6,11) STAAH
   11 FORMAT(1H , 'GROUND X-SLOPE IS EQUAL TO OR EXCEEDS UPPER CUT BANK
     1SLOPE AT STA',F7.0)
      GO TO 396
  851 IF(S1-S5)853,853.854
  853 WRITE(6,12) STAAH
   12 FORMAT(1H , 'GROUND X-SLOPE IS EQUAL TO OR EXCEEDS FILL BANK SLOPE
     1AT STA',F7.0)
      GO TO 396
  854 IF(STABK-STAAH)857,857,855
  855 IF(COL79)857,856,857
  856 WRITE(6,14) STABK, STAAH
   14 FORMAT(1H , 'STATION NOS. DO NOT INCREASE AND NOT A STATION EQUATI
```

```
      GO TO 396
  857 A1=B/2.
      A7=S2*D
      X10=A1+A7
      X2=-X10
      X3=X2-WL
      X12=X10+WR
      Y5=(S3*D-S1*F+X3)/(S3-S1)
      X5=-S1*(Y5-F)
      Y14=(S1*F-X12+S3*D)/(S3+S1)
      X14=S1*(F-Y14)
      A8=S1*Z
      A12=S5*D
      A20=D*(X10+A1)
      A30=S1*D
      X17=A8-A30
      X36=S1*Z
      X35=-S1*(D-Z)
      IF(Y14-D)102,102,101
  102 Y14=D
      X14=X12
      IF(Y5-D)103,103,101
  103 Y5=D
      X5=X3
  101 IF(S1-S4)5008,5008,5010
C
 5008 Y30=Y5
      X30=X5
      GO TO 5009
 5010 Y30=(S4*Y5-A8-S3*(Y5-D)+X3)/(S4-S1)
      X30=A8-S1*Y30
 5009 Y31=(A8-S3*(Y14-D)-X12+S4*Y14)/(S4+S1)
      X31=A8-S1*Y31
      A25=X3*(D-Y5)
      A4=D*(A1-X2)+A25+X5*(D-Y30)
      A24=X30*(Y5-Y31)+X31*(Y30-Y14)
      IF(Y31-D)120.110,110
  110 EXCAV=(A4+A24+X14*(Y31-D)+X12*(Y14-D)+A20)/2.
      CEMB=0.
      FILL=0.
      ROW=X31-X30
      GO TO 130
  120 Y8=(A8-A1)/(S2+S1)
      Y15=(A12-A8+X12)/(S5-S1)
      X15=A8-S1*Y15
      X8=A8-S1*Y8
      A3=X12*(D-Y15)
      IF(X17-X10)150,140.140
  140 EXCAV=(A4+X30*(Y5-D)+X17*(Y30-D)+A20)/2.
      FILLR=(X17*(Y15-D)+A3)/2.
      FILLL=0.
      CEMBL=0.
      CEMBR=0.
      GO TO 800
  150 X6=A8
      A32=E*(1.+S2)+A1+WC
      Y13=(A32-A8)/(1.-S1)
      X9=S2*E+A1
      X11=X9+WC
      A2=X11*(E-Y13)
      X13=A8-S1*Y13
      IF(X6-A1)180.170.170
  170 FILLR=(X8*(Y15-D)+X10*(Y8-D)+A3+X15*(D-Y8))/2.
      IF(Y8-E)190,200,200
  200 CEMBR=0.
  210 IF(S1-S2)220,220,900
  900 Y1=(A8+A1)/(S1-S2)
      IF(Y1-D)230,220,220
  220 FILLL=0.
      CEMBL=0.
      IF(Y8)250,250,240
  250 IF(X35-X2)2000,251,251
 2000 EXCAV=0.5*(X35*(Y30-D)+X3*(D-Y5)+X5*(D-Y30)+X30*(Y5-D))
      FILL=0.5*(X35*(Y15-D)+X2*D-0.5*B*D-0.5*B*D-X10*D+X12*(D-Y15))
      CEMB=0.5*(X19*(Y13-E)+X18*E-0.5*B*E-0.5*B*E-X9*E+X11*(E-Y13))
      FILL=FILL-CEMB
      ROW=X15-X30
      GO TO 130
  251 EXCAV=(A4+X30*Y5+X6*Y30)/2.
  800 ROW=X15-X30
      GO TO 160
  240 EXCAV=(A4+X30*(Y5-Y8)+X8*Y30+A1*Y8)/2.
      GO TO 800
  190 CEMBR=(X8*(Y13-E)+X9*(Y8-E)+A2+X13*(E-Y8))/2.
```

```
 160 FILLR=(X6*Y15+D*(X15-A1-X10)+A3)/2.
     CEMBR=(X6*Y13+E*(X13-A1-X9)+A2)/2.
     GO TO 210
 230 X1=A8-S1*Y1
     Y4=(A12+A8-X3)/(S1+S5)
     A6=(Y1*(A1+X8)+Y8*(A1-X1))/2.
     A10=X2*(D-Y1)
     A31=Y1*(A1+X6)/2.
     X34=-S1*(Y1-Z)
     Y34=(S1*Z+B/2.)/(S1-S2)
     IF(Y4-D)260,270,270
 260 X4=A8-S1*Y4
     FILLL=(X4*(Y1-D)+X3*(Y4-D)+A10+X1*(D-Y4))/2.
     IF(Y1-E)420,410,410
 410 CEMBL=0.
     GO TO 400
 420 Y21=(A32+A8)/(S1+1.)
     X18=-X9
     A27=X18*(E-Y1)
     IF(Y21-E)440,430,430
 440 X20=-X11
     X21=A8-S1*Y21
     CEMBL=(X21*(Y1-E)+X20*(Y21-E)+A27+X1*(E-Y21))/2.
     GO TO 400
 430 X19=A8-S1*E
     CEMBL=(X19*(Y1-E)+A27)/2.
 400 IF(Y34)2002,2002,401
2002 EXCAV=0.
     FILL=0.5*(X4*(Y15-D)+X3*(Y4-D)+X2*D-0.5*B*D-0.5*B*D-X10*D+X12*(D-Y
    115)+X15*(D-Y4))
     CEMB=0.5*(X21*(Y13-E)+X20*(Y21-F)+X18*E-0.5*B*E-0.5*B*E-X9*E+X11*(
    1E-Y13)+X13*(E-Y21))
     FILL=FILL-CEMB
     ROW=X15-X4
     GO TO 130
 401 IF(Y8)280,280,290
 280 EXCAV=A31
 801 ROW=X15-X4
     GO TO 160
 290 EXCAV=A6
     GO TO 801
 270 X16=X17
     FILLL=(X16*(Y1-D)+A10)/2.
     CEMBL=0.
     A23=(A25+X5*(D-Y30)+X30*(Y5-D)+X16*(Y30-D))/2.
     IF(Y8)300.300,310
 300 IF(X36+B/2.)2001,301,301
2001 EXCAV=0.5*(X34*(Y30-D)+X2*(Y34-D)+X3*(D-Y5)+X5*(D-Y30)+X30*(Y5-Y34
    1))
     FILL=0.5*(X34*Y15-0.5*B*Y34-0.5*B*D-X10*D+X12*(D-Y15)+X15*(D-Y34))
     CEMB=0.5*(X34*Y13-0.5*B*Y34-0.5*B*E-X9*E+X11*(E-Y13)+X13*(E-Y34))
     FILL=FILL-CEMB
     ROW=X15-X30
     GO TO 130
 301 EXCAV=0.5*(Y34*B/2.+X36*Y34+X35*(Y30-D)+X3*(D-Y5)+X5*(D-Y30)+X30*(
    1Y5-D))
     GO TO 802
 310 EXCAV=A6+A23
 802 ROW=X15-X30
 160 CEMB=CEMBL+CEMBR
     FILL=FILLL+FILLR-CEMB
 130 X6=S1*F
     A21=(D*(A1-X2)+A25)/2.
     IF(ICEMB)131,132,131
 131 FILL=FILL+CEMB
     CEMB=0.
 132 IF(F)510,500,510
 500 ROCK=0.
     GO TO 660
 510 IF(Y14-D)530,530,520
 520 ROCK=EXCAV-(X5*(Y14-Y30)+A24+X14*(Y31-Y5))/2.
     GO TO 660
 530 X17=X6-A30
     IF(X17-X10)550,540,540
 540 ROCK=A21+(X17*(Y5-D)+D*(X10+A1))/2.
     GO TO 660
 550 Y8=(X6-A1)/(S2+S1)
     X8=X6-S1*Y8
     IF(S1-S2)560,560,901
 901 Y1=(X6+A1)/(S1-S2)
     IF(Y1-D)590,590,560
 560 IF(Y8)580,580,570
 570 ROCK=A21+(X5*(D-Y8)+X8*Y5+A1*Y8)/2.
     GO TO 660
 580 IF(X35-X2)2003,581,581
```

```
 2003 ROCK=0.5*(X16*(Y5-D)+X3*(D-Y5))
      GO TO 660
  561 ROCK=A21+(X5*D+X6*Y5)/2.
      GO TO 660
  590 X1=X6-S1*Y1
  591 A22=(A1*(Y1+Y8)-X1*Y8+X8*Y1)/2.
      A28=Y1*(A1+X6)/2.
      IF(Y5-D)630,630.600
  600 X16=X17
      A26=(X16*(Y5-D)+A25)/2.
      IF(Y8)620,620,610
  610 ROCK=A22+A26
      GO TO 660
  620 IF(X36+B/2.)2004,621.621
 2004 ROCK=0.5*(X1*(Y5-D)+X2*(Y1-D)+X3*(D-Y5)-X5*(D-Y1))
      GO TO 660
  621 ROCK=A28+A26
      GO TO 660
  630 IF(Y1)2005,2005.631
 2005 ROCK=0.
      GO TO 660
  631 IF(Y8)650,650,640
  640 ROCK=A22
      GO TO 660
  650 ROCK=A28
  660 COMMN=EXCAV-ROCK
      IF(T)730,700,730
  700 COMMV=0.
      ROCKV=0.
      FILLV=0.
      CEMBV=0.
      BAL=0.
      T=1.
      RKBLV=0.
      ZCOMM(J) = COMMV
      ZROCK(J) = ROCKV
      ZFILL(J) = FILLV
      ZCEM(J) = CEMBV
      YBAL(J) = BAL
      XCOMM(J) =0.
      XROCK(J) = 0.
      XFILL(J) = 0.
      XCEM(J) = 0.
      XBLST(J) = 0.
C
      GO TO 720
  730 IF(COL79)740.710,740
  740 DIST=0.
      GO TO 750
  710 DIST=(STAAH-STABK)/54.
  750 COMMV=(COMM1+COMMN)*DIST+COMMV
      ROCKV=(ROCK1+ROCK)*DIST+ROCKV
      FILLV=(FILL1+FILL)*DIST+FILLV
      CEMBV=(CEMB1+CEMB)*DIST+CEMBV
C
      ZCOMM(J) = COMMV
      ZROCK(J) = ROCKV
      ZFILL(J) = FILLV
      ZCEM(J) = CEMBV
C
C
C


      RKBAL=(ROCK1+ROCK)*DIST*PCT/100.
      COMST=(COMM1+COMMN)*DIST
      ROKST=(ROCK1+ROCK)*DIST
      CEBST=(CEMB1+CEMB)*DIST
      FILST=(FILL1+FILL)*DIST
      XCOMM(J) = COMST
      XROCK(J) = ROKST
      XFILL(J) = FILST
      XCEM(J) = CEBST
C
C
      IF(RKBAL-FILST*C1)3002,3002,3001
 3001 RKBAL=FILST*C1
 3002 BALST=COMST-FILST*C1-CEBST*C2+RKBAL
      XBLST(J) = BALST
 3003 FORMAT(1H ,26X,F8.0,9X,F8.0,9X,F8.0,9X,F8.0,9X,F8.0)
      RKBLV=RKBLV+RKBAL
      BAL=COMMV-FILLV*C1-CEMBV*C2+RKBLV
  720 STABK=STAAH
      COMM1=COMMN
```

```
      FILL1=FILL
      CEMB1=CEMB
 3005 FORMAT(1H ,' STATION    X    TOTAL   ROCK    COMMON EXCAV',6X,'ROCK EX
     1CAV    COMPACT. EMBANK.    FILL BANK',9X,'BALANCE',10X,'ROW')
 3006 FORMAT(1H ,9X,'SLOPE  CUT    CUT  STA-STA  ACCUMUL STA-STA  ACCUMUL
     1 STA-STA  ACCUMUL STA-STA  ACCUMUL STA-STA  ACCUMUL'/)
      STA=STAAH/100.+.005
      ISTA=STA
      ASTA=ISTA
      BSTA=ASTA*100.
      CSTA=STAAH-BSTA
      JSTA=CSTA
      KISTA(J) = ISTA
      KJSTA(J) = JSTA
      YCOM(J) = COMMV
      YROC(J) = ROCKV
      YCEM(J) = CEMBV
      YFILL(J) = FILLV
      YBAL(J) = BAL
      YROW(J) = ROW
      IF(BAL) 6000,6001,6001
 6000 IF(ABS(BAL)-ABS(AMIN)) 6002,6002,6003
 6003 AMIN=BAL
      GO TO 6002
 6001 IF(BAL-AMAX) 6002,6002,6004
 6004 AMAX=BAL
 3007 FORMAT(1H ,I5,'+',I2,F6.2,2F6.1,8X,F9.0,8X,F9.0,8X,F9.0,8X,F9.0,8X
     1,F9.0,F9.1)
 6002 N=N+2
      ISIG=COL79
      TSMAX=STAAH
      TBAL = BAL
      IF(IPLOT.NE.0)GOTO 137
      IF(COL80.NE.0.)GO TO 137
C
C
  129 CONTINUE
  137 IF(TBAL.GT.-500..AND.TBAL.LT.500.)GO TO 211
      IF(S1.LT.10.)GO TO 911
      IF(TBAL.GT.0.)XCRE = XCRE -.01
      IF(TBAL.LT.0.) XCRE =XCRE + .01
      GO TO 913
  911 IF(S1.LT.5.)GO TO 915
      IF(TBAL.GT.0.)XCRE = XCRE - .01
      IF(TBAL.LE.0.)XCRE = XCRE + .01
      GO TO 913
  915 IF(TBAL.GT.0.)XCRE = XCRE -.01
      IF(TBAL.LE.0.)XCRE = XCRE + .01
  913 CONTINUE
      IF(XSTAAH(1).EQ.0.)T = 0.
      STABK = XDIST
      COMMV = 0.
      ROCKV = 0.
      FILLV = 0.
      CEMBV = 0.
      BAL = 0.
      RKBLV = XRKBLV
      COMM1 = XCOMM1
      ROCK1 = XROCK1
      CEMB1 = XCEMB1
C
      N = 50
      Z = Z + CLCNG
      GO TO 117
  211 DO 212 JJ = 1,NN
      TCOM = TCOM + XCOMM(JJ)
      TROC = TROC + XROCK(JJ)
      TFIL = TFIL + XFILL(JJ)
      TROW = TROW + YROW(JJ)
  212 TCEM = TCEM + XCEM(JJ)
      XNNN = NN
      TKROW = TKROW + XNNN
      IF(KQ.NE.MAXQ)GO TO 1566
C
      NTIT = 1
      NPAGE = 1
      DO 1011 JK=1,NN
      IF(NTIT.NE.1)GO TO 1569
      WRITE(6,798)CAN,TITLE
  798 FORMAT(1H1,//,T5,A4,17A4)
      WRITE(6,3004)KQ
 3004 FORMAT( //,T28,'>>>>>>    EARTHWORK COMPUTATION FOR THIS REACH
     +<<<<<<<<<'///,T45,'        Q = ',I4//)
      WRITE(6,3005)
      WRITE(6,3006)
```

```
      NTIT = 0
 1569 WRITE(6,3003)XCOMM(JK),XROCK(JK),XCEM(JK),XFILL(JK),XBLST(JK)
      WRITE(6,3007)KISTA(JK),KJSTA(JK),XS1(JK),ZX(JK),XF(JK),
     ↰ZCOMM(JK),ZROCK(JK),ZCEM(JK),ZFILL(JK),YBAL(JK),YROW(JK)
      NPAGE = NPAGE + 2
      IF(NPAGE.LT.50)GO TO 1011
      NPAGE = 1
      NTIT = 1
 1011 CONTINUE
C
 1566 IF(IPLOT.NE.0)GO TO 6007
      IF(C80(NN).NE.0.) GO TO 320
      XMILE = XMILE + XSTAAH(NN)
      XDIST = XSTAAH(NN)
      N = 50
      STABK = XDIST
      COMMV = 0.
      ROCKV = 0.
      FILLV = 0.
      CEMBV = 0.
      RKBLV = 0.
C
      BAL = 0.
      XCEMB1 = CEMB1
      XCOMM1 = COMM1
      XROCK1 = ROCK1
      XRKBLV = RKBAL
C
      Z = Z + CLCNG
C
      GO TO 122
  320 WRITE(6,397)
  397 FORMAT(//,T20,'IF DATA ON PRISM CARD CHANGES----> BREAK IT
     ↰ IT TO ANOTHER REACH'//)
      GO TO 396
C
C
C
C
 6006 LOC=LOC-1
      WRITE(6,52)
   52 FORMAT(//,T20,'PLOTTING PROGRAM HAS BEEN CALLED---------
     'WAS NOT INCORPORATED IN THIS PROGRAM'/)
 6007 CONTINUE
      AVEROW = TROW / TKROW
      IF(KQ.NE.MAXQ)GO TO 396
      WRITE(6,399)KQ, TCOM,TROC,TFIL,TCEM,AVEROW
  399 FORMAT(  //.T30,'>>>>>>  SUMMARY OF EARTHWORK FOR THIS REACH
     ↰     <<<<<<',//T47,' Q = '.I5,' CFS' ////
     ↰  T15,'COMMON EXCAVATION TOTAL'.T50,F10.0,' CU YD'//
     ↰T15,'ROCK EXCAVATION TOTAL'.T50,F10.0,' CU YD'//
     ↰T15,'BACKFILL TOTAL',T50,F10.0,' CU YD'//
     ↰T15.'COMPACTING BACKFILL TOTAL ',T50,F10.0,' CU YD'//
     'T15,'AVERAGE R-O-W',T50,F10.0.' FT'//)
C
  396 RETURN
      END


C   SUBROUTINE SIPHON...CALLED BY MAIN  WRDCANAL....
      SUBROUTINE SIPHON(Q,B,D,H,S,AZ,V,W,D1,V1,L2,L3,L4,C,S1,S2,S3,TSIP,
     ↰KQ,MAXQ)
C/    LIST.NONE
C
C
C----THIS IS A MODIFIED VERSION OF U.S.B.R. PROGRAM #SIPHN#
C    THIS PROGRAM ESTIMATES SIPHON QUANTITIES
C
C
      REAL L1,L2,L3,L4,L5
      DIMENSION    KHEAD(10), XL(10)
      COMMON UEXC, UEXST, UEXSI, UESPT, UERC, UERST, UERSI, UERPT,
     ↰UBACK, UBFST, UBFSI, UBFPT, UPREP, UCOMP, UCOMB, CLN, CNSTR,
     ↰CNSIP, USTEL, UCEM
      COMMON WAGE,EQUIP,AREA,IHAUL1,IHAUL2,WAGEM,STELIN,CEMINX
      COMMON CAN,TITLE(17)
      DATA KOV/1HA/
C
      S4=S*D
C
C     Q - CAPACITY, CFS
C     B - CANAL BOTTOM WIDTH, FEET
C     D - CANAL NORMAL DEPTH, FEET
C     H , TOTAL DEPTH, FEET
C     S - FREEBOARD AT CUTOFF END
C     AZ- CANAL WATER PRISM AREA
```

```
C     W - WIDTH OF O AND M ROAD, FEET
C     D1- PIPE INSIDE DIAMETER, INCHDS
C     V1- PIPE VELOCITY IN PIPE, FPS
C     L1- LENGTH OF PIPE, UPSTREAM SLOPE
C     L2- LENGTH OF PIPE, BOTTOM SLOPE
C     L4- LENGTH OF PIPE, DOWNSTREAM SLOPE
C     C - TRANSITION LOSS COEFFICIENT
C
      H2=D+1.0
      IF(D.LT.6.0)GO TO 250
      IF(D.LT.10.)GO TO 220
      D5=3.00
      T1=1.00
      GO TO 270
  220 D5=2.33
      T1=.67
      GO TO 270
  250 D5=1.5
      T1=.50
  270 H3=T1+D5
      IF (B.GT.D1) GO TO 320
  290 L1=AINT(((S4-(D1-B)/2.)/.52057)+.5)
  300 L5=AINT(((S4-(D1-B)/2.)/.41421)+.5)
      GO TO 350
  320 L1=AINT(((S4+(B-D1)/2.)/.52057)+.5)
  330 L5=AINT(((S4+(B-D1)/2.)/.41421)+.5)
  350 V2=V**2./64.4
      V3=V1**2./64.4
      T=(V3-V2)*C
      H1=H-(D+V2)+(T+V3+D1)
      IF(Q.LT.200.)GOTO 630
      IF(Q.LT.400.)GOTO 440
      IF(Q.LT.800.)GOTO 470
      IF(Q.LT.2000.)GOTO 500
      GO TO 530
  440 T1=.67
      F=1.00
      GO TO 550
  470 T1=.83
      F=1.50
      GO TO 550
  500 T1=1.17
      F=2.00
      GO TO 550
  530 T1=1.50
      F=2.50
  550 H2=D+F
      IF(B.GT.D1) GO TO 600
      S4=H2*S
      A1=((SQRT((H2)**2.+(S4+1.0)**2.)+H1)/2.*SQRT(L1**2.+(S4-(D1-B)/2.)
     &*2.)*2.)*T
      GO TO 670
  600 S4=H2*S
  610 A1=((SQRT(H2)**2.+(S4+1.)**2.+H1)/2.*SQRT(L1**2.+(S4+(B-D1)/2.)**2
     &)*2.)+T1
      GO TO 670
  630 IF(B.GT.D1)GO TO 660
      A1=(T1*((1.0+H1)/2.*SQRT(L1**2.+(S4+(D1-B)/2.)**2.)))*2.
      GO TO 670
  660 A1= T1*(1.0+H1)/2.*SQRT(L1**2.+(S4+(B-D1)/2.)**2.)*2.
  670 A2=(T1*SQRT(S4**2.+D**2.)*L1/2.)*2.
      A3=T1*(B+D1)/2.*L1
      A4=T1*((H1*D1)-(D1**2.*3.142/4.))
      IF(Q.LT.200.)GO TO 740
      H2=D+1.0
      A5=T1*((H2+H3)*(B+S4+H3)-B*H2-H2*S4-(S4/2.+H3)**2./S)
      GO TO 750
  740 A5=T1*((H2+H3)*(2.*S4+T1)*2.+(2.*D5+B)-(B+S4)*D-(B+2.*S4)-(S4/2.+
     &H3)**2.)
  750 C1=(A1+A2+A3+A4+A5)/27.
      IF(Q.LT.200.)GOTO 790
      R1=150.*C1
      GO TO 800
  790 R1=130.*C1
  800 H5=(D1-D)+H
      IF(Q.LT.200.) GO TO 1000
      IF(Q.LT.400.)GO TO 860
      IF(Q.LT.800.)GO TO 890
      IF(Q.LT.2000.)GO TO 920
      GO TO 950
  860 T1=.67
      F1=1.0
      GOTO 970
  890 T1=.83
      F = 1.5
```

```
      GO TO 970
  920 T1=1.17
      F = 2.0
      GO TO 970
  950 T1 = 1.5
      F= 2.5
  970 H2=D+F
      B1=((SQRT((H2)**2.)+(S*D+1.**2.)+H5)/2.*SQRT(L5**2.+(S*D+1.)**2.))
     &*T5
      GO TO 1160
 1000 IF(D.LT.6.0)GO TO 1080
      IF(D.LT.10.)GO TO 1050
      D5=3.00
      T5=1.00
      GO TO 1100
 1050 D5=2.33
      T5=.67
      GO TO 1100
 1080 D5=1.50
      T5=.50
 1100 H6=D5+T5
 1110 IF(B.LT.D1)GO TO 1130
      IF(B.GT.D1)GO TO 1150
 1130 B1=(T5*((1.0+H5)/2.*SQRT(L5**2.+((S*D)*(D1-B)/2.)**2.)))*2.
      GO TO 1160
 1150 B1=(T5*((1.+H5)/2.*SQRT(L5**2.+(S4*(B-D1)/2.)**2.)))*2.
 1160 B2=(T5*SQRT((S*D)** 2.+D**2.)*L5/2.)*2.
      B3=T5*(B+D1)/2.*L5
      B4=T5*((H5*D1)-(D1**2.*3.142/4.))
      B5=T5*((D+H6+1.)*(2*S4+T5)*2.+(2*D5+B)-(B+S4)*D-(B+2.*S4)-(S4/2.+H
     &6)**2.)
      C2=(B1+B2+B3+B4+B5)/27.
      IF(Q.LT.200.)GO TO 1240
      R2=150.*C2
      GO TO 1250
 1240 R2=130.*C2
 1250 C3=AINT (C1+C2)
      C4=AINT (C3*5.64)
      R3=AINT (R1+R2)
      E1=(B+S*(D+T1))*(D+T1)
      E2=(D1+2.*T1)+(H1-H+D1+T1)**2.
      E3=(E1+E2)/2.*L1/27.
      E4=(B+S*(D+T5))*(D+T1)
      E5=(D1+2.*T5)+(H5-H+D1+T5)**2.
      E6=(E4+E5)/2.*L5/27.0
      E7=AINT(E3+E6)
      D2=D1*1.167
      P1=((D2+1.)+(D2+3.))*(D2+3.)*L2
      P2=((D2+1.)+(D2+10.))*(D1+10.)*L3
      P3=((D2+1.)+(D2+3.))*(D2+3.)*L4
      P4=AINT((P1+P2+P3)/27.0)
      P5=((H1-H+D1+T1)+2.)*(H1-H+D1+T1)+(H-D)**2.
      P6=P5/2.*L1/27.0
      P7=((H5-H+D1+T5)+2.)*(H5-H+D1+T5)+(H-D)**2.
      P8=P7/2.*L5/27.0
      P9=AINT(P6+P8)
      Q1=(((D2+1.)+(.375*D2))*(.375*D2)-(.2739*D2**2.))*(L2+L3+L4)/27.
      Q6 = AINT(Q1)
      W6=AINT(Q1)
      Q2=P1-(D2**2.*3.142/4.)*L2
      Q3=P2-(D2**2.*3.142/4.)*L3
      Q4=P3-(D2**2.*3.142/4.)*L4
      Q5=AINT((Q2+Q3+Q4)/27.)
C
C---COMPUTE COST OF EXCAVATION, CONCRETE, ETC.
C   INCLUDES COST OF INLET AND OUTLET TRANSITIONS
C
      CST1 = C3 * CNSTR
      CST2 = C4 * UCEM
      CST3 = R3 * USTEL
      CST4 = E7 * UEXST
      CST5 = P9 * UCOMB
      CST6 = P9 * UBFSI
      CST7 = P4 * UEXSI
      CST8 = Q6 * UCOMB
      CST9 = Q5 * UBFSI
      CST10 = CST1+CST2+CST3+CST4+CST5+CST6+CST7+CST8+CST9
C
      D3=D1*12.
      U=25.0-(D+H-H1)
      W=25.0-(D+H-H1)
      U1=AINT(U/S1)
      W1=AINT(W/S3)
      U2=AINT(25.0/S1)
```

```
      IF(U1.LT.L2) GO TO 1810
      X=L2+L3+L4
      GO TO2620
 1810 X2=U1+U2
      X3=W1+W2
      IF(X2.LT.L2)GO TO 1870
      X1=U1+W1
      X2=(L2-U1)+(L4-W1)+L3
      GO TO 2690
 1870 U3=AINT(25.0/S1)
      W3=AINT(25.0/S3)
      X=U1+U2+U3
      IF(X.LT.L2)GO TO 1950
      X1=U1+W1
      X2=U2+W2
      X3=(L2-(U1+U2))+(L4-(W1+W2))+L3
      GO TO 2770
 1950 U4=AINT(25.0/S1)
      W4=AINT(25.0/S3)
      X=U1+U2+U3+U4
      IF(X.LT.L2)GO TO 2040
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=(L2-(U1+U2+U3))+(L4-(W1+W2+W3))+L3
      GO TO 2860
 2040 U5=AINT(25.0/S1)
      W5=AINT(25.0/S3)
      X=U1+U2+U3+U4+U5
      IF(X.LT.L2)GO TO 2140
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=U4+W4
      X5=(L2-(U1+U2+U3+U4))+(L4-(W1+W2+W3+W4))+L3
      GO TO 2960
 2140 U6=AINT(25.0/S1)
      W6=AINT(25.0/S3)
      X=U1+U2+U3+U4+U5+U6
      IF(X.LT.L2)GO TO 2250
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=U4+W4
      X5=U5+W5
      X6=(L2-(U1+U2+U3+U4+U5))+(L4-(W1+W2+W3+W4+W5))+L3
      GO TO 3070
 2250 U7=AINT(25.0/S1)
      W7=AINT(25.0/S3)
      X=U1+U2+U3+U4+U5+U6+U7
      IF(X.LT.L2) GO TO 2370
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=U4+W4
      X5=U5+W5
      X6=U6+W6
      X7=(L2-(U1+U2+U3+U4+U5+U6))+(L4-(W1+W2+W3+W4+W5+W6+W7))+L3
      GO TO 3190
 2370 U8=AINT(25.0/S1)
      W8=AINT(25.0/S3)
      X=U1+U2+U3+U4+U5+U6+U7+U8
      IF(X.LT.L2) GO TO 2500
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=U4+W4
      X5=U5+W5
      X6=U6+W6
      X7=U7+W7
      X8=(L2-(U1+U2+U3+U4+U5+U6+U7))+(L4-(W1+W2+W3+W4+W5+W6+W7))+L3
      GO TO 3320
 2500 U9=AINT(25.0/S1)
      W9=AINT(25.0/S3)
      X1=U1+W1
      X2=U2+W2
      X3=U3+W3
      X4=U4+W4
      X5=U5+W5
      X6=U6+W6
      X7=U7+W7
      X8=U8+W8
      X9=L2-U1-U2-U3-U4-U5-U6-U7-U8+L4-W1-W2-W3-W4-W5-W6-W7-W8+L3
      GO TO 3460
C
```

```
 2620 N = 1
      XL(1) = X1
      GO TO 3620
 2690 N= 2
      XL(1) = X1
      XL(2) = X2
      GO TO 3620
 2770 N= 3
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      GO TO 3620
 2860 N = 4
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
C
      GO TO 3620
 2960 N = 5
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
      XL(5) = X5
      GO TO 3620
 3070 N = 6
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
      XL(5) = X5
      XL(6) = X6
      GO TO 3620
 3190 N= 7
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
      XL(5) = X5
      XL(6) = X6
      XL(7) = X7
      GO TO 3620
 3320 N= 8
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
      XL(5) = X5
      XL(6) = X6
      XL(7) = X7
      XL(8) = X8
      GO TO 3620
 3460 N = 9
      XL(1) = X1
      XL(2) = X2
      XL(3) = X3
      XL(4) = X4
      XL(5) = X5
      XL(6) = X6
      XL(7) = X7
      XL(9) = X9
      XL(8) = X8
C
C---N= NO OF HEADS
C
 3620 TCST =0.
      IF(KQ.NE.MAXQ)GO TO 627
      WRITE(6,998) L1,L5,C3.C4.R3.E7,P9.P9,P4,Q6.Q5
  998 FORMAT(///, T30,'SIPHON QUANTITY ESTIMATES'/
     +T20,'LENGTH OF INLET TRANS., FT .........',T55,F9.0/
     +T20,'LENGTH OF OUTLET TRANS., FT..........'.T55,F9.0/
     +T20.'CONCRETE IN STRUCTURES. CU YDS...........',T55,F9.0/
     +T20.'CEMENT, CWT ..........................',T55,F9.0/
     +T20,'REINFORECEMENT, LB .......................',T55,F9.0/
     +T20,'EXCAVATION FOR STRUCTURES, CU YD.........',T55,F9.0/
     +T20,'COMPACTED BACKFILL ABOUT STRUCTURES...',T55,F9.0/
     +T20.'BACKFILL ABOUT STRUCTURES, CU YD......',T55,F9.0/
     +T20.'EXCAVATION FOR PIPE. CU YD ..............',T55.F9.0/
     +T20.'COMPACTED BACKFILL ABOUT PIPE, CU YD....',T55,F9.0/
     +T20.'BACKFILL ABOUT PIPE. CU YD...............'.T55,F9.0)
C
  627 CONTINUE
```

```
      TSIP = 0.
      DO 52 K=1,N
      COST = 0.
      IDIAM = D3
      NHEAD = NHEAD + 25
      KHEAD(K) = NHEAD
  629 FORMAT(T20.'LENGTH OF',I4.' INCHES'.I5,' FT HEAD- PIPE ',F9.0,
     ''       UNIT COST...',F9.0)
      CALL PIPER(WAGE,EQUIP,AREA.IHAUL1.IHAUL2.IDIAM,ICOVER.
     +NHEAD.COST)
      IF(KQ.EQ.MAXQ)WRITE(6,629)IDIAM,KHEAD(K),XL(K),COST
C
      TCST = TCST + COST * XL(K)
   52 CONTINUE
C
C---COMPUTE TOTAL COST OF SIPHON
C
      TSIP = TCST + CST10
      RETURN
      END
C     SUBROUTINE RECHAN...CALLED BY  CANAL   (MAIN)  CANAL PROGRAM
C-----READ UNIT COST INPUT
C
C
      SUBROUTINE RECHAN
C/    LIST,NONE
C
C
C----THIS PROGRAM COMPUTES COST OF OPEN CHANNEL
C
C
      COMMON UEXC, UEXST, UEXSI, UEXPT, UFRC, UERST, UERSI, UERPT,
     +UBACK, UBFST, UBFSI, UBFPT, UPREP. UCOMP, UCOMB, CLN, CNSTR,
     #CNSIP, USTEL, UCEM, UHAUL
      COMMON WAGE,EQUIP,AREA,IHAUL1,IHAUL2,WAGEM,STELIN,CEMINX
      COMMON CAN,TITLE(17)
C
      DIMENSION A(50), CTANN(500),QX(500)
      DIMENSION TNO(50), TSZ(50)
      DIMENSION XSTAAH(100),XS1(100),XF(100),C79(100),C80(100),
     +IP(100).XZ(100)
      DIMENSION CXN(10),LXD(10),CXQ(10)
      DATA CN1,CN2/4HEND ,4HSKIP/
      DATA ADD0,ADD1,ADD2,ADD3,ADD4/4H    ,4HBH=1,4HBH=2,4HCHK ,4HDRP /
      KXQ = 0
      NNT = 0
  255 FORMAT('1',///)
  500 FORMAT(/,' TYPE THE FF INFORMATION:'/
     '' ''READ---LINED CANAL''...THEN REACH IDENTIFIER>>IF LINED CANAL'/
     '' ''READ---UNLINED CANAL''...IF CANAL IS NOT LINED')
  502 FORMAT(/,' TYPE THE FF DATA COMMON TO ALL REACHES'/
     '' 1-PERCENT CONTINGENCY COST, CANAL OR LATERAL STRUCTURES'/
     '' 2-PERCENT CONTINGENCY COST , EARTHWORK'/
     '' 3-PERCENT CONTINGENCY COST. ROW'/
     '' 4-PERCENT CONTINGENCY COST. CANAL LINING'/
     '' 5-CANAL STRUCTURES COST INDEX, BASE IS 1976'/
     '' 6-CODE FOR LINING MATERIAL USED :'/
     ''                                (0) NO LINING'/
     ''                                (1) UNREINFORCED PORTLAND CEM'/
     ''                                (2) REINFORCED PORTLAND CEM'/
     ''                                (3) ASPHALTIC CONCRETE'/
     ''                                (4) SHOTCRETE'/)
  504 FORMAT(/,' TYPE DESIGN CHANNEL PROPERTIES'/
     '' 1-DESIGN SIDE SLOPE OF CANAL'/
     '' 2-SIDE SLOPE OF OUTSIDE OF NEW, DESIGN CHANNEL'/
     '' 3-MANNINGS ROUGHNESS COEF'/
     '' 4-MINIMUM ALLOWABLE VELOCITY, FPS'/
     '' 5-MAXIMUM ALLOWABLE VELOCITY, FPS'/
     '' 6-MINIMUM CHANNEL DEPTH. FT'/)
  506 FORMAT(/,' TYPE BRIDGE DATA'/
     '' 1-WIDTH OF COUNTY BRIDGE, FT'/
     '' 2-UNIT COST FOR COUNTY BRIDGE, $/SQ FT'/
     '' 3-WIDTH OF FARM BRIDGE. FT'/
     '' 4-UNIT COST OF FARM BRIDGE, $/SQ FT'/)
  508 FORMAT(/,' TYPE THE FF DATA'/
     '' 1-LIFE OF PROJECT, YEARS'/
     '' 2-ANNUAL INTEREST RATE. PERCENT'/
     '' 3-SALVAGE VALUE AS A PERCENT OF ORIGINAL COST'/)
  510 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-VALUE OF WATER LOST FROM CANAL SECTION, $/AF'/
     '' 2-NO OF DAYS CANAL IS OPERATING 75 PERCENT OF PEAK LOAD'/
     '' 3-OTHER OPERATIONAL LOSSES AS A PERCENT OF ''Q'' '/)
  512 FORMAT(/,' >>AT THIS POINT. DATA ARE FOR SPECIFIC REACH ONLY<<'/
     '/,' TYPE THE FF DATA FOR THIS REACH:'/
```

```
     '' 1-SEEPAGE COEF, MORITZ EQUATION'/
     '' 2-PRESENT ROW, FT'/
     '' 3-VALUE OF ROW, $/AC'/
     '' 4-AREA FOR SEVEPANCE PAYMENT, AC'/
     '' 5-UNIT COSTS FOR SEVERANCE PAY, $/AC'/
     '' 6-DISTANCE TO BORROW AREA(COMMON), MILES'/)
 514 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-LENGTH OF REACH, FT'/
     '' 2-ELEVATION OF CHANNEL BOTTOM AT OUTLET, FT'/
     '' 3-ELEVATION OF CHANNEL BOTTOM AT INLET, FT'/
     '' 4-REQUIRED MIN. WATER ELEV. AT OUTLET FOR T.O. OPERATION '/)
 516 FORMAT(/,' TYPE NUMBER AND CORRESPONDING SIZES OF T.O., CFS'/
     ''     NOTE: REACH IS SIZED WITH THE ASSUMPTION THAT'/
     ''           TURNOUTS ARE LOCATED AT THE END OF REACH, DIRECTLY'/
     ''           UPSTREAM OF DROP/CHECK STRUCTURE, IF ONE IS REQUIRED'/)
 518 FORMAT(/,' TYPE NUMBER OF STRUCTURES TO BE INCLUDED IN REACH:'/
     ''        (1) RECTANGULAR INCLINED DROP'/
     ''        (2) CONCRETE CHECK, W/O APRON'/
     ''        (3) MODIFIED PARSHALL FLUME'/
     ''        (4) COUNTY BRIDGE'/
     ''        (5) FARM BRIDGE'/
     ''        (6) SIPHON'/
     ''        (7) TUNNEL'/
     ''       NOTE: STRUCTURE #1 IS ASSUMED TO BE LOCATED AT THE OUTLET'/
     ''             OF THE DESIGN REACH...IF CHECKS ARE TO BE INCLUDED'/
     ''             ALONG THE CHANNEL, THIS ROUTINE WILL PLACE ONE'/
     ''             AT THE END OF THE REACH.'///)
 520 FORMAT(/,' TYPE DATA FOR SIPHON'/
     '' 1-HEAD LOSS DESIRED, FT/1000 FT'/
     '' 2-MAXIMUM VELOCITY IN PIPE, FPS'/
     '' 3-LENGTH OF PIPE, UPSTREAM SLOPE, FT'/
     '' 4-LENGTH OF PIPE, BOTTOM SLOPE, FT'/
     '' 5-LENGTH OF PIPE, DOWNSTREAM SLOPE, FT'/
     '' 6-TRANSITION LOSS COEF'/
     '' 7-PIPE SLOPE, UPSTREAM, FT/FT'/
     '' 8-PIPE SLOPE, BOTTOM, FT/FT'/
     '' 9-PIPE SLOPE, DOWNSTREAM, FT/FT'/
     ''10-WIDTH OF R-O-W, FT'/)
 522 FORMAT(/,' TYPE DATA FOR TUNNEL'/
     '' 1-HEAD LOSS DESIRED, FT/1000 FT'/
     '' 2-DESIRED VELOCITY ON TUNNEL, FPS'/
     '' 3-ELEVATION OF JOB, FEET'/
     '' 4-LENGTH OF TUNNEL, FT'/
     '' 5-NO. OF HEADINGS TO BE USED'/)
 524 FORMAT(/,' TYPE DATA FOR PRISM OF OLD CHANNEL'/
     '' 1-BASE WIDTH OF OLD CHANNEL, FT'/
     '' 2-SIDE SLOPE (AVE) OF INSIDE OF OLD CHANNEL'/
     '' 3-AVE RELATIVE HEIGHT OF BERMS ABOVE OLD CHANNEL BOTTOM, FT'/
     '' 4-AVE TOP WIDTH OF OLD BERM ON LEFTSIDE (FACING UPSTREAM)'/
     '' 5-AVE TOP WIDTH OF OLD BERM ON RIGHTSIDE OF CHANNEL'/
     '' 6-SIDE SLOPE OF OUTSIDE FACE OF LEFT CHANNEL BERM'/
     '' 7-SIDE SLOPE OF OUTSIDE FACE OF RIGHT CHANNEL BERM'/
     '' 8-ELEV OF NATURAL TERRAIN TO LEFT OF CHANNEL AT INLET'/
     '' 9-ELEV OF NATURAL TERRAIN TO RIGHT OF CHANNEL AT INLET'/
     '' 10-ELEV OF NATURAL TERRAIN TO LEFT OF CHANNEL AT OUTLET'/
     '' 11-ELEV OF NATURAL TERRAIN TO RIGHT OF CHANNEL AT OUTLET'/)
 532 FORMAT(/,' TYPE MINIMUM Q(CFS), MAXIMUM A(CFS) AND *Q* INTERVAL'/)
 534 FORMAT(/,' ARE THERE SOME MORE REACH TO PROCESS--------'/
     '' IF ''NO''  TYPE.... ''END DATA'' '/
     '' IF ''YES'' TYPE.... ''SKIP---LINED CANAL'' OR'/
     ''                     ''SKIP---UNLINED CANAL'' '//)
C
      WRITE(9,500)
    1 CONTINUE
      READ(5,150) CON,CAN,TITLE
      WRITE(9,150)CON,CAN,TITLE
  150 FORMAT (A4,3X,A4,17A4)
      IF (CON.EQ.CN1) GO TO 98
      IF (CON.EQ.CN2) GO TO 3
C---READ CONTINGENCIES AND COST INDEX
C
C
C       ' CTGST = PERCENT CONTINGENCY COST FOR CANAL OR LATERAL STRUCTS.
C       ' CTGER = PERCENT CONTINGENCY COST FOR EARTHWORK
C       ' CTGRW = PERCENT CONTINGENCY COST FOR RIGHT OF WAY, ETC.
C       ' CTGLN = PERCENT CONTINGENCY COST FOR CANAL LINING
C       ' CIDX  = COST INDEX FOR CANAL/LATERAL STRUCTURES WITH A BASE
C                 YEAR IN  JAN 1976
C       ' LCODE = CODE FOR LINING MATERIALS
C
      WRITE(9,502)
C
      CALL INPUT(A,NC)
C
```

```
      CTGRW = A(3)
      CTGLN = A(4)
      CIDX  = A(5)
      LCODE = A(6)
C
C---- READ IN CHANNEL PROPERTIES
C
C          Z = SIDE-SLOPE OF CHANNEL
C         RN = MANNINGS ROUGHNESS COEFFICIENT
C         VMX = MAXIMUM ALLOWABLE VELOCITY
C         VMN = MINIMUM ALLOWABLE VELOCITY, FPS
C          YMN = MINIMUM CHANNEL DEPTH IN FEET
      WRITE(9,504)
C
      CALL INPUT(A,NP)
C
      Z   = A(1)
      ZZ  = A(2)
      RN  = A(3)
      VMN = A(4)
      VMX = A(5)
      YMN = A(6)
C
C-----READ BRIDGE DATA
      WRITE(9,506)
C
      CALL INPUT(A,NB)
C
C       ' BRDW = WIDTH OF COUNTY BRIDGE
C       ' CBRD = UNIT COST FOR COUNTY BRIDGE ($/SQ.FT)
C       ' BFDW = WIDTH OF FAPM BRIDGE
C       ' CBFD = UNIT COST FOR COUNTY BRIDGE ($/SQ.FT)
C
      BRDW = A(1)
      CBRD = A(2)
      BFDW = A(3)
      CBFD = A(4)
      WRITE(9,508)
C
      CALL INPUT(A,NR)
C
C       ' TLFE = LIFE OF PROJECT
C       ' RINT = ANNUAL INTEREST RATE IN PERCENT
C       ' SVAL = SALVAGE VALUE AS A PERCENT OF THE ORIGINAL COST
C
      TLFE = A(1)
      RINT = A(2)/ 100.
      SVAL = A(3)
C
C   READ IN DATA PERTAINING TO OPERATIONAL WASTE
C         DPV = VALUE OF WATER LOST FROM CANAL SECTION IN $/ACRE-FOOT
C         DPT = NUMBER OF DAYS CANAL IS CARRYING 75  OF PEAK DEMAND
C                (BASED ON BUREAU GUIDELINE OF CAP = 120-150  AVE DEMAND)
      WRITE(9,510)
      CALL INPUT(A,NO)
C
C       ' PLOS = OTHER OPERATIONAL LOSSES AS A PERCENT OF Q
C
      DPV  = A(1)
      DPT  = A(2)
      PLOS = A(3)
C
C-----READ SEEPAGE.EXCAVATION & ROW DATA
C
C----BRANCH TO ANOTHER REACH
C
    3 CONTINUE
      WRITE(9,512)
C
      CALL INPUT(A,NS)
C
C       ' CMZ  = SEEPAGE COEFFICIENT 'C' IN MORITZ EQUATION
C       ' PERK = PERCENT OF ROCK EXCAVATION
C       ' RWID = PRESENT WIDTH OF RIGHT OF WAY, FT, OF OLD CHANNEL
C       ' RVAL = VALUE OF ROW, $/AC
C       ' ASER = AREA FOR SEVERANCE PAYMENT,AC
C       ' UCSEV = UNIT COST SEVERANCE PAYMENT,$/AC
C     ' XBRW = AVERAGE DISTANCE TO BORROW AREA (FOR ADDITIONAL COMMON FI
C
      CMZ   = A(1)
      RWID  = A(2)
      RVAL  = A(3)
      ASER  = A(4)
      UCSEV = A(5)
```

```
      WRITE(9,514)
C
      CALL INPUT(A,NL)
C
      SLEN = A(1)
      ELO  = A(2)
      ELI  = A(3)
      ELTO = A(4)
      OELO = ELO
      OELI = ELI
C
C     READ THE NUMBER AND CORRESPONDING SIZE OF TURNOUTS--USE CHO
      WRITE(9,516)
C
      CALL INPUT(A,NT)
C
      DO 10 K=2,NT,2
      TNO(K/2)=A(K-1)
   10 TSZ(K/2)=A(K)
      NT = NT/2
C
C
C---READ DATA FOR DRAINAGE CROSSINGS
      WRITE(9,617)
  617 FORMAT(/,' TYPE DATA FOR DRAINAGE CROSSINGS'/
     '' 1-NUMBER OF CROSSINGS'/
     '' 2-DIAMETER, INCHES'/
     '' 3-APPROXIMATE CAPACITY, CFS'/
     '' ---IF NO DRAINAGE CROSSING,  ENTER  0. 0. 0. '/)
      CALL INPUT(A,NCX)
      DO 620 K=3,NCX,3
      CXN(K/3) = A(K-2)
      LXD(K/3) = A(K-1)
      CXQ(K/3) = A(K)
  620 CONTINUE
      NCX = NCX/3
C     READ OTHER STRUCTURES
      WRITE(9,518)
C
      CALL INPUT(A,NS)
C
C        ' XDRP = NUMBER OF DROPS
C        ' XCMB = NUMBER OF CHECKS
C        ' XMFL = NUMBER OF MODIFIED PARSHALL FLUME
C        ' XBRD = NUMBER OF PUBLIC BRIDGE
C        ' XBFD = NUMBER OF FARM BRIDGE
C        ' XSIP = NUMBER OF SIPHON (LIMIT TO ONE PER REACH)
C        ' XTUN = NUMBER OF TUNNEL (LIMIT TO ONE PER REACH)
C
C
      XDRP = A(1)
      XCMB = A(2)
      XMFL = A(3)
      XBRD = A(4)
      XBFD = A(5)
      XSIP = A(6)
      XTUN = A(7)
      IF(XSIP.EQ.0.) GO TO 110
C
C---READ INFO FOR SIPHON
      WRITE(9,520)
C
      CALL INPUT(A,NN)
      HD = A(1)
      VPIP = A(2)
      XL2 = A(3)
      XL3 = A(4)
      XL4 = A(5)
      C = A(6)
      SX = A(7)
      SY = A(8)
      SZ = A(9)
      RXWID = A(10)
C
  110 IF(XTUN.EQ.0.) GO TO 112
C---READ INFO FOR TUNNEL
      WRITE(9,522)
      CALL INPUT(A,NTN)
C        ' HDTUN - MAX HEAD LOSS DESIRED
C        ' VTUN - MAX DESIRED VELOCITY IN TUNNEL
C        ' ELEV - ELEVATION OF JOB IN FEET
C       LENTUN - LENGTH OF TUNNEL IN FEET
C        ' NPORT - NUMBER OF HEADINGS TO BE USED
C
      HDTUN = A(1)
```

```
      VTUN = A(2)
      ELEV = A(3)
      LENTUN = A(4)
      NPORT = A(5)
C
  112 CONTINUE
C
C---INPUT ONE PRISM CARD FOR EACH REACH
C   DATA SHOULD BE REPPESENTATIVE OF PRESENT DIMENSIONS AND CONDITION
C   OF EXISTING CHANNEL TO BE REHABILITATED
C
C   READ PRISM CARD
      WRITE(9,524)
C
      CALL INPUT(A,NO)
      OBW  = A(1)
      OZ   = A(2)
      OBMH = A(3)
      OBMWL= A(4)
      OBMWR= A(5)
      OZBML= A(6)
      OZBMR= A(7)
      ETLI = A(8)
      ETRI = A(9)
      ETLO = A(10)
      ETRO = A(11)
C
      WRITE(9,532)
C
      CALL INPUT(A,NM)
C
      MINQ = A(1)
      MAXQ = A(2)
      KNTQ = A(3)
C
      WRITE(9,566)
  566 FORMAT(/,' >>>>>>>END OF DATA FOR THIS REACH<<<<<<<'///)
C
C   COMPUTE COSTS FOR A RANGE OF DISCHARGES
C
      KX = 0
      WRITE(6,760)CAN, TITLE
      WRITE(6,793)
  793 FORMAT( //,4X,'Q',8X,'COST OF',7X.'COST OF',9X,'COST OF',7X,'COST
     &OF',8X,'TOTAL CONST.',4X,'ANNUAL EQUI',5X,'CONVEYANCE',/2X,'(CFS)'
     &.5X,'STRUCTURE',5X,'EARTHWORK',8X.'LINING',6X,'RIGHT OF/WAY',8X,
     ''COST',11X,' COST ',8X,'EFFICIENCY',/)
C
  760 FORMAT(1H1,//,T5,A4,17A4,/)
C
      TSRT = 0.
      LTS = 0
      TDRP = XDRP
      TCMB = XCMB
C
      DO 49 KQ=MINQ,MAXQ,KNTQ
      KX = KX + 1
      V = 0.
      Q = KQ
      XDRP = TDRP
      XCMB = TCMB
      XDRP3 = 0.
C---- DETERMINE  BH RATIO
C
      IF(LCODE.NE.0) GO TO 202
C
C     COMPUTE BH RATIO FOR UNLINED CANAL-VARIABLE
C     USE  BR CRITERIA   10 CFS = 2:1 :  10.000 CFS = 8:1 RATIO
C
      BH = .0006 * Q + 2.
C
      GO TO 204
C
C     COMPUTE BH RATIO FOR LINED CANAL
C     USE BR CRITERIA
C
  202 IF( Q.LE.200.) BH = 3.
      IF( Q.GT.200.AND. Q.LE.1000.) BH = 1.2
      IF( Q.GT.1000.) BH = 1.7
C
  204 CONTINUE
C
      OSLP = (OELI-OELO)/SLEN
C
C
```

```
      ELI=OELI
      ELO=OELO
C   DETERMINE HYDRAULIC GRADIENT
   11 SLP =(ELI-ELO)/SLEN
      IF(SLP.LE.0.)GO TO 199
      GO TO 99
  199 ELI = ELI+1
      GO TO 11
C   DETERMINE BOTTOM WIDTH AND WATER DEPTH FOR GIVEN B:H RATIO
   99 Y=((Q*RN/(1.49*(SLP**0.5)))**0.375)*((2*(1.+Z*Z)**0.5+BH)**0.25)/
     &((Z+BH)**0.625)
      YS = Y
      IF(Y.LT.YMN) GO TO 80
      GO TO 85
   80 BH=BH-1.
      IF(BH.LE.0.) GO TO 85
      GO TO 99
   85 IF(BH.LE.0.) BH=1.
      BW=BH*YS
      IF(YS.GT.(ELTO-ELO)) GO TO 40
      IF(XCMB.LE..5) XCMB = 1.
      IF(V.EQ.0.) GO TO 40
      IF((ELTO-ELO-YS).GT.1..AND.((V-VMN)/(VMX-VMN)).GT.1.) GO TO 39
      GO TO 40
   39 ELO = ELO + 1
      GO TO 11
   40 CONTINUE
C----- TOP WIDTH
C
      XLN = BW   + (2. * YS * Z)
C
C--------WETTED PERIMETER
C
      WPER = BW + 2.* YS * ((1.+Z**2.0)**(1./ 2.))
C
C   CHECK VELOCITY AGAINST MAX AND MIN ALLOWABLE VELOCITY
      V =(1.49/RN)*((Z*Y*Y+BW*Y)/(BW+2*Y*((1.+Z*Z)**0.5)))**0.66667
     &    *(SLP**0.5)
      IF(V.LE.VMX) GO TO 30
C   INSERT DROP STRUCTURE IF VELOCITY IS GREATER THAN  VMX
      IF(XCMB.EQ.0..AND.XDRP.EQ.0.) XDRP = 1.
  933 ELO = ELO +1.
      GO TO 11
C
   30 IF(V.GE.VMN) GO TO 32
      IF(ELO.LT.OELO) GO TO 35
      ELO = ELO-1
      GO TO 31
   35 ELI = ELI+1
   31 GO TO 11
C
   32 CONTINUE
C
      IF((ELTO-ELO-YS).LT.-1..AND.ELI.GT.OELI) GO TO 56
      GO TO 57
   56 ELI = ELI-1
      ELO = ELO-1
   57 CONTINUE
C
C-----CALCULATE COST OF EACH STRUCTURE
C
C-----COST OF TURNOUTS >>> USE CONSTANT HEAD ORIFICE  (CHO)
C
      TOCST = 0
      DO 200 K=1,NT
C     GAP---INDEX FOR STEEL GATES AND PIPE (CMP). BASE=1976
      GAP=1.0
      QQ=TSZ(K)
      TOCST = TOCST+TNO(K)*(UEXST*13.64*QQ**.4326+UBFST*12.26*QQ**.3421
     &        +UCOMB*11.35*QQ**.3583+CNSTR*1.00*QQ**.4572
     &        +USTEL*99.27*QQ**.4143 +GAP*247.3*QQ**.3910)
  200 CONTINUE
      TOCST = TOCST * CIDX
C
C     DECIDE IF DROP OF END OF REACH IS GREATER THAN 3. FEET
C     IF BOTH A CHECK AND DROP ARE SPECIFIED BY THE HYDRAULICS, INSERT A
C     DROP/CHECK COMBINATION STRUCTURE....
C
      DIFFE = ELO - OELO
      IF(XCMB.EQ.1..AND.DIFFE.GT.1.) XDRP=1.
      IF(XCMB.EQ.1..AND.DIFFE.GT.3.) XDRP3=1.
      IF(XDRP3.EQ.1.) XDRP=0.
      IF(XDRP.EQ.1..AND.XCMB.EQ.1.) XCMB=XCMB-1.
      IF(TCMB-XCMB.GT.0..AND.XCMB.NE.0.) XCMB = TCMB
```

```
C
      ADD6=ADD0
      ADD7=ADD0
      ADD8=ADD0
      IF(XCMB.GT.TCMB) ADD7=ADD3
      IF((XDRP+XDRP3).GT.TDRP) ADD8=ADD4
      IF(BH.LT.3.) ADD6=ADD2
      IF(BH.LT.2.) ADD6=ADD1

C       COST OF DROPS.....USE RECTANGULAR INCLINED DROP/CHECK COMBINATION
C
C       DROP AND CHECK EQUATIONS REGRESSED FOR 5.< Q < 100. CFS  AND
C                                           $150.< COST CONCRETE < $200.
C
      TCDRP = XDRP*(UEXST*1.42*Q**.7716+CNSTR*.973*Q**.5456
     &       +USTEL*64.71*Q**.4756)
C
      TCDRP3 = XDRP3*(UEXST*1.42*Q**.7716+CNSTR*.973*Q**.5456
     &         +USTEL*64.71*Q**.4756)*1.3
      TCDRP = TCDRP+TCDRP3
C
C     COST OF CHECKS......USE CHECK WITHOUT DROP AND WITH APRON
C
      TCCMB = XCMB*(UEXST*.83*Q**.8675+CNSTR*.36*Q**.7084
     &       +USTEL*21.45*Q**.7180)
C
C
C-----COST OF HEADWORKS/MEASURING STRUCTURE
C     FOR SMALL FLOWS >>>> USE  CHO*S
C     FOR LARGER FLOWS >>>> USE  MODIFIED PARSHALL FLUMES
C
      IF(Q.GT.65.) GO TO 222
      GAP=1.0
      TCMFL = XMFL*(UEXST*13.64*Q**.4326+UBFST*12.26*Q**.3421
     &        +UCOMB*11.35*Q**.3583+CNSTR*1.00*Q**.4572
     &        +USTEL*99.27*Q**.4143+ GAP*247.3*Q**.3910)
      GO TO 224
  222 TCMFL = XMFL*2687.*Q**.521*CIDX
  224 CONTINUE
C
C
C
C     COMPUTE HEIGHT OF BANK ABOVE WS FOR OPEN CHANNEL
C     BASED ON BR CURVE
C
      IF(Q.LE.15.) FBC=1.2
      IF(Q.GT.15..AND.Q.LE.1000.) FBC=.56*Q**.2745
      IF(Q.GT.1000.) FBC=1.1*Q**.1795
C
C---- COST OF PUBLIC BRIDGE
C     UNIT COST IS IN $/SQ FT OF BRIDGE
C     COMPUTE FIRST THE REQUIRED LENGTH OF SPAN
C     TOTAL LENGTH =  WS WIDTH  +  ADD.WIDTH FOR FOOTING
C
      TWID=BW+2.*(YS+FBC)*Z
C
      TXBRD = XBRD * TWID *  BRDW * CBRD
C
C-----COST OF FARM BRIDGE
C
      TXBFD = XBFD * TWID *  BFDW * CBFD
C
C
      CTS = TOCST + TCDRP + TCCMB + TCMFL + TXBRD + TXBFD
C
C
C
  612 YFB = YS + FBC
      IF(LCODE.EQ.0)GO TO 226
C-----COMPUTE HEIGHT OF LINING ABOVE  W.S.
C
      IF(Q.LE.40.) HLNG = 0.5
      IF(Q.GT.40..AND.Q.LE.400.) HLNG = 0.1 * Q ** 0.419
      IF(Q.GT.400.) HLNG = 0.275 * Q ** 0.25
C
C-----COMPUTE TOTAL HEIGHT OF LINING
C
      YLN = YS + HLNG
C
C
C
C
C-----COMPUTE THICKNESS OF HARDSURFACE LINING
C-----BASED ON BR CURVES ; THICKNESS DEPENDS ON  Q  & TYPE OF MATERIAL
C
```

```
      GO TO(210,212,214,216),LCODE
C
C-----UNREINFORCED PORTLAND CEMENT CONCRETE
C
  210 IF(Q.LE.200.)THLN= 2.2
      IF(Q.GT.200..AND.Q.LE.500.)  THLN = 2.5
      IF(Q.GT.500..AND.Q.LE.1500.) THLN = 3.1
      IF(Q.GT.1500..AND.Q.LE.3500.)THLN = 3.5
      IF(Q.GT.3500.)THLN= 4.0
      GO TO 218
C
C-----REINFORCED PORTLAND CEMENT CONCRETE
C
  212 IF(Q.LE.500.)THLN=3.5
      IF(Q.GT.500..AND.Q.LE.2000.) THLN = 4.0
      IF(Q.GT.2000.) THLN = 4.5
      GO TO 218
C
C-----ASPHALTIC CONCRETE
C
  214 IF(Q.LE.200.)THLN=2.15
      IF(Q.GT.200..AND.Q.LE.1500.) THLN = 3.2
      IF(Q.GT.1500.) THLN = 4.0
      GO TO 218
C
C-----SHOTCRETE
C
  216 IF(Q.LE.100.)THLN=1.25
      IF(Q.GT.100..AND.Q.LE.200.) THLN = 1.5
      IF(Q.GT.200..AND.Q.LE.400.) THLN = 2.75
      IF(Q.GT.400..AND.Q.LE.510.) THLN = 3.15
      IF(Q.GT.510.) WRITE(6,220)
  220 FORMAT(/,T10,'SORRY---NO SHOTCRETE ABOVE 510 CFS',/)
C
  218 CONTINUE
C
C     COMPUTE CONCRETE QUANTITIES FOR LINING MATERIAL
C     THIS COMPUTATION IS BASED ON  BR PROCEDURE;
C     WHERE SIDE SLOPE =  Z  : 1
      ZLING = (Z**2.+ 1.)**.5
      THLN = THLN /12.
      VOL =(BW*THLN + 4*.302775*THLN**2. + ZLING * YLN * THLN * 2.+
     1 8.*THLN*2./12.)*SLEN/27.
C
C-----COMPUTE LINING COSTS
      CTL = VOL * CLN
      CTL = CTL + (CTL* CTGLN/100.)
  226 CONTINUE
C
C   CALCULATE CROSS-SECTIONAL AREA OF EXCAVATION
      ZREA = YFB*(BW + Z*YFB)
      AW = Q/V
C---COMPUTE COST OF SIPHON
C
  347 FORMAT( //,T30,'ESTIMATED COST OF STRUCTURES
     ' '//T45,'Q = ',I5,' CFS'/)
      IF(XSIP.EQ.0.)GO TO 310
C
C---COMPUTE APPROXIMATE DIAMETER OF SIPHON
C
      DIASIP = AINT( (4.*Q/(3.141592*VPIP))**(1./2.) * 12.)
      DIASIP = DIASIP/12.
      CALL SIPHON(Q,BW,YS,YFB,FBC,AW,V,PXWID,DIASIP,VPIP,
     +XL2,XL3,XL4,C,SX,SY,SZ,TSIP,KQ,MAXQ)
      GO TO 312
  310 TSIP = 0.
  312 CONTINUE
  348 FORMAT(/,T20,'ESTIMATED COST OF SIPHON.........................
     '',T80,F10.0)
C
      CTS = CTS + TSIP
C
      IF(XTUN.EQ.0.)GO TO 326
      DIATUN = AINT((4.*Q/(3.141592*VTUN))**(1./2.)*12.)
      DIATUN = DIATUN/12.
      CALL TUNNEL(WAGEM,STELIN,CEMINX,EQUIP,ELEV,DIATUN,
     $LENTUN,NPORT,ICOST)
      CSTUN = ICOST
      IF(KQ.NE.MAXQ) GO TO 328
      TLENG = LENTUN
      XPORT = NPORT
      WRITE(6,330)VTUN,DIATUN,TLENG,ELEV,XPORT
  330 FORMAT( /,T30,'TUNNEL COST ESTIMATE '//
     +T20,'MAXIMUM DESIRED VELOCITY IN TUNNEL.',T55,F9.2/
     +T20,'DIAMETER OF TUNNEL,FEET............',T55,F9.2/
```

```
     +T20,'LENGTH OF TUNNEL,FEET..............',T53,F11.2/
     +T20,'ELEVATION OF TUNNEL,FEET...........',T53,F11.2/
     +T20,'NUMBER OF HEADINGS.................',T55,F9.2/)
      GO TO 328
  326 CSTUN = 0.
  328 CTS = CTS + CSTUN
C
C
  349 FORMAT(/,T20,'ESTIMATED COST OF TUNNEL..........................
     '',T80,F10.0)
  350 FORMAT(/,T20,'ESTIMATED COST OF DROPS..........................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF CONCRETE CHECKS................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF MODIFIED P. FLUME..............
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF TURNOUTS.......................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF COUNTY BRIDGE..................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF FARM BRIDGE....................
     '',T80,F10.0/
     '/,T20,'ESTIMATED COST OF DRAINAGE CROSSINGS..........
     '',T80,F10.0/
     '/,T30,'CONTINGENCIES (', I3 ,' )..................
     '',T80,F10.0/
     '/,T20,'TOTAL COST OF STRUCTURES FOR THIS REACH...........
     '',T80,F10.0/)
C
C-----COMPUTE EARTHWORK COST
C
C-----TOTAL COMMON EXCAVATION
C
      CALL REARTH(OBW,OZ,OBMH,OBMWL,OBMWR,OZBML,OZBMR,
     2ETLI,ETRI,ETLO,ETRO,ELTO,OELI,OELO,
     3ELI,ELO,OSLP,SLP,BW,Z,ZZ,YFB,YLN,TCOM,
     4TFILL,TCEM,OHAUL,TNEW,KM,KQ,MAXQ,
     5AVEROW,CAN,TITLE,SLEN)
C
C
C
      CTEX = TCOM * UEXC
C
C
      TCOMP = TCEM * UCOMP
C
C
      THAUL = OHAUL * UHAUL * XBRW
C
      TBACK = TFILL * UBACK
C
C-----PREPARING FOUNDATION - FOR LINED CANAL ONLY
C
      TPREP = (TCOM *20./100.) * UPREP
      IF(LCODE.EQ.0)TPREP = 0.
C
C-----TOTAL COST OF EARTHWORK
C
      CTX = CTEX + TCOMP + TBACK + TPREP + THAUL
C
C-----ADD  CONTINGENCIES
C
      FCEP = CTX +(CTX* CTGER/100.)
C
C
C---COMPUTE COST OF DRAINAGE CROSSINGS
      TDRA = 0.
C----ASSUME TYPE A COVER - 5 FEET
      ICOV = 1
      LHEAD = 25
      DO 625 NXZ = 1,NCX
      IF(LXD(NXZ).EQ.0)GO TO 625
      CALL PIPER(WAGE,EQUIP,AREA,IHAUL1,IHAUL2,LXD(NXZ),ICOV,IHEAD,
     *LHEAD,COST)
      TBAR = COST*AVEROW
C---ADD COST OF EARTHWORK-ASSUME EVEN GROUND SLOPE
      DIA = LXD(NXZ)
      IF(DIA.LE.6.) WT = 2.0
      IF(DIA.GT.6.AND.DIA.LE.18.) WT = .083*DIA + 2.00
      IF(DIA.GT.18.AND.DIA.LE.24.) WT = .083*DIA + 3.33
      IF(DIA.GT.24.) WT = .097*DIA + 3.0
      TOP = 4.
C---COMPUTE DEPTH OF EXCAVATION
      DEP = DIA + TOP
```

```
      TEXC = XVOL * UEXC
C---BACKFILL COST
      BCST = XVOL * .50 * UBACK
C---COMPACTING BACKFILL COST
      CPCST = XVOL * .50 * UCOMP
C---TOTAL EARTHWORK
      TERT = TEXC + BCST + CPCST
C---UNLISTED ITEMS 5
      TERT = TERT + TERT * .05
C---TRANSITION COST
      CTRAN = 39. * CXQ(NXZ)**0.963 * CXN(NXZ)*CIDX
C---TOTAL COST OF CROSSINGS
      TDRA = TDRA + CTRAN + TBAR + TERT
  625 CONTINUE
      CTS = CTS + TDRA
C
C---ADD CONTINGENCIES TO STRUCTURES
      FCTNG = CTS * CTGST / 100.
      FCSTR = CTS + FCTNG
      ICON = CTGST
      IF(KQ.EQ.MAXQ)WRITE(6.760)CAN,TITLE
      IF(KQ.EQ.MAXQ)WRITE(6,347) KQ
      IF(KQ.EQ.MAXQ)WRITE(6,348)TSIP
      IF(KQ.EQ.MAXQ)WRITE(6,349)CSTUN
      IF(KQ.EQ.MAXQ)WRITE(6,350)TCDRP,TCCMB,TCMFL,TOCST,
     * TXBRD,TXBFD,TDRA.ICON,FCTNG,FCSTR
C
C-----COMPUTE RIGHT OF WAY AND RELATED COSTS
C
C-----RIGHT OF WAY  COST
      AVEROW = AMAX1(AVEROW-RWID.0.)
C
      CROW = AVEROW * SLEN * RVAL/43560.
C
C-----SEVERANCE COST
C
      CSEV  =  ASER * UCSEV
C
C
C-----TOTAL COST
C
      TCROW = CROW + CSEV
C
C-----ADD CONTINGENCIES
C
      FCROW = TCROW + (TCROW * CTGRW/100.)
C
C-----COMPUTE TOTAL  FIELD COST
C
      TFCONS =  FCSTR + FCER  + TCROW + CTL + TDRA
C
C-----COMPUTE ANNUAL COST EQUIVALENT
C
C
      CANN  =     TFCONS * (RINT * (1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.
     &)     -   SVAL * .01*(FCSTR + CTL)*RINT/(((RINT+1.)**TLFE)-1.)
C
C
C-----COMPUTE SEEPAGE LOSSES
C     USE *MORITZ* EQUATION
C     THE MORITZ EQUATION COMPUTES SEEPAGE LOSSES IN
C     CUBIC FEET PER SECOND PER MILE OF CANAL
C
      SEEP = 0.2*CMZ*((Q/V)**0.5)*SLEN/5280.
C
C---  CONSIDER OTHER LOSSES.IF THERE ARE ANY.
C     THESE MAY BE DUE TO OPERATIONAL LOSSES,SPILLS,ETC.
C
      OTLOS = Q * PLOS/100.
C
C---- CONVEYANCE EFFICIENCY
C
      EFF  = (Q - (SEEP + OTLOS))*100./Q
C
C---- COMPUTE VOLUME OF WATER LOST FOR THE SEASON
C     BASED ON NUMBER OF DAYS CANAL IS CARRYING 75  OF PEAK LOAD
C
      DPVOL = SEEP * 1.98 * DPT
C---COMPUTE AVERAGE SEEPAGE-AC-FT/CFS OF FLOW
      SRAT = DPVOL/Q
      TSRT = TSRT + SRAT
      LTS = LTS + 1
C
C---- COMPUTE VALUE OF WATER DUE TO SEEPAGE
C
```

```
      CTDP = DPVOL * DPV
C
C-----COMPUTE TOTAL VOLUME OF WATER LOST IN ONE DAY
C
      DAYSEP = (SEEP + OTLOS) * 1.98
C
      CTANN(KX) = CANN + CTDP
C
C
C   WRITE OUT RESULTS
      IF(KQ.EQ.MAXQ)WRITE(6,797)
  797 FORMAT(//,T30,'COST SUMMARY FOR THIS #Q# ')
C
      IF(KQ.EQ.MAXQ)WRITE(6,793)
C
C     ADD6='BH=2', IF DESIGN DEPTH = YMN AND BH<3.
C     ADD7=CHK, IF CHECK HAS BEEN ADDED TO REACH
C     ADD8=DRP, IF DROP HAS BEEN ADDED TO REACH
C
      WRITE(6,401)Q,FCSTR,FCER,CTL,TCROW,TFCONS,CTANN(KX),EFF,ADD6,ADD7,
     +ADD8
  401 FORMAT(2X,F5.0,2X,4F14.0,F18.0,2F14.1,3(1X,A4))
C
      QX(KX) = KQ
C
   49 CONTINUE
C
C
   70 WRITE(6,260)          EFF
  260 FORMAT(///,      10X,'CONVEYANCE EFFICIENCY =' ,F5.1,' ')
      ZTZ = LTS
C
      XRTS = TSRT/ZTZ
      WRITE(6,261)XRTS
  261 FORMAT(/,10X,'AVERAGE CANAL SEEPAGE (AF-FT/CFS OF FLOW) = ',
     ' F8.4,/)
C
C
C   DETERMINE LINEAR REGRESSION COEFFICIENTS FOR THE DATA OBTAINED
      IF(CTANN(1).NE.0.)GO TO 670
      WRITE(6,677)
  677 FORMAT(T10,///,' ------------------  NO STRUCTURES ADDED --HENCE,
     &O ANNUAL FIXED COSTS FOR THIS SECTION -------------------'//)
      GO TO 675
  670 CONTINUE
      CALL REGLIN (QX,CTANN,KX,AC,BC,R)
  675 CONTINUE
      WRITE(9,534)
C---GO TO ANOTHER REACH
C
      GO TO 1
C
   98 RETURN
      END
      SUBROUTINE REARTH(OBW,OZ,OBMH,OBMWL,OBMWR,OZBML,OZBMR,
     2ETLI,ETRI,ETLO,ETRO,ELTO,OELI,OELO,
     3ELI,ELO,OSLP,SLP,BW,Z,ZZ,YFB,YLN,TCOM,
     4TFILL,TCEM,OHAUL,TNEW,KM,KQ,MAXQ,
     5AVEROW,CAN,TITLE,SLEN)
C
C       THIS ROUTINE IS USED TO COMPUTE EARTH MOVEMENT AND
C       EXCAVATION AND COMPACTMENT VOLUMES INVOLVED IN THE
C       REHABILITATION AND LINING OF A WATER CONVEYANCE CHANNEL
C
C
C  OBW     OLD BASE WIDTH
C  OZ      OLD INSIDE SIDE SLOPE
C  OBMH    HEIGHT OF OLD BERM ABOVE OLD CHANNEL BOTTOM
C  OBMWL   OLD BERM WIDTH -LEFTSIDE (FACING UPSTREAM)
C  OBMWR   OLD BERM WIDTH -RIGHTSIDE
C  OZBML   AVERAGE SLOPE OF OUTSIDE OF OLD BERM -LEFTSIDE
C  OZBMR   AVERAGE SLOPE OF OUTSIDE OF OLD BERM -RIGHTSIDE
C  ETLI    ELEVATION OF NATURAL TERRAIN TO LEFT OF OLD CHANNEL INLET
C  ETRI    ELEVATION OF NATURAL TERRAIN TO RIGHT OF OLD CHANNEL INLET
C  ETLO    ELEVATION OF NATURAL TERRAIN TO LEFT OF OLD CHANNEL OUTLET
C  ETRO    ELEVATION OF NATURAL TERRAIN TO RIGHT OF OLD CHANNEL OUTLET
C  ELTO    MINIMUM ELEVATION OF WATER SURFACE FOR DIVERSION THROUGH TURNO
C  OELI    ELEVATION OF INLET OF OLD CHANNEL
C  OELO    ELEVATION OF OUTLET OF OLD CHANNEL
C  ELI     ELEVATION OF INLET OF DESIGN CHANNEL
C  ELO     ELEVATION OF OUTLET OF DESIGN CHANNEL (ABOVE CHECK/DROP)
C  OSLP    OLD BOTTOM SLOPE
C  SLP     DESIGN BOTTOM SLOPE
C  BW      DESIGN BASE WIDTH
C  Z       DESIGN INSIDE SIDE SLOPE
```

```
C  YLN    DESIGN VERTICAL DEPTH OF LINING
C  TCOM   TOTAL VOLUME OF EXCAVATION -CU. YD.
C  TFILL  TOTAL VOLUME OF COMPACTED BACKFILL IN CHANNEL
C  TCEM   TOTAL VOLUME OF COMPACTED EMBANKMENT
C  OHAUL  TOTAL VOLUME OF FILL TO BE HAULED FROM OUTSIDE REACH
C  TOLD   VOLUME OF FILL OBTAINED FROM EXCAVATION
C  SLEN   LENGTH OF REACH
C
C
C
      NEX = 0
      R2D2 = 0.
      A=OELI
      B=OELO
      C=ELI
      D=ELO
      ETR=ETRO
      ETL=ETLO
C
   50 AREAR=0.
      AREAT=0.
      AREAS=0.
      AREAM=0.
      PAREA=0.
      RAREA=0.
      YVERT=0.
      ARECA=0.
C
C   CALCULATE AREA OF OLD CHANNEL BELOW BERM OF DESIGN CHANNEL
C
C
      Y1 = ELO + YFB
      Y2 = YFB + ELO - OELO
      Y3 = ELO - OELO
      AREAC = OBW * Y2 + OZ * Y2**2
C
C   CALCULATE MINIMUM TOP WIDTH OF SOIL BERM ON DESIGN CONCRETE CHANNEL
C
      BERMR = AMAX1((Y1-ETR+2.8),.0001)**.667
      BERML = AMAX1((Y1-ETL+2.8),.0001)**.667
      BERMR=(BERMR+BERML)/2.
      BERML=BERMR
C   CALCULATE DIFFERENCES IN AREA SECTIONS BETWEEN CHANNELS
      AREA3 = (OBW + Y3 * OZ) * Y3
      POWID = OBW + Y3 * 2 * OZ
      IF(Y3.LT.R2D2) POWID = OBW
      TOPW = OBW + 2 * OZ * Y2
      DTOPW=BW+2*Z*YFB
      CWID = DTOPW + BERMR + BERML
C
      NPLUS = 1
      IF(DTOPW.GT.TOPW) NPLUS = -1
      AREA1 = AREA3
      IF(AREA3.LE.R2D2) AREA3=0.
      AREAR=0.
      WID = POWID - BW - YFB * Z * 2
      AREAS = YFB**2*Z
      IF(CWID.GT.TOPW) GO TO 100
      IF(WID.LE.R2D2) GO TO 150
      AREAR = (BERMR+BERML) * YFB
C
C   CALCULATE IRREGULAR AREAS BETWEEN BERMS OF OLD AND DESIGN CHANNELS
C     FOR VARIOUS CASES
C
      Y5 = (POWID - CWID)/ZZ/2.
      IF(Y5.LT.0.) GO TO 40
      Y4 = ZZ/OZ * (YFB-Y5)/(1.+ZZ/OZ)
      AREAT = OZ * Y4**2
      IF(Y4.LT.0.) AREAT = ZZ*YFB**2
      AREAM = (YFB + Y4)*(POWID-CWID)/2.
      IF(Y4.LT.0.) AREAM=0.
      GO TO 200
   40 Y5 = -(POWID-CWID)/OZ/2.
      Y4 = YFB-Y5
      AREAT = OZ*ZZ/(OZ+ZZ)*Y4**2
      AREAR = AREAR + (POWID-CWID)*(YFB+Y4)/2.
      AREAM = 0.
      GO TO 200
C
C   CALCULATE VARIOUS AREAS OF CUT AND FILL FOR CASES WHERE TOPWIDTH +
C     BERM WIDTH OF DESIGN EXCEEDS WIDTH OF OLD CHANNEL AT ELO + YFB
C
  100 AREAR = ((TOPW-DTOPW)+POWID)/2.*YFB
      ARECA = (CWID-TOPW)*((Y1-ETL)+(Y1-ETR))/2.
```

```
      PAREA = (Y1-ETL)**2*(OZ+77)/2.
      IF((Y1-ETR).LT.0.) RAREA = -RAREA
      IF((Y1-ETL).LT.0.) PAREA = -PAREA
      ARECA = -ARECA-PAREA-RARFA
      IF(Y1.LT.(OBMH+OELO)) GO TO 200
      Y4 = Y1-(OBMH+OFLO)
      ARFAM = Y4*(CWID-TOPW)+Y4**2*(ZZ+07)
      ARECA = ARECA+AREAM
      GO TO 200
C
C   CALCULATE VARIOUS AREAS OF CUT AND FILL FOR CASES WHERE TOP WIDTH OF
C     DESIGN CHANNEL EXCEEDS THE WIDTH OF OLD CHANNEL AT ELO.
C
  150 WID = ABS(WID)
      ZW = YFB * 2 * Z
      AREAS = AREAS-(WID/2.)*(WID/2.)/Z
      IF(WID.GT.ZW) AREAS=0.
      Y4 = (WID/2.)/OZ
      Y5 = YFB-Y4
      AREAR = Y5**2*OZ
      X4 = AMAX1((TOPW-CWID),R2D2)
      Y4 = X4/(OZ+ZZ)
      AREAR = AREAR-Y4*X4
      IF(Y5.LT.0.) AREAR=0.
      Y5 = Y1-(OBMH+OELO)
      IF(Y5.GT.0.) AREAT=Y5*(BERML+BERMR)+Y5**2*ZZ-AREAR
      GO TO 200
C
C
C  COMPUTE AREAS OF CHANNEL BACKFILL
C
  200 AREA4 = AREAR + AREAT + AREAS + AREAM
      TFILL = AREA4 + AREA3
C
C   COMPUTE AREA OF CUT
C
      YBHR = AMIN1(OBMH - (ETR - OELO),OBMH)
      YBHL = AMIN1(OBMH - (ETL - OELO),OBMH)
      CUTL = OBMWL * YBHL + YBHL**2 * (OZ + OZBML) / 2.
      CUTR = OBMWR * YBHR + YBHR**2 * (OZ + OZBMR) / 2.
      CUTT = CUTL + CUTR
C
      IF(NPLUS.EQ.1) CUTT = CUTT + ARECA
      IF(AREA1.LE.0) CUTT = CUTT + ABS(AREA1)
      TCOM = CUTT
      TOLD = CUTT / 1.25
      OHAUL = TFILL - TOLD
C
C   IF OHAUL IS NEGATIVE, EXTRA FILL EXISTS IN THE PRISMATIC AREA.
C
C   CALCULATE DEPTH OF COMPACTED BACKFILL IN OLD CHANNEL PRISM
C
  220 DFILL = (TFILL / AREAC) * ((ETR + ETL)/2. - ELO)
C
C   USE AN ITERATION PROCESS TO CONVERGE UPON THE CORRECT DEPTH
C
  230 YFILL = TFILL / (OBW + DFILL * OZ)
      DFILL = DFILL + (YFILL - DFILL) / 2.
      IF((DFILL-YFILL).LT..05) GO TO 250
      GO TO 230
C
  250 Y98 = ETR - ELO
      Y99 = ETL - ELO
      Y45 = AMIN1(Y98,Y99)
      FAREA = OBW * Y45 + Y45**2 * Z
      IF (YFILL.LE.Y45) GO TO 260
C
      XCEM = TFILL - FAREA
      Y55 = AMAX1(Y98,Y99)
      TWIDT = (CWID + YFB * 2 * ZZ) / 2. + OBW / 2. + Y55 * OZ
      YFILL = Y45 + XCEM / TWIDT
      TWIDH = CWID + YFB * 2 * 7Z
      HFILL = Y45 + XCEM / TWIDH
      IF(HFILL.LT.YFILL) YFILL = HFILL
C
  260 CONTINUE
C
C   CALCULATE THE DEPTH OF THE COMPACTED EMBANKMENT
C
      DTOPD = YFB - (YFILL - (ELO - OELO))
      TCEM = (BERML + BERMR) * DTOPD + DTOPD**2 * (Z + ZZ)
C
C   CONVERT AREAS INTO VOLUMES
C
```

```
      RCOM = TCOM * SLEN / 27.
      ROLD = TOLD * SLEN / 27.
      RFILL = TFILL * SLEN / 27.
      RCEM = TCEM * SLEN / 27.
      RHAUL = OHAUL * SLEN / 27.
      RBERMR = BERMR
      RBERML = BERML
      H5 = Y1 - ETL
      H6 = Y1 - ETR
C
C   RECALCULATE VOLUMES AND AREAS OF EARTH MOVEMENT FOR INLET OF REACH
C
      OELO = OELI
      ETR=ETRI
      ETL=ETLI
      ELO = ELI
      NEX = 1
      GO TO 50
C
  300 OHAUL = OHAUL * SLEN / 27.
      TCOM = TCOM * SLEN / 27.
      TOLD = TOLD * SLEN / 27.
      TFILL = TFILL * SLEN / 27.
      TCEM = TCEM * SLEN / 27.
      IF(RHAUL * OHAUL) 600.400,400
C
C   AVERAGE INLET AND OUTLET VOLUME ESTIMATES.  ADD EXTRA FILL TO
C     COMPACTED EMBANKMENT.  BORROW POSITIVE OHAUL FROM NEGATIVE OHAUL.
C
  400 IF(RHAUL) 500.500,550
  500 TCEM = (TCEM + RCEM) * .5 - (OHAUL + RHAUL) * .5
      OHAUL = 0.
      GO TO 650
C
  550 OHAUL = (OHAUL + RHAUL) * .5
      GO TO 635
C
  600 OHAUL = (OHAUL + RHAUL) * .5
      IF(OHAUL) 625,635,635
C
  625 TCEM = (TCEM + RCEM) * .5 - OHAUL
      OHAUL = 0.
      GO TO 650
C
  635 TCEM = (TCEM + RCEM) * .5
C
  650 TCOM = (TCOM + RCOM) * .5
      TOLD = (TOLD + ROLD) * .5
      TFILL = (TFILL + RFILL) * .5
C
C   ADD 10.0 FEET TO TOTAL WIDTH OF DESIGN CHANNEL SECTION FOR MINIMUM R
C
      AVEROW = BW + AMAX1(H5*(7+ZZ)+RBERML+H6*(Z+ZZ)+RBERMR,
     &(Y1-ETL)*(Z+ZZ)+BERML+(Y1-ETR)*(Z+ZZ)+BERMR) + 10.0
C
      OELO= B
      ELO = D
C
C
      RHAUL=0.
C
C     IF OVERHAUL IS POSITIVE, BORROW REQUIRED FILL BY EXCAVATING ON
C     GRADE ADJACENT TO THE DESIGN CHANNEL.  IF OVERHAUL INTO THE REACH
C     AREA FROM A BORROW AREA IS DESIRED. DELETE THE FOLLOWING THREE
C     STATEMENTS.
C
      RHAUL = OHAUL
      OHAUL = 0.
      TCOM = TCOM + AMAX1(RHAUL.R2D2)
C
C   WRITE OUT TABLE OF EXCAVATION AND FILL VOLUMES
C
      IF(KQ.NE.MAXQ) GO TO 700
      WRITE(6,690) KQ.TCOM,TOLD.TFILL,TCEM,RHAUL,OHAUL.AVEROW
      WRITE(6,695) A,B.C,D
      WRITE(6,698) YFB.BW,SLEN
C
  690 FORMAT(  //,T30.'*****  SUMMARY OF EARTHWORK FOR REHABILATATION OF
     2 THIS REACH *****'.//  T47.' Q = '.I5.' CFS' ////
     3 T15,'COMMON EXCAVATION TOTAL',T50.F10.0.'CU YD'//
     4 T15,'FILL FROM CHANNEL EXCAVATION',T50.F10.0,'CU YD'//
     5 T15,'CHANNEL COMPACTED BACKFILL TOTAL',T50,F10.0,'CU YD'//
     6 T15,'COMPACTED EMBANKMENT TOTAL',T50,F10.0.'CU YD'//
     7 T15.'FILL FROM ADJACENT EXCAVATION',T50.F10.0,'CU YD'//
     8 T15,'OVERHAUL',T50,F10.0.'CU YD'//
     8 T15,'AVERAGE MINIMUM RIGHT OF WAY',T50.F10.0.'FEET'//)
  695 FORMAT(T15,'OLD INLET AND OUTLET ELEV',T50.F10.1,2X.F10.1.' FEET'/
     2 T15,'DESIGN INLET AND OUTLET ELEV',T50,F10.1.2X.F10.1,' FEET'//)
  698 FORMAT(//T15.'DESIGN DEPTH OF CHANNEL'.T50,F10.1,' FEET'/
     2 T15.'DESIGN WIDTH OF CHANNEL'.T50,F10.1.' FEET'/
     3 T15,'LENGTH OF REACH'.T50.F10.0.' FEET'/)
  700 RETURN
      END
```

```
      SUBROUTINE TUNNEL(WR,SI,CI,EI,EL,DIA,LEN,NP,NUM)
C
C       APPRAISAL COST OF DRILL AND BLAST FREE FLOW TUNNELS
C
C       06-03-77
C
C       CALL TUNNEL (WAGE,STEEL,CONC,EQUIP,ELEV,DIAM,LENGTH,NPORT,ICOST)
C
C       JIM POOL -- CODE ER-1432 -- 234-3064
C
      DIMENSION Q(4),P(4)
      NPORT =NP
      IF(NPORT.NE.1) NPORT = 2
      HF = LEN / 105600. / NPORT + 178.1472 * NPORT / LEN + .91695
      EF = 1.023 - .001105 * SQRT(EL) + .4294E-4 * EL
C
C       EXCAVATION
C
      R = .0423 * DIA* DIA+ .88
      P(1) = 58.33 * R**(-.713 + .09724* ALOG(R))*(WR +3.6 *EI)/6. *
     @EF *HF
      Q(1) = R * LEN
C
C       LINING
C
      R = (.0074 * DIA + .1152) * DIA + .16
      P(2) = (17.5 + 33560. * DIA**(-8.769 + 3.277 * ALOG(DIA) -
     @ .365 * ALOG(DIA)**2.) / R) * (WR + .88 * EI) / 4.15 *
     @ EF * HF + 5.64 * CI
      Q(2) = R * LEN
C
C       SUPPORTS
C
      R = (1.1745 * DIA - 7.086) * DIA + 44.68
      P(3) = (.16 * SI + .01 * WR) * 1.35 * HF * R * LEN
      Q(3) = 1.
C
C       PORTALS
C
      P(4) = .9391E-15 * DIA**(48.62 - 16.82 * ALOG(DIA) +
     @ 1.948 * ALOG(DIA) * ALOG(DIA)) * (WR * .88 * EI) / 4.15
      Q(4) = 1.
C
C       TOTAL COST
C
      R =0.
      DO 100 I =1,4
        CALL ROUND (P(I))
        CALL ROUND (Q(I))
      R = R + P(I) * Q(I)
  100 CONTINUE
      R = R * 1.375
        CALL ROUND (R)
      NUM=R +.001
      RETURN
      END
```

```
C          DATA SET WIRPIPE     AT LEVEL 028 AS OF 01/05/78
C      MAIN PROGRAM PIPE......COMPUTES COSTS OF IRRIGATION PIPE SYSTEMS
C
       DIMENSION A(50)
       COMMON UEXC, UEXST, UEXSI, UEXPT, UERC, UERST, UERSI, UERPT,
      &UBACK, UBFST, UBFSI, UBFPT,UPREP, UCOMP, UCOMB,  CLN, CNSTR,
      &CNSIP, USTEL, UHAUL, IREHAB
    10 FORMAT(/,' THIS PROGRAM COMPUTES PIPE SYSTEMS COSTS'/
      ')
    12 FORMAT(/,' TYPE UNIT COST OF EXCAVATION FOR THE FF ITEMS:'/
      '' 1-COMMON, CANAL, $/CY'/
      '' 2-COMMON, STRUCTURES,$/CY'/
      '' 3-COMMON, SIPHON, $/CY'/
      '' 4-PIPE TRENCH, $/CY'/
      '' 5-ROCK, CANAL, $/CY'/
      '' 6-ROCK, STRUCTURE, $/CY'/
      '' 7-ROCK, SIPHON, $/CY'/
      '' 8-ROCK, PIPE TRENCH, $/CY'/)
    14 FORMAT(/,' TYPE THE FF UNIT COSTS:'/
      '' 1-BACKFILL, CANAL,(COMPACTED  BOTTOM FILL FOR REHAB OF CANAL'/
      '    ' TO PIPE SYSTEM, $/CY'/
      '' 2-BACKFILL, STRUCTURES, $/CY'/
      '' 3-BACKFILL, SIPHON,$/CY'/
      '' 4-BACKFILL, PIPE TRENCH, $/CY'/
      '' 5-BED PREPARATION, CANAL LINING, $/CY'/
      '' 6-COMPACTING EMBANKMENT, $/CY'/
      '' 7-COMPACTING BACKFILL, $/CY'/
      '' 8-OVERHAUL, $/YD-MI'/)
    16 FORMAT(/,' TYPE THE FF UNIT COSTS:'/
      '' 1-CONCRETE IN CANAL LINING, $/CY'/
      '' 2-CONCRETE IN STRUCTURES, $/CY'/
      '' 3-CONCRETE IN SIPHON, $/CY'/
      '' 4-STEEL, $/LB'/)
    18 FORMAT(//,' THIS PROGRAM IS TERMINATED SUCCESSFULLY'///
      '' THE OUTPUT OF THIS PROGRAM IS OBTAINED AT THE '/
      '' TERMINAL - DATA 100 LINE PRINTER'///
      '' GOODLUCK------------BYE.............'/)
   200 FORMAT(1H1,//////////,T40,'OUTPUT OF PROGRAM ''PIPCST'' '//
      'T40,'COST OF PIPE DISTRIBUTION SYSTEM'/)
   412 FORMAT(//,'  TYPE ONE OF THE FOLLOWING SYMBOLS TO DESCRIBE THE'/
      '' PLANNING CODE:'/
      ''     (0)---PIPE IS TO BE PLACED IN NATURAL, UNDISTURBED TERRAIN'/
      ''     (1)---PIPE IS TO REPLACE AN EXISTING UNLINED CHANNEL'/
      ''            (I.E., PIPE WILL BE PLACED DIRECTLY IN OLD CHANNEL,'/
      ''             ALONG WITH THE REQUIRED EXCAVATION AND BACKFILL.'/)
C
       WRITE(9,10)
       WRITE(9,412)
       CALL INPUT (A,JL)
       IREHAB = A(1)
       WRITE(9,12)
       CALL INPUT(A,NX)
       UEXC = A(1)
       UEXST = A(2)
       UEXSI = A(3)
       UEXPT = A(4)
       UERC = A(5)
       UERST = A(6)
       UERSI = A(7)
       UERPT = A(8)
       WRITE(9,14)
       CALL INPUT(A,NY)
       UBACK = A(1)
       UBFST = A(2)
       UBFSI = A(3)
       UBFPT = A(4)
       UPREP = A(5)
       UCOMP = A(6)
       UCOMB = A(7)
       UHAUL = A(8)
       WRITE(9,16)
       CALL INPUT(A,NZ)
       CLN = A(1)
       CNSTR = A(2)
       CNSIP = A(3)
       USTEL = A(4)
       WRITE(6,200)
       CALL PIPCST
       WRITE(9,18)
       STOP
       END
```

```
C     SUBROUTINE PIPCST.......CALLED BY WRDPIPE  (MAIN)
C    SUBROUTINE PIPCST CALCULATES THE ANNUAL COST OF A PIPELINE
C    IN RELATION TO THE FLOW RATE OF WATER CONVEYED
C
      SUBROUTINE PIPCST
C     LIST,NONE
C
      COMMON UEXC, UEXST, UEXSI, UEXPT, UERC, UERST, UERSI, UERPT,
     +UBACK, UBFST, UBFSI, UBFPT, UPREP, UCOMP, UCOMB, CLN, CNSTR,
     +CNSIP, USTEL, UHAUL, IREHAB, DPFILL
      INTEGER SZE
C
      DIMENSION A(50),SZE(80),TAC(500),QT(500)
      DIMENSION TACT(500),QX(500),TSZ(500),TNO(500)
      DIMENSION XSTA2(100),XGLE(100),XPGE(100)
      DIMENSION TITLE(17),TPCST(4)
      DIMENSION TYPEP(3),TYPEQ(3),PIPCTG(4),CPIP(4)
      DATA CN1,CN2,SYS1/4HEND ,4HSKIP,4HGRAV/
      DATA TYPEP/4HCONC,4HSTEE,4HPVC /
      DATA TYPEQ/4HRETE,4HL   ,4H    /
      KXQ=0
C
  500 FORMAT(/,'    TYPE THE FF INFORMATION:'/
     ''  ''READ---GRAVITY PIPE''...THEN REACH IDENTIFIER  OR'/
     ''  ''READ---HIGH PRESSURE PIPE''  '/
     ')
  502 FORMAT(/,' TYPE THE FF DATA FOR CONCRETE PIPE:'/
     '' 1-WAGE RATE FOR PIPE LAYER'/
     '' 2-EQUIPMENT INDEX, BASE IS 1976'/
     '' 3-AREA FACTOR'/
     '' 4-HAUL DISTANCE OF PIPE FOR UP TO 150 FT HEAD'/
     '' 5-HAUL DISTANCE OF PIPE OVER 150 FT HEAD'/
     '' 6-CODE FOR TYPE OF COVER:'/
     ''        (1)  A  COVER - 5 FT '/
     ''        (2)  B  COVER - 10 FT '/
     ''        (3)  C  COVER - 15 FT'/
     ''        (4)  D  COVER 20 - FT'/
     '' 7-COST INDEX FOR PIPE DIST. SYSTEM, BASE IS 1976'/
     '' 8-DEPTH OF BACKFILL OVER TOP OF PIPE, FT'/
     '' 9-HEAD CLASS (IN FEET) OF CONCRETE PIPE'/)
  504 FORMAT(/,' TYPE TE FF DATA:'/
     '' 1-CONTINGENCY COST FOR EARTHWORK, PERCENT'/
     '' 2-CONTINGENCY COST FOR STEEL RESERVOIR, PERCENT'/
     '' 3-CONTINGENCY COST FOR R O W. PERCENT'/
     ''   CONTINGENCY COST FOR PIPES,VALVES,ETC,PERCENT FOR:'/
     ''   4-CONCRETE PIPE'/
     ''   5-STEEL PIPE'/
     ''   6-PVC PIPE'/
     '' 7-HEAD CLASS DESIRED FOR PVC PIPE '/
     ''    TYPE:'
     ''   1 FOR  63 PSI BELL END'/
     ''   2 FOR 125 PSI BELL END'/
     ''   3 FOR 160 PSI BELL END'/)
  506 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-LIFE OF PROJECT, YEARS'/
     '' 2-INTEREST RATE, PERCENT'/
     '' 3-SALVAGE VALUE, PERCENT OF THE ORIGINAL COST'/)
  508 FORMAT(/,' TYPE DATA FOR ELEVATED TANK'/
     '' (IF NO STEEL TANK IS DESIRED, TYPE---0., 0., 0., 0.)'/
     '' 1-TOWER HEIGHT, FT'/
     '' 2-MINIMUM *Q* OF TANK, CFS'/
     '' 3-MAXIMUM *Q* OF TANK, CFS'/
     '' 4-*Q* INTERVAL'/)
  510 FORMAT(/,'  >>>AT THIS POINT, DATA  RE FOR SPECIFIC REACH ONLY>>>'
     '' ...THIS IS---',18A4/)
  511 FORMAT(/,' TYPE THE FF DATA FOR THIS REACH'/
     '' 1-LENGTH OF REACH, FT'/
     '' 2-HGL ELEVATION AT PIPE OUTLET, FT'/
     '' 3-ELEVATION AT PIPE OUTLET, FT'/
     '' 4-HGL ELEVATION AT PIPE INLET, FT'/
     '' 5-ELEVATION AT PIPE INLET, FT'/)
  512 FORMAT(/,' TYPE THE FF DATA:'/
     '' 1-WIDTH OF EASEMENT, FT'/
     '' 2-VALUE OF EASEMENT FOR CROPPED LAND, $/AC'/
     '' 3-VALUE OF EASEMENT FOR OTHER LAND, $/AC'/
     '' 4-LENGTH OF OTHER EASEMENT, PERCENT OF TOTAL LENGTH'/
     '' 5-ROCK EXCAVATION, PERCENT OF COMMON EXCAV.'/
     '' 6-DISTANCE TO BORROW AREA (COMMON),MILES'/)
  513 FORMAT(/,' TYPE NUMBER AND CORRESPONDING SIZES OF T.O.(INCHES)'/)
  514 FORMAT(/,' TYPE DATA FOR PIPE TRENCH:'/
     '' 1-STATION, FEFT'/
     '' 2-GROUND LINE ELEVATION OF STATION, FT'/
     '' 3-PROFILE GRADE ELEVATION OF STATION, FT'/
     ''  (TO END STATION DATA---TYPE  0.,0.,0.)'///
     '' -----------START TYPING STATION DATA----------'/)
```

```
  516 FORMAT (' TYPE MOPE STATION DATA')
  518 FORMAT(/,'  ----------END OF STATION DATA----------'/)
  520 FORMAT(/,' TYPE MINIMUM Q(CFS), MAXIMUM Q(CFS), AND'/
     '' ''Q'' INTERVAL'/)
  522 FORMAT(/,'  >>>>> END DATA FOR THIS REACH <<<<<'//)
  524 FORMAT(/,'  ARE THERE SOME MORE REACH TO PROCESS ------'/
     '' IF ''NO'' TYPE... ''END DATA'' '/
     '' IF ''YES'' TYPE... ''SKIP---GRAVITY PIPE'' OR'/
     ''            TYPE... ''SKIP---HIGH PRESSURE PIPE'' '/)
  526 FORMAT(/,' TYPE CODE FOR TURNOUTS:'/
     ''        (0) T.O. - NO PRESSURE REGULATING VALVE'/
     ''        (1) T.O. - WITH PRESSURE REGULATING VALVE'/
     '' ALSO TYPE MISCELLANEOUS COSTS FOR ADDITIONAL TURNOUT ITEMS,'/
     ''     (SUCH AS BUTTERFLY VALVES,METERS,ETC). ENTER $ 0.00 IF NO'/
     ''      ADDITIONAL ITEMS ARE REQUIRED'/)
C
C   READ IN CONTROL FOR PROPER BRANCHING AND A TITLE
C   IF THE WORD BEGINNING IN COLUMN 1 IS:
C        'READ'  CONTROL IS SHIFTED TO STATEMENT 5
C        'SKIP'  CONTROL IS SHIFTED TO STATEMENT 3
C        'END'   CONTROL IS SHIFTED TO STATEMENT 98
C         NOTE:  THE SKIP CONTROL IS USED TO MINIMIZE THE ENTRY OF
C                REDUNDANT DATA.  STATEMENT 3 IS A 'CONTINUE'
C                STATEMENT THAT MAY BE MOVED IF DESIRED.
C   THE TITLE BEGINS IN COLUMN 8
      WRITE(9,500)
    1 CONTINUE
      READ (5,150) CON,SYS, TITLE
  150 FORMAT (A4,3X,A4,17A4)
      IF (CON.EQ.CN1) GO TO 98
      IF (CON.EQ.CN2) GO TO 3
    5 CONTINUE
C
C
C---SET UP RANGE  OF DIAMETER CONSIDERED
C   MINIMUM DIA IS 4 INCHES
C   MAXIMUM DIA IS 120 INCHES
C   INCREMENT USED -- EVERY 2 INCHES
      KB = 0
C
      DO 6 K= 4,120,2
      KB = KB + 1
      SZE(KB) = K
    6 CONTINUE
      N = (120-4)/2
C
C   READ DATA FOR COMPUTING CONCRETE PIPE COST
C   USE U.S.B.R.  SUBROUTINE 'PIPER' IN COMPUTING COST
C   INPUT DATA NEEDED ARE:
C      WAGE = WAGE RATE
C     EQUIP = EQUIPMENT INDEX
C     AREA = AREA FACTOR
C     IHAUL1= HAUL DISTANCE UP TO 150 FEET HEAD
C     IHAUL2= HAUL DISTANCE OVER 150 FEET HEAD
C     ICODE = TYPE OF COVER
C        1---A COVER (5 FT)
C        2---B COVER (10 FEET)
C        3---C COVER (15 FEET)
C        4---D COVER (20 FEET)
C      CIDX = COST INDEX FOR PIPE SYSTEMS---BASE IS 1976
C      DPFILL = DEPTH OF FILL OVER TOP OF PIPE IN TRENCH
      WRITE(9,502)
C
      CALL INPUT(A,NY)
      WAGE = A(1)
      EQUIP = A(2)
      AREA = A(3)
      IHAUL1 = A(4)+.0001
      IHAUL2 = A(5)+.0001
      ICODE =  A(6)+.0001
      CIDX = A(7)
      DPFILL = A(8)
      AHEAD = A(9)
C-----READ PERCENT CONTINGENCIES AND COST INDEX
      WRITE(9,504)
C
      CALL INPUT(A,KT)
C
C        * TRNCTG = PERCENT CONTINGENCY COST FOR EARTHWORK
C        * STCNTG = PERCENT CONTINGENCY COST FOR STEEL RESERVOIR
C        * RWCNTG = PERCENT CONTINGENCY COST FOR RIGHT OF WAY
C        * PIPCTG = PERCENT CONTINGENCY COST FOR PIPES,VALVES,ETC.
C
      TRNCTG = A(1)
```

```
      RWCNTG = A(3)
      PIPCTG(1)=A(4)
      PIPCTG(2)=A(5)
      PIPCTG(3)=A(6)
      ICLP = A(7)
C
C-----READ LIFE OF PROJECT,INTEREST,SALVAGE VALUE
      WRITE(9,506)
C
      CALL INPUT(A,NR)
C
C       * TLFE  = LIFE OF PROJECT, YEARS
C       * RINT  = INTEREST RATE, PERCENT
C       * SVAL  = SALVAGE VALUE, PERCENT
C
      TLFE = A(1)
      RINT = A(2) * .01
      SVAL = A(3)
C
C-----READ DATA FOR ELEVATED STEEL TANK (RESERVOIR - FOR PRESSURE PIPE)
C     IF NO STEEL TANK IS DESIRED - INPUT ZERO
      WRITE(9,508)
C
      CALL INPUT(A,NST)
C       * H = TOWER HEIGHT,FEET
C
      H = A(1)
      KNTQ = A(4)
      MAXQ = A(3)
      MINQ = A(2)
C
C-----AT THIS POINT, COMPUTE COST OF TANK/RESERVOIR
C
      IF(H.EQ.0.)GO TO 3
C
C-----FIRST,COMPUTE SIZE OF TANK NEEDED,IN GALLONS
C     USE SIZING GUIDE CURVES DEVELOPED BY U.S.B.R.
      NCT=0
      WRITE(6,170)
      DO 127 KR=MINQ,MAXQ,KNTQ
      NCT = NCT + 1
      Q = KR
      QX(NCT) = Q
C
      GAL = (3.05 * Q + 20.) * 1000.
C
C-----FIND WEIGHT OF STEEL TANK WITHOUT TOWER
C
      IF(GAL.GT.225000.) GO TO 156
C
      TANKW =(0.27 *GAL+ 17000.)
      GO TO 158
  156 TANKW =(0.16 *GAL+ 102000.)
C
  158 CONTINUE
C
C --- FIND WEIGHT OF TOWER --DEPENDENT ON  TOWER HEIGHT  AND  CAP
C     USE CURVES-DEVELOPED BY USBR
C
      IF(GAL.LE.50000.)W =378.*H -20000.
      IF(GAL.GT.50000.AND.GAL.LE.75000.)W =(378.*H+740.*H-55000.)/2.
      IF(GAL.GT.75000.AND.GAL.LE.100000.)W =740.*H-35000.
      IF(GAL.GT.100000.AND.GAL.LE.125000.)W =(740.*H+963.*H-82500.)/2.
      IF(GAL.GT.125000.AND.GAL.LE.150000.)W =(963.*H-47500.)
      IF(GAL.GT.150000.AND.GAL.LE.175000.)W =(963.*H+1214.*H-102500.)/2.
      IF(GAL.GT.175000.AND.GAL.LE.200000.)W=1214.*H-55000.
      IF(GAL.GT.200000.AND.GAL.LE.250000.)W=(1214.*H+1533.*H-119000.)/2.
      IF(GAL.GT.250000.AND.GAL.LE.300000.)W=1533.*H-64000.
      IF(GAL.GT.300000.AND.GAL.LE.350000.)W=(1533.*H+1686.*H-109000.)/2.
      IF(GAL.GT.350000.AND.GAL.LE.400000.)W=1686.*H-45000.
      IF(GAL.GT.400000.AND.GAL.LE.450000.)W=(1686.*H+1937.*H-84000.)/2.
      IF(GAL.GT.450000.AND.GAL.LE.500000.)W=1937.*H+39000.
      IF(GAL.GT.500000.AND.GAL.LE.550000.)W=(1937.*H+2223.*H-79000.)/2.
      IF(GAL.GT.550000.AND.GAL.LE.600000.)W=2223.*H-40000.
      IF(GAL.GT.600000.AND.GAL.LE.650000.)W=(2223.*H+2630.*H-89700.)/2.
      IF(GAL.GT.650000.AND.GAL.LE.700000.)W=2630.*H-49700.
      IF(GAL.GT.700000.AND.GAL.LE.750000.)W=2829.*H-45000.
      IF(GAL.GT.750000.AND.GAL.LE.875000.)W=(2829.*H+3765.*H-85000.)/2.
      IF(GAL.GT.875000.AND.GAL.LE.1000000.)W=3765.*H-40000.
      IF(GAL.GT.1000000.)GO TO 161
  160 FORMAT(/,T15,'SORRY,THE  TANK CAPACITY IS OUT OF RANGE FOR Q >',
     *F4.0,' CFS',///)
      GO TO 176
  161 NCT = NCT - 1
      WRITE(6,160)Q
```

```
      GO TO 227
C
C---- COMPUTE COST OF STEEL
C
  176 STELCS = (TANKW + W) * USTEL
C
C---- ADD  10 PERCENT   FOR FOUNDATION,ROW,MANIFOLDING
C
      TNKCT  = STELCS +  STELCS * .10
C
C---- ADD  5  ALLOWANCE FOR UNLISTED ITEMS
C
      TNKCT  = TNKCT  + TNKCT  * 0.05
C-----ADD CONTINGENCY COST
      TNKCT = TNKCT + TNKCT * STCNTG
C
C-----COMPUTE ANNUAL COST EQUIVALENT
C
      TANC =  TNKCT * (RINT*(1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.)
     & - SVAL *0.01 * TNKCT *RINT/(((1.+RINT)**TLFE)-1.)
C
      TACT(NCT) = TANC
C-----WRITE RESULTS
C
  170 FORMAT(1H1,//,T47,' COST OF STEEL TANK'////
     &6X,'Q             CAPACITY          WT OF TANK        HT OF TOWER       WT
     & OF TOWER          COST OF STEEL  TOTAL COST 1/     ANNUAL COST'/
     &4X,'(CFS)           (GAL)               (LB)              (FT)
     &    (LB)               ($)               ($)            ($/AN)'//)
C
      WRITE(6,172)Q,GAL,TANKW,H.W,STELCS.TNKCT,TACT(NCT)
  172 FORMAT(F9.0.F15.0,4F18.0.2F15.0)
C
  127 CONTINUE
C
  227 WRITE(6,174)STCNTG
  174 FORMAT(T15,'N O T E : ' //
     &T17,'1/ TOTAL COST INCLUDES:  10.0   FOR FOUNDATION.VALVES,ETC.'/
     &T17,'                          5.0   FOR UNLISTED ITEMS'/
     &T42,F4.1,                       '    FOR CONTINGENCIES'/)
C
      CALL REGLIN(QX,TACT.NCT.AC.BC,R)
C
    3 CONTINUE
C
C---- READ DATA FOR SPECIFIC SEGMENT/REACH
C
C---- READ SECTION LENGTH,ELEVATION AND HYDRAULIC  HEADS
      WRITE(9.510)SYS.TITLE
      WRITE(9,511)
C
      CALL INPUT(A,NL)
C
C   READ IN SECTION LENGTH AND THE ELEVATION AND HYDRAULIC
C   HEAD AT THE SECTION OUTLET AND INLET
C          SLEN = LENGTH OF SECTION IN FEET
C          ELO = ELEVATION IN FEET AT PIPE OUTLET
C          ELI = ELEVATION IN FEET AT PIPE INLET
C          HGLO = HYDRAULIC G.L. REQ. IN FEET AT PIPE OUTLET
C          HGLI = HYDAULIC G.L. REQ. IN FEET AT PIPE INLET
      SLEN = A(1)
      HGLO  = A(2)
      ELO  = A(3)
      HGLI  = A(4)
      ELI  = A(5)
C
C   READ IN PIPE TYPE
C
      WRITE(9,530)
  530 FORMAT(5X,'ENTER THE TYPE OF PIPE DESIRED FOR THIS REACH:'/
     '' TYPE:'/
     ''    1 FOR CONCRETE'/
     ''    2 FOR STEEL (AWWA TAR COAT)'/
     ''    3 FOR PVC (4 TO 14 INCH DIAM)'/
     ''    4 PROGRAM WILL SELECT THE LEAST COST PIPE TYPE (1,2,OR 3).'/)
C
      CALL INPUT(A.NL)
      PIPE = A(1)
C
      WRITE(9,620)
  620 FORMAT(/,'    TYPE WATER HAMMER FACTOR - FOR HEAD CLASS SELECTION'/
     '' TYPE..  1.0 WHEN NO H.C. INCREASE IS DESIRED'/
     ''         1.5 WHEN 50 PERCENT H.C. INCREASE IS DESIRED, ETC.'/)
C
```

```
      WHF = A(1)
C
C-----READ DATA ON RIGHT OF WAY
      WRITE(9,512)
C
      CALL INPUT(A,NR)
C
C       ' RWID = WIDTH OF EASEMENT
C       ' RVAL = VALUE OF EASEMENT FOR CROPPED LAND
C       ' ROVAL= VALUE OF EASEMENT FOR OTHER  LAND
C       ' PERD = PERCENT OF LENGTH FOR OTHER LAND
C       ' PERK = PERCENT OF ROCK EXCAVATION
C       ' XBOR = DISTANCE OF BORROW AREA FROM REACH
C
      RWID = A(1)
      RVAL = A(2)
      ROVAL= A(3)
      PERD = A(4)
      PERK = A(5) / 100.
      XBOR = A(6)
C
C-----READ CODE FOR TURNOUT
C         1-NO PRESSURE REGULATING VALVE
C         2-WITH PRESSURE REGULATING VALVE
C-----READ MISCELLANEOUS TURNOUT COSTS
C
      WRITE(9,526)
      CALL INPUT(A,NZZ)
      CDPV = A(1)
      TMISC = A(2)
      WRITE(9,513)
C
C-----READ THE NUMBER AND CORRESPONDING SIZE OF TURNOUTS
      CALL INPUT(A,NT)
C
      DO 10 K=2,NT,2
      TNO(K/2) = A(K-1)
   10 TSZ(K/2) = A(K)
      NT=NT/2
C
C-----DETERMINE IF THIS PROJECT IS A REHABILITATION (LAYING PIPE IN
C     EXISTING CHANNEL)
C
      IF(IREHAB.GT.0) GO TO 302
C
C---READ DATA FOR PIPE TRENCHING
      WRITE(9,514)
C
      KM = 0
  331 KM = KM + 1
      IF(KM.GT.1)WRITE(9,516)
      CALL INPUT(A,NS)
      XSTA2(KM) = A(1)
      XGLE(KM) = A(2)
      XPGE(KM) = A(3)
      IF(XGLE(KM).NE.0.)GO TO 331
      WRITE(9,518)
      GO TO 398
  324 FORMAT(/,' TYPE DATA FOR OLD CHANNEL PRISM'/
     '' DATA ARE TO BE REPRESENTATIVE OF THE ENTIRE REACH:'/
     '' 1-BASE WIDTH OF OLD CHANNEL'/
     '' 2-INSIDE SIDE SLOPE (AVE) OF OLD CHANNEL'/
     '' 3-AVERAGE RELATIVE HEIGHT OF BERMS ABOVE OLD CHANNEL BOTTOM'/
     '' 4-AVERAGE TOP WIDTH OF BERM ON LEFTSIDE OF CHANNEL (FACING',
     '' UPSTREAM)'/
     '' 5-AVERAGE TOP WIDTH OF BERM ON RIGHTSIDE OF CHANNEL'/
     '' 6-AVERAGE SIDESLOPE OF OUTSIDE OF LEFTSIDE BERM'/
     '' 7-AVERAGE SIDESLOPE OF OUTSIDE OF RIGHTSIDE BERM'/
     '' 8-ELEV OF NATURAL TERRAIN TO LEFT  OF REACH INLET'/
     '' 9-ELEV OF NATURAL TERRAIN TO RIGHT OF REACH INLET'/
     ''10-ELEV OF NATURAL TERRAIN TO LEFT  OF REACH OUTLET'/
     ''11-ELEV OF NATURAL TERRAIN TO RIGHT OF REACH OUTLET'/
     ''12-WIDTH OF PRESENT RIGHT OF WAY'/
     ''13-ELEV OF OLD CHANNEL BOTTOM AT INLET'/
     ''14-ELEV OF OLD CHANNEL BOTTOM AT OUTLET'/)
  302 WRITE (9,324)
      CALL INPUT (A,NOLD)
      OBW = A(1)
      OZ  = A(2)
      OBMH = A(3)
      OBMWL = A(4)
      OBMWR = A(5)
      OZBML = A(6)
      OZBMR = A(7)
```

```
      ETLI  = A(8)
      ETRI  = A(9)
      ETLO  = A(10)
      ETRO  = A(11)
      OLROW = A(12)
      OELI  = A(13)
      OELO  = A(14)
C
C-----READ RANGE OF DISCHARGE UNDER CONSIDERATION
  398 WRITE(9,520)
C
      CALL INPUT(A,NL)
C
      MINQ = A(1)
      MAXQ = A(2)
      KNTQ = A(3)
C
C-----COMPUTE COSTS FOR THE RANGE OF DISCHARGES
      WRITE(9,522)
C
      NQ=0
      WRITE(6,260)SYS,TITLE
C-----WRITE TITLE
C
      WRITE(6,401)
  401 FORMAT(4X,'Q      DIAMETER   LENGTH     PIPE COST 1/    TURNOUTS 2/
     &RIGHT OF WAY       EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TY
     &PE'
     & /' (CFS)        (IN)         (FT)           ($)                ($)
     &($)                    ($)              ($)              ($)'/)
C
      DO 49 KQ=MINQ.MAXQ.KNTQ
      NQ = NQ + 1
      Q=KQ
C   DETERMINE MAXIMUM HYDRAULIC GRADIENT
      DH = HGLI - HGLO
C
C-----COMPUTE PIPE DIAMETER USING SCOBEY'S EQUATION FOR CONCRETE AND
C     STEEL AND HAZEN-WILLIAM'S EQUATION FOR PVC.
C
C-----FOR CONCRETE DIAMETER:     < 24 IN. --USE CS = 0.345
C                                > 23 IN. --USE CS = 0.370
C                                   STEEL --USE CK = 0.320
C
C     COMPUTE HEADLOSS IN FEET/1000. FT LENGTH
C
      SL = DH / SLEN  * 1000.
C
      CS = 0.370
      CK = 0.320
      CP = 150.
C
      DIAC = (Q / (.00545 * CS * SL**(1./2.0)))**(1./2.625)
      DIAS = (Q * 770.86 * CK**.5263/SL**.5263)**(1./2.58)
      DIAP = 68.5888 * ((Q / CP)**1.852/SL)**(1./4.8655)
C
      IF(DIAC.GE.24.)GO TO 202
      CS = 0.345
      DIAC = (Q / (.00545 * CS * SL**(1./2.0)))**(1./2.625)
  202 CONTINUE
      DO 16 NRC = 1,3
      DIA = DIAC
      IF(NRC.GT.1) DIA=DIAS
      IF(NRC.GT.2) DIA=DIAP
      DO 15 NK=1.N
      IF(DIA.GT.SZE(NK))GO TO 9
      IF(NK.EQ.1)GO TO 12
      BP = SZE(NK-1) + 0.3*(SZE(NK)-SZE(NK-1))
      IF(DIA-BP)11.12.12
   11 IDA = NK - 1
      GO TO 20
   12 IDA = NK
      GO TO 20
    9 IF(NK.EQ.N)GO TO 50
   15 CONTINUE
C-----COMPUTE PIPE TRENCH COST
   20 CONTINUE
      IF(NRC.EQ.1) IDIAC=SZE(IDA)
      IF(NRC.EQ.2) IDIAS=SZE(IDA)
      IF(NRC.EQ.3) IDIAP=SZE(IDA)
   16 CONTINUE
C
      IF(KQ.EQ.MAXQ)WRITE(6,403)
C
C
```

```
C
C-----SELECT TYPE OF COVER
C
      ICOVER = ICODE
C
      XHEAD = ((HGLI-ELI)+(HGLO-ELO))/2.
      XHEAD = XHEAD * WHF
  557 IHEAD = XHEAD
      IF(XHEAD.LE.AHEAD) IHEAD=AHEAD
C
C-----USE USBR SUBROUTINE *PIPER* TO COMPUTE CONCRETE PIPE COST
C
      NPIPE = PIPE + .0001
  110 IF(NPIPE.EQ.2.OR.NPIPE.EQ.3) GO TO 700
      IDIAM = IDIAC
      CALL PIPER(WAGE,EQUIP,AREA,IHAUL1,IHAUL2,IDIAM,ICOVER,IHEAD,COST)
C
      TPCST(1) = SLEN * COST
C
  700 IF(NPIPE.NE.2.AND.NPIPE.NE.4) GO TO 720
      CALL SPIPE(IDIAS,COST)
      TPCST(2) = COST * SLEN
  720 IF(NPIPE.LT.3) GO TO 735
      CALL PPIPE(IDIAP,ICLP,COST,NPIPE)
      TPCST(3) = COST * SLEN
      IF(NPIPE.NE.5) GO TO 730
      NPIPE = 4
      GO TO 110
  730 CONTINUE
C
C-----COMPUTE COST OF FITTINGS,VALVES,BLOCKING,ETC.
C
C      USE XX.X PERCENT OF TOTAL PIPE COST
C
  735 DO 740 IPQ=1,3
      FVCST = TPCST(IPQ)*PIPCTG(IPQ)/100.
C     ADD 5 % COSTS FOR UNLISTED ITEMS
      CPIP(IPQ) = TPCST(IPQ)*1.05 + FVCST
  740 CONTINUE
      IF(NPIPE.GT.3) GO TO 750
      CPIPE = CPIP(NPIPE)
      NPTP = NPIPE
      GO TO 760
  750 CPIPE = CPIP(1)
      NPTP = 1
      IF(CPIP(2).LT.CPIPE) NPTP=2
      IF(NPTP.EQ.2) CPIPE=CPIP(2)
      IF(CPIP(3).LT.CPIPE) NPTP=3
      IF(NPTP.EQ.3) CPIPE=CPIP(3)
  760 CONTINUE
      IF(NPTP-2) 761,762,763
  761 IDIAM=IDIAC
      GO TO 765
  762 IDIAM=IDIAS
      GO TO 765
  763 IDIAM=IDIAP
  765 CONTINUE
C
C-----COMPUTE COST OF TURNOUTS
C
C     TEST WHETHER GRAVITY PIPE OR PRESSURE PIPE
      XDIAM=IDIAM
C
      CSTO = 0.
      IF(SYS1.EQ.SYS) GO TO 151
C
C-----COST OF PRESSURE PIPE TURNOUTS
C     TURNOUT UNIT INCLUDES:
C              (1) GATE VALVE OR BUTTERFLY VALVE
C              (2) LINE METER
C              (3) PRESSURE REDUCING VALVE
C              (4) STEEL PIPE DELIVERY
C              (5) ROADWAY BOX
C              (6) CONCRETE PIPE ERECTED VERTICALLY
C
C-----TEST WHETHER PRESSURE REGULATING VALVE IS DESIRED
C     CODE USED:
C              (0) NO PRESSURE REGULATOR
C              (1) WITH PRESSURE REGULATOR
C
      IF(CDPV.LE..1) GO TO 152
C
C-----COST OF T.O. WITH PRESSURE REGULATOR
      DO 165 J=1,NT
```

```
  165 CONTINUE
      GO TO 154
C-----COST OF T.O. WITHOUT PRESSURE REGULATOR
  152 DO 166 JJ=1,NT
      CSTO = CSTO+TNO(JJ)*560.*TSZ(JJ)**0.883
  166 CONTINUE
      GO TO 154
C
C-----COST OF T.O. FOR GRAVITY PIPE
  151 DO 167 JK=1,NT
      CSTO = CSTO+TNO(JK)*1025.*TSZ(JK)**.2900
  167 CONTINUE
  154 CSTO = (CSTO+TMISC)*CIDX
C---COMPUTE TRENCHING COST USING USBR PROGRAM *EARTH2*
C
      RELO=ELO
      JWYATT=5
      CALL EARTH2(XDIAM.XSTA2.XGLE.XPGE.TEXC.TCBF,TBF,SLEN,
     *KQ.MAXQ,CBF,IREHAB.OBW.OZ.OBMH,OBMWL.OBMWR,OZBML,OZBMR.ETLI,ETRI,
     &ETLO,ETRO,OELI.OELO.ELI,ELO,THAUL.NPTP,TEXCO,DPFILL)
      ELO=RELO
C   COST OF COMMON EXCAVATION
      EXC = TEXC * UEXPT + TEXCO * UEXC
C---COST OF ROCK EXCAVATION
      EXR = TEXC*PERK*UERPT
C---COST OF BACKFILL
      BCST = TBF * UBFPT
      CBCST =CBF * UBACK
C---COST OF COMPACTING BACKFILL
      CPCST = TCBF * UCOMB
C---TOTAL EARTHWORK COST
      CHAUL = THAUL * UHAUL * XBOR
      TERT  = EXC + EXR + BCST + CPCST + CHAUL + CBCST
C
C-----ADD CONTINGENCY COST
C
      TERT  = TERT  + (TERT * TRNCTG/100.)
C
C-----COMPUTE RIGHT OF WAY COST
C
C---- EASEMENT LENGTH - CROPPED LAND
C
      ROW = RWID *(SLEN -PERD*SLEN/100)/43560.
C
      RWCST = ROW * RVAL
C
C-----EASEMENT LENGTH - OTHER LANDS
C
      RWA    = RWID * (PERD * SLEN/100.)    / 43560.
      RWACST= RWA * ROVAL
C
C-----TOTAL ROW  COST
C
      TROW = RWCST + RWACST
C-----ADD CONTINGENCY COST
C
      TROW = TROW + (TROW * RWCNTG/100.)
C
C
C     DETERMINE TOTAL COST OF CONSTRUCTION
C
      CST  = CPIPE+  CSTO  +  TERT  + TROW
C
C-----COMPUTE ANNUAL COST EQUIVALENT
C
      CANN = CST*(RINT*(1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.)
     & - SVAL *0.01*(CST-TERT-TROW)* RINT/(((1.+RINT)**TLFE) -1.)
C
      TAC(NQ) = CANN
C
C-----WRITE RESULTS
C
      IF(KQ.EQ.MAXQ)WRITE(6,401)
      WRITE(6.402)Q,XDIAM,SLEN.CPIPE,CSTO,TROW,TERT.CST.TAC(NQ),
     &TYPEP(NPTP),TYPEQ(NPTP)
  402 FORMAT(1X,F6.0.2F10.0.2F13.0,F16.0,F15.0,F17.0,F14.0,3X,2A4)
C
      QT(NQ) = Q
      XNK = NK
   49 CONTINUE
      GO TO 57
   50 WRITE(6,404)
  404 FORMAT(//,T15,'COMPUTED DIAM > MAX DIAM CONSIDERED'///)
      NQ = NQ - 1
```

```
 57 KXQ = KXQ + 1
    IF (KXQ.LT.7) GO TO 70
    KXQ = 0
    WRITE (6,255)
255 FORMAT('1',///)
 70 WRITE(6,260) SYS.TITLE
260 FORMAT(1H1,///.T45.18A4.///)
C
C
403 FORMAT(/// T15.'NOTE: '//
   & T17,'1/PIPE COST INCLUDES COST OF PIPE,LAYING OF PIPE,COST OF FIT
   &TINGS.VALVES,BLOCKING,ETC.'/
   &T17,'2/TURNOUT COST INCLUDES GATE VALVE,LINE METER,PRESSURE REDUCI
   &NG VALVE,CONCRETE PIPE,STEEL PIPE DELIVERY,ETC'/
   &T17,'3/EARTHWORK COST INCLUDES TRENCHING, BACKFILLING AND COMPACTI
   &NG BACKFILL'/)
C
C
    WRITE(6,210)CIDX,SLEN,ELO,ELI.HGLO.HGLI,RWID,RVAL,ROVAL.PERD
210 FORMAT(//,T10,'SUMMARY FOR THIS REACH:'///
   &T15,'COST INDEX FOR PIPE SYSTEM(B=1976)=',F7.0/
   &T15,'LENGTH OF REACH IN FEET           =',F7.0/
   &T15,'ELEVATION OF PIPE OUTLET, FEET    =',F7.0/
   &T15,'ELEVATION OF PIPE INLET, FEET     =',F7.0/
   &T15,'H.G.L. REQ. AT PIPE OUTLET.FEET   =',F7.0/
   &T15,'H.G.L. REQ. AT PIPE INLET, FEET   =',F7.0/
   &T15,'WIDTH OF EASEMENT. FEET           =',F7.0/
   &T15,'VALUE OF EASEMENT FOR CROPPED LAND=',F7.0/
   &T15,'VALUE OF EASEMENT FOR OTHER LAND  =',F7.0/
   &T15,'PERCENT LENGTH OF OTHER EASEMENT  =',F7.0/
   &T15,'NUMBER OF TURNOUTS:'//)
C
    DO 215 KY=1,NT
215 WRITE(6,217)TNO(KY),TSZ(KY)
217 FORMAT(T20,'NUMBER=',F4.0.6X,' SIZE (IN)=',F4.0/)
C
C  DETERMINE LINEAR REGRESSION COEFFICIENTS FOR THE DATA OBTAINED
C
    WRITE(6,218)Q
218 FORMAT(///,T15,'CHECK DATA FOR .....Q = ',F6.0,' CFS'//)
C
    XDIAM = IDIAM
    XHEAD = IHEAD
C
    COST=TPCST(NPTP)/SLEN
    WRITE(6,219)Q,XDIAM,XHEAD,ICOVER,COST,TMISC
219 FORMAT(T15,'CAPACITY.CFS                   =',F7.0/
   ↰        T15,'DIAMETER.INCHES (ROUNDED)   =',F7.0/
   ↰        T15,'AVERAGE HEAD CLASS, FEET    =',F7.0 /
   ↰        T15,'TYPE OF COVER               =',5X,A1/
   -        T15,'PIPE COST, $/FT             =',F9.2/
   -        T15,'MISC COST, (DOLLARS)        =',F9.2/)
C
 55 CALL REGLIN (QT.TAC,NQ,AC.BC.R)
    GO TO 99
 96 WRITE(6,201)DIA.SZE(NK)
201 FORMAT(10X,'DIA =',F10.3,'SZE =',F10.3)
 99 CONTINUE
    WRITE(9,524)
    GO TO 1
 98 RETURN
    END
```

```
C
C     SURROUTINE SPIPE CALLED RY WIRPIPE
      SURROUTINE SPIPE(IDIAS.COST)
C
C-----SURROUTINE SPIPE DETERMINES COST OF STEEL PIPE.
C     COST IS FOR PIPE LAID AND WELDED IN PLACE IN TRENCH
C     COSTS ARE FOR STEEL PIPE. RAPE INSIDE. AWWA TAR COAT OUTSIDE.
C     IDIAS IS THE PIPE O.D. (INCHES) AND IS AN EVEN INTEGER.
      DIMENSION S(48)
      DATA S/
     *00.00,00.00. 2.28, 2.95, 3.66, 4.46, 5.23, 6.10,20.50,29.30,32.20,
     * 35.1, 38.1. 41.0, 44.0, 47.0. 49.9. 52.9,100.8,106.1,111.5,116.8,
     *122.2,127.5,165.9.172.5,179.2.185.9,192.6,199.2,205.6,212.6.219.3,
     *225.9,232.6,239.3.246.0,252.6.259.3.266.0,272.7,335.0.343.0,351.0,
     *359.0,367.0,375.0,383.0/
C
C--NOTE:
C     HEAD = < 300. FEET
C     COVER = < 5.0 FEET
C     6-18 IN.  12 GAGE
C    20-36 IN.  10 GAGE
C    36-48 IN.  1/4 INCH
C    50-82 IN.  5/16 INCH
C    84-96 IN.  3/8 INCH
C
      DIAS = IDIAS
      IOD = IDIAS/2
      IF(IDIAS.GE.18) GO TO 40
      COST = S(IOD) + .02*DIAS
      GO TO 90
   40 IF(IDIAS.GE.24) GO TO 50
      COST = S(IOD)*.34 + .03*DIAS
      GO TO 90
   50 IF(IDIAS.GE.98) GO TO 60
      COST = S(IOD)*.34 + .08333*DIAS
      GO TO 90
   60 WEIGHT = 489.60
      THICK = 3./8. * 3.14159 * DIAS/144. * WEIGHT
      COST = THICK * .34 + .10 * DIAS
   90 RETURN
      END

C
C
C-----SUBROUTINE PPIPE...CALLED BY WIRPIPE
      SUBROUTINE PPIPE(ICLP,IDIAP,COST,NPIPE)
C
C     SURROUTINE PPIPE DETERMINES COST OF INSTALLED PVC (1977)
C
C     IP IS 1 FOR  63 PSI BELL END
C           2 FOR 125 PSI BELL END
C           3 FOR 160 PSI BELL END
C     IOD IS THE O.D. PIPE SIZE FROM 4 TO 14 INCHES
C     DATA P IS COST INCLUDING SEALERS AT PIPE ENDS
      DIMENSION P(3,6)
      DIMENSION N1(3)
      DATA N1/63,125,160/
      DATA P/0.0,0.57,0.71,0.82,1.30,1.56.1.71,2.08,2.55,1.92,3.30,3.97,
     *2.23,4.26,0.00,2.37,0.00/
      IOD=IDIAP
      IP=ICLP
      IF(IOD.LT.4) GO TO 50
      IF(IOD.EQ.4) IP2=1
      IF(IOD.EQ.6) IP2=2
      IF(IOD.EQ.8) IP2=3
      IF(IOD.EQ.10)IP2=4
      IF(IOD.EQ.12)IP2=5
      IF(IOD.EQ.14)IP2=6
      IF(IOD.GT.14) GO TO 50
      COST = P(ICLP,IP2) + .95
C     INSTALLATION IS ESTIMATED AT .95 PEP FOOT
      IF(P(IP,IP2).EQ.0) GO TO 50
      GO TO 70
   50 IF(NPIPE.EQ.3) WRITE(6,40) N1(ICLP),IOD
   40 FORMAT(/5X,'COST FOR CLASS ',I3,' PSI PIPE OF DIAMETER ',I4,
     *' INCHES IS NOT AVAILABLE.'/,5X,'STEEL AND CONCRETE WILL BE'
     *' SUBSTITUTED.'/)
      IF(NPIPE.EQ.3) NPIPE=5
      COST = 10.**10.
   70 RETURN
      END
```

```
C       SUBROUTINE EARTH2......CALLED BY WRDPIPE        ...G.GALINATO
        SUBROUTINE EARTH2(DI,XTA2.XGLE.XPGE.TEXC,TCBF,TBF,SLEN,
       *KQ,MAXQ,CBF,IREHAB,OBW,OZ,OBMH,OBMWL,OBMWR,OZBML,OZBMR.ETLI.ETRI,
       &ETLO,ETRO,OELI,OELO,ELI,ELO,THAUL.NPIPE,TEXCO,DPFILL)
        DIMENSION XTA2(100),XGLE(100).XPGE(100)
        REAL L
        R2D2 = 0.
        REHAB = IREHAB
        KODE = 1
        IF(KQ.NE.MAXQ)GO TO 77
        WRITE(6,10) KQ
   10 FORMAT(1H1,25X.'PIPE EARTHWORK FOR THE ABOVE REACH'///T45,
      * 'Q = ',I5,' CFS',//)
C
C---KODE = 1.....PRINTOUT IS DESIRED
C   KODE = 2.....ONLY TOTAL IS DESIRED
C
   77 IF(KODE .EQ. 2)GO TO 900
      IF(KQ.NE.MAXQ)GO TO 900
      WRITE(6,25)
   25 FORMAT(32X,'V  O  L  U  M  E  S' )
      WRITE(6,30)
   30 FORMAT(11X,'PIPE')
      IF(IREHAB.GT.0) GO TO 900
      WRITE(6.35)
   35 FORMAT( ' STATION',4X,'DIA.',9X,'EXCAVATION',3X,'BACKFILL',3X,
     -'C. BACKFILL',3X,'GLE-PGE',4X,'DIAM + DESIGN COVER',4X,'TRENCH'
     -,' WIDTH'/)
  900 CONTINUE
      STA1=0.0
      TEXC=0.0
      TCBF=0.0
      TBF=0.0
      NX = 0
  300 CONTINUE
      IF(IREHAB.GT.0) GO TO 805
C
      NX = NX + 1
      STA2 = XTA2(NX)
      GLE = XGLE(NX)
      PGE = XPGE(NX)
      IF(PGE.EQ.0.)GO TO 920
C
  930 CONTINUE
      L=STA2-STA1
C
C---DI = INSIDE DIAMETER IN INCHES
C   B = BASE PF TRENCH IN FEET
  805 IF(DI.LE.6.) B = 2.
      IF(DI.GT.6.AND.DI.LE.18.) B= 0.083*DI+2.
      IF(DI.GT.18.AND.DI.LE.24.) B = .083*DI+3.33
      IF(DI.GT.24.) B = .097*DI + 3.
C---OUTSIDE DIAMETER OF PIPE IN FEET
      IF(DI.LE.6.) DOUT = (DI +2.)/12.
      IF(DI.GT.6. AND.DI.LE.18)DOUT =(DI+4.)/12.
      IF(DI.GT.18.AND.DI.LE.24.)DOUT = (DI+4.)/12.
      IF(DI.GT.24.)DOUT=1.167*DI/12.
      IF(NPIPE.GT.1) DOUT=DI/12.
C---DEPTH OF COMPACTED BACKFILL
      X = .37 * DOUT
C---TOTAL DEPTH OF TRENCH - USE 4 FEET COVER
C     IF DEPTH OF FILL IS NOT INPUT OR IS NEGATIVE
      IF(DPFILL.LE.0.) DPFILL = 4.
      TH = DOUT + DPFILL
C
      ROUT=DOUT/2.0
  880 REXC = 0.
      RFIL = 0.
      YAVE = 0.
      OAREA = 0.
      INLET = 0
      T = (DOUT - DI/12.) / 2.
      APIPE=3.14159265*(ROUT**2.0)
      IF(IREHAB.GT.0) GO TO 810
      H=GLE-PGE
      ASEG1=1.07605312*(ROUT**2.0)
      H=H+T
  890 IF(H .LT. 0.0)GO TO 100
      IF(H .GT. TH)GO TO 110
      IF(H .GT. X)GO TO 120
      GO TO 130
  100 CONTINUE
      AEXC2=0.
      Y=X-H
```

```
      D=TH-H
      ABF2=B*D+1.5*(D**2.)-APIPE-ACBF2
      ABF3=0.
      GO TO 140
  110 CONTINUE
      AEXC2=(B*(H-YAVE)+REXC)
      Y=AMAX1(YAVE-H,0.)
      ACBF2=B*X + X**2 - ASEG1
      ABF2=AEXC2-ACBF2-APIPE
      GO TO 140
  120 CONTINUE
      AEXC2=B*H
      ACBF2=B*X - ASEG1
      Y=H-YAVE
      IF(Y.LT.X) ACBF2=ACBF2+(X-Y)**2*1.5
      D=TH-H
      A2=B*D + D**2 * 1.5
      ABF2=AEXC2-ACBF2-APIPE+A2
      GO TO 140
  130 CONTINUE
      AEXC2=B*H
      Y=H-YAVE+TH
      D=X-H
      A1=B*D+D**2*1.5
      ACBF2=AEXC2+A1-ASEG1
      D2=TH-H
      A2=B*D2+D2**2*1.5
      ABF2=AEXC2-APIPE-ACBF2+A2
  140 CONTINUE
      OHAUL = AMAX1(ABF2+ACBF2-AEXC2,R2D2)
      RSURP = AMAX1(AEXC2-ABF2-ACBF2,R2D2)
      IF(NX.EQ.1) GO TO 200
      VEXC=((AEXC1+AEXC2)*L)/54.0
      VCBF=((ACBF1+ACBF2)*L)/54.0
      VBF=((ABF1+ABF2)*L)/54.0
      TEXC=TEXC+VEXC
      TCBF=TCBF+VCBF
      TBF=TBF+VBF
      IF(KQ.NE.MAXQ)GO TO 79
      IF(KODE .EQ. 2)GO TO 910
      WRITE(6,40)VEXC,VBF,VCBF
   40 FORMAT(24X,3F12.2)
  200 CONTINUE
   79 IF(KQ.NE.MAXQ)GO TO 910
      IF (KODE .EQ. 2)GO TO 910
      WRITE(6,50)STA2,DI,H,TH,B
   50 FORMAT(2F8.2,45X,3F13.2)
  910 CONTINUE
      STA1=STA2
      AEXC1=AEXC2
      ACBF1=ACBF2
      ABF1=ABF2
      GO TO 820
  850 CONTINUE
      IF(INLET) 860,860,870
  860 TEXC2 = AEXC2
      TCBF2 = ACBF2
      TEXC1 = AEXC1
      TEXC3 = AEXC3
      TBF2  = ABF2
      THAUL = OHAUL
      TSURP = RSURP
      INLET = 1
      AA=ETRO
      BB=ETLO
      CC=OELO
      DD= ELO
      ETRO  = ETRI
      ETLO  = ETLI
      OELO  = OELI
      ELO   = ELI
      GO TO 810
C
C     AVERAGE VOLUMES BETWEEN INLET AND OUTLET
C     (ASSUME OLD CHANNEL AND NEW PIPE GRADE LINES ARE CONSTANT IN SLOPE
C
  870 TEXC = (TEXC2+AEXC2)*SLEN/54.
      TCBF = (TCBF2+ACBF2)*SLEN/54.
      TBF  = (TBF2+ABF2)*SLEN/54.
      TEXC1 = (TEXC1+AEXC1)*SLEN/54.
      TEXC3 = (TEXC3+AEXC3)*SLEN/54.
      THAUL = (OHAUL+THAUL-RSURP-TSURP)*SLEN/54.
      ETRO=AA
      ETLO=BB
      OELO=CC
```

```
      ELO =DD
C     FOR MOST CASES, IN PLACE OF OVERHAUL FROM AN OUTSIDE AREA,
C     EXCAVATE REQUIRED FILL FROM AREA ADJACENT TO PIPE LINE.
C
      TEXCO = AMAX1(THAUL,0.)
      TEXCO = TEXCO+TEXC1
      THAUL=0.
C
C     COST FOR BACKFILL QUANTITIES OF MATERIAL EXCAVATED FROM JOB SITE,
C     OTHER THAN FROM THE PIPE TRENCH, IS CONSIDERED TO BE $0.00.
C     (FOR INSTANCE, BACKFILL TO FILL IN OLD CHANNEL = $0.00, IF ALREADY
C     PAID FOR IN EXCAVATION COST)
C
      CBF=0.
      GO TO 920
  810 CONTINUE
C
C     CALCUALTE AREA OF OLD CHANNEL BELOW AVERAGE ELEV OF NATURAL TERRAI
C
      YAVE = (ETLO+ETRO-OELO*2.)/2.
      OAREA= OBW*YAVE + YAVE**2.*OZ
      IF(YAVE.LT.0.) OAREA=0.
C
C     CALCULATE AREA OF EXCAVATION REQUIRED TO LEVEL EXISTING BERMS
C     OF OLD CHANNEL TO ELEVATION OF NATURAL TERRAIN
C
      TDL=OBMH+OELO-ETLO
      TDR=OBMH+OELO-ETRO
      IF(TDL.LE.0..OR.TDR.LE.0.) GO TO 815
      ARE1=TDL*OBMWL+TDL**2*(OZBML+OZ)/2.
      ARE2=TDR*OBMWR+TDR**2*(OZBMR+OZ)/2.
      GO TO 817
  815 ARE1=0.
  816 ARE2=0.
C
C     DETERMINE IF ADDED COVER IS REQUIRED ABOVE THE AVERAGE ELEVATION
C     OF THE NATURAL TERRAIN AND IF EXCAVATION INTO THE CHANNEL BOTTOM
C     TO ACCOMODATE THE PIPE AT DESIGN ELEVATION IS REQUIRED
C
  817 H=(ETRO+ETLO)/2.-ELO+T
      REXC = ARE1+ARE2
      RFIL = OAREA
C
      Y=H-YAVE
      ACBF2=B*X-ASEG1
      IF(Y.LT.0.) ACBF2 = -Y*X + Y**2*1.5 - ASEG1
      AEXC2 = AMAX1((Y*B),0.)
      ABF2=AEXC2-ACBF2-APIPE
      IF(ABF2.LT.0.) ABF2=0.
      AEXC1=REXC
      AEXC3=ABF2+OAREA+ACBF2-REXC-AEXC2
      IF(Y2.LT.0.) AEXC3=AEXC3-APIPE
      Y2=H-DPFILL-YAVE
      IF(Y2.GT.0.) GO TO 950
      FILL = Y2**2*1.5 - Y2*X
      AEXC3=AEXC3+FILL
      ABF2=FILL
  950 OHAUL = AMAX1(AEXC3,0.)
      RSURP = R2D2-AMIN1(AEXC3,0.)
      GO TO 850
  820 GO TO 300
  920 CONTINUE
      IF(KODE.EQ.2) GO TO 99
      IF(KQ.NE.MAXQ)GO TO 99
      IF(IREHAB.GT.0) WRITE(6,85)
   85 FORMAT(/,' REHABILITATION PLAN---LAYING PIPE IN OLD CHANNEL'/)
      WRITE(6,70)TEXC
   70 FORMAT(' TOTAL EXCAVATION =',T29,F13.0,' CUBIC YARDS'/)
      WRITE(6,80)TCBF
   80 FORMAT (' TOTAL COMPACTED BACKFILL=',T29,
     +F13.0,' CUBIC YARDS'/)
      IF(IREHAB.EQ.1) WRITE (6,84) CBF
   84 FORMAT(/,' TOTAL BACKFILL (OLD CHAN)=',T29,F13.0,
     ''CUBIC YARDS'/)
      WRITE (6,82) THAUL
   82 FORMAT(/,' TOTAL OVERHAUL =',T29,F13.0,'CUBIC YARDS'/)
      IF(IREHAB.EQ.1) WRITE(6,86) TEXCO
   86 FORMAT(/,' SUBSTITUTE EXCAVATION FROM AREA ADJACENT TO PIPELINE',
     &/,' IN PLACE OF OVERHAUL FROM OUTSIDE AREA.',
     &/,' ADJACENT EXCAVATION = ',T29,F13.0,' CUBIC YARDS'/)
C
      WRITE(6,90)TBF
   90 FORMAT(' TOTAL BACKFILL =',T29,F13.0,' CUBIC YARDS'///)
   99 RETURN
      END
```

```
C        DATA SET WIRPIPER   AT LEVEL 028 AS OF 03/09/78
      SUBROUTINE PIPER
     +(WAGE,EQUIP,AREA,IHAUL1,IHAUL2,IDIAM,ICOVER,IHEAD,COST)
C       THIS SUBROUTINE IS A MODIFIED U.S.B.R. ROUTINE FOR DETERMINING
C       COSTS OF CONCRETE PIPE....FOR USE WITH IBM ASSEMBLER
C       SUBFUNCTIONS  'IAND' AND 'SHIFT'......
      DIMENSION A(192),M(312),B(36)
      DIMENSION M1(104),M2(104),M3(104).A1(96).A2(96)
      EQUIVALENCE (M1(1),M(1)).(M2(1).M(105)),(M3(1),M(209))
      EQUIVALENCE (A1(1),A(1)).(A2(1).A(97))
      DATA MSK1/Z0000000F/
      DATA      A1                           /.0018,2.,.0024.2...003.2..
     $.0036.2.,.00236,2.,.00296,2.,.00356.2.,.00416,2.,.00292,2...00352,
     +2...00412,2...00472.2.,.00348,2...00408,2.,.00468,2...00528,2.,
     +.00404.2...00464,2.,.00524,2.,.00584.2.,.0046,2.,.0052,2...0058,
     +2.,.0064,2.,-2.47155E-8,4.232.0,0.1.1579E-6,3.45,6.9775E-5,
     +2.75151,0.,0.,1.04315E-6,3.29402.1.12108E-6,3.47548.7.13888E-5.
     +2.78151,4.48983E-4,1.89466,4.67114E-4.2.06906,1.63829E-4,2.4813,
     +7.12697E-5,2.80909,4.81305E-4,2.04483.3.65517E-4,2.24422,
     +1.67888E-4,2.52017,8.43175E-5,2.79119.1.02074E-3,1.94287,
     +4.02171E-4,2.31158,5.30243E-4,2.31536.2.61835E-4,2.56219,
     +4.93438E-4,2.18653,5.31063E-4,2.30929,3.61891E-4,2.4541.2.826E-4,
     +2.56627/
      DATA      A2                            /3.52299E-4,2.31719.
     +8.3563E-4,2.25107.5.50352E-4,2.38939,5.90846E-4.2.41859,
     +2.52348E-4,2.44108.6.84543E-4,2.32231.8.6025E-4,2.31626,
     +1.29849E-3,2.25895,7.65917E-4,2.23277.1.22744E-3,2.21329,
     +1.20331E-3,2.26783,1.55209E-3,2.23875,8.49729E-4,2.23602,
     +1.19887E-3,2.23636.1.79602E-3,2.21148,2.81348E-3,2.12619,
     +1.06156E-3,2.21456,2.53837E-3,2.07901,1.98897E-3,2.19993,
     +2.38881E-3,2.18898,2.30801E-3.2.08255.2.18089E-3,2.14152.
     +2.47327E-3,2.16518,2.00275E-3,2.25277,2.07039E-3.2.128,2.08237E-3,
     +2.1731,2.28672E-3,2.20002,2.13053E-3,2.26274,6.31052E-3,1.89747,
     +3.61429E-3.2.06767,1.6988E-3,2.31596.3.29764E-3,2.17865,
     +5.15191E-2,1.36719.2.65675E-2.1.56479.2.34765E-2,1.63912.
     +2.2229E-2,1.69838,4.61979E-2.1.40891.2.14081E-2,1.62808,
     +2.03426E-2.1.68834,1.90821E-2.1.74984,5.66253E-2,1.37698,
     +2.9058E-2,1.57308,1.99657E-2,1.71145.1.64647E-2.1.80104,
     +4.47578E-2,1.44786,2.2833E-2,1.64734.1.8329E-2,1.75049,1.72937E-2,
     +1.80075/
      DATA      M1       /Z03333333,Z33333333,Z03333333,Z33333333.
     +Z03433343,Z33333333,Z05544544,Z34433443,Z06666665,Z65555554.
     +Z07777777.Z66666666,Z08888888,Z77777777,Z09999998,Z88888888.
     +Z03333333,Z99999999.Z03333333.Z33333333,Z03433343,Z33333333,
     +Z05443543,Z34433433,Z06556554,Z65445543,Z06676667,Z66666656.
     +Z07887787.Z77777777.Z09888888,Z88888888,Z09999999,Z99999998,
     +Z01131113,Z11121119,Z01431142,Z11321132.Z05432543,Z25321432,
     +Z06546543,Z65435432,Z06676657,Z66566546,Z07877787,Z76776677.
     +Z09888888,Z78877877,Z09999998.Z99889888.Z01132110,Z09909999,
     +Z01431143,Z11421142,Z05421542,Z15321532.Z05436543,Z65325432,
     +Z06576556.Z65465546.Z06776677,Z66766676.Z08877877,Z78777777,
     +Z09889888.Z88888887.Z09909999,Z99999989,Z01431143,Z11431100.
     +Z05421542,Z15421432.Z05425532,Z54315431,Z05466546,Z54365436.
     +Z06766676,Z65765566,Z08777877,Z67766776,Z08888887,Z88778877,
     +Z09999989.Z98898889,Z01532100.Z99099909,Z05421542,Z15421542,
     +Z05426531,Z54315431,Z05365436,Z54265426.Z05766576,Z54665466.
     +Z07766776.Z67766766.Z08778877,Z87778776,Z08898889,Z88888878,
     +Z09099909,Z99999899,Z05421541.Z15311009/
      DATA      M2        /Z04315421,Z54215421.Z04265426,Z53265326.
     +Z04665466,Z53654365.Z07766766,Z57665765,Z07778776,Z77667766,
     +Z08888878,Z87788778,Z09999899,Z88998898,Z05311009,Z90999099.
     +Z04215421,Z54215411,Z04265315.Z43154315,Z03654365,Z42654265.
     +Z07665765.Z47654665.Z07667766.Z77667665,Z07788778,Z77787768.
     +Z08998898,Z88888788.Z00999099,Z99998998,Z04215421.Z53210099,
     +Z03154315,Z43154215,Z03654265,Z32653154.Z07654665,Z36543654,
     +Z07667665,Z76657654,Z07787768.Z76677667,Z08988788,Z77887787,
     +Z09998998.Z89988988,Z03210099,Z09990999,Z02154215,Z42154215,
     +Z02653265,Z31543154,Z06643654.Z36542653,Z06657654,Z76546653,
     +Z06677667,Z76676657,Z07887787.Z77877687,Z09988988,Z89887887,
     +Z09990999.Z99989988.Z02154215,Z42100990,Z01543154,Z31542154,
     +Z06542654,Z26532653.Z06546653,Z66436543.Z06676657,Z66576547,
     +Z07877687,Z66776677.Z09887887,Z78877877,Z09989988,Z99889888,
     +Z02100990,Z99909999,Z01543154,Z21542154,Z06532653,Z16531543,
     +Z06536543,Z65426542,Z06576547.Z65466536,Z06776677,Z66766576.
     +Z08877877,Z78776776,Z09889888.Z88878877,Z09909999,Z99899889,
     +Z01542154,Z21009909,Z06531643.Z15431542/
      DATA      M3         /Z05426542,Z65416531.Z05466536,Z65366436,
     +Z06766576,Z65765476,Z08776876,Z67766776,Z08878877,Z88778777.
     +Z09899889,Z98898889,Z01009909.Z99099999,Z05431543,Z15421542,
     +Z05416531.Z65316531,Z05366436,Z54265426,Z05765476.Z54665366,
     +Z07766776.Z67665766,Z08778777.Z87768766.Z08898889,Z88788778.
     +Z09099999,Z98998899,Z05421542,Z10099099,Z05316531.Z54315431,
     +Z04265426,Z54265316,Z04765366.Z53664365.Z07765766,Z57664765.
     +Z07768776,Z77667766.Z08788778,Z87787778,Z08998899.Z88988898,
     +Z00099099.Z90999999.Z04315431.Z54315431.Z04265316.Z53165316.
```

```
     +Z07787778.Z77687767,Z08988898.Z87887788.Z00999999,Z89988998,
     +Z04315431,Z00990999,Z03165316.Z43164315.Z02654265,Z42654165,
     +Z07653665,Z36643664,Z07657665.Z76647654,Z07687768,Z76677667,
     +Z07888788,Z77887787.Z00988998,Z89888988.Z00090099.Z00990998,
     +Z03154315,Z43154310,Z02654165.Z31653164,Z06643664,Z26542654.
     +Z06647654,Z76536653,Z06677667,Z76576657,Z07887787,Z76877687,
     +Z09888988,Z79887887,Z09999998.Z99889988/
      DATA      B                          /.626221.1.4377..537402.
     +1.5126,.547986.1.5357,.426069.1.71056,.57167.1.62029,.439791,
     +1.82659,.4019,1.87718,.426438.1.90321..452103,1.92518..220413,
     +1.82037,.283496,1.76531,.247914,1.89029,.275161,1.87091,.271968,
     +1.90276,.413699,1.8339,.295814,2.00121,.285465.2.06558,.333242,
     +2.06309/
      COEF = (WAGE / 30. + .9 * EQUIP) * AREA
      FACT1 = IHAUL1 * 2.4838E-5 + 3.31174E-3
      FACT2 = IHAUL2 * 4.32E-5 + 5.665E-3
      IC = ICOVER
      S = 3.
      IF (IDIAM .GE. 72) S = 6.
      ID = (IDIAM - 1) / S + 1.001
      D = ID * S
      IF (D .GT. 120.) D = 120.
      IH = (IHEAD - 1) / 25 + 1.001
      IF (IH .LT. 1) IH = 1
      IF (IH .GT. 32) IH = 32
      J = (IH-1) * 8 + (IC-1) * 2
      COST = 5000.
      IF (D .LT. 12.) GO TO 110
      IF (IH .GT. 6) GO TO 100
      COST = ((.28 + (D / 42.)**3 / 100.) * D + FACT1 * D**1.81422 +
     +A( J + 1 ) * D**A( J + 2 )) * COEF
      GO TO 110
  100 IF (IH .GT. 24) GO TO 110
      IF (D .GT. 69. .AND. IH .GT. 19) GO TO 110
      IF (D .GT. 54. .AND. IH .GT. 20) GO TO 110
      IF (D .GT. 36. .AND. IH .GT. 22) GO TO 110
      COST = ((.2 + (D / 42.)**3.5 / 100.) * D + FACT2 * D**1.70679 +
     +A( J + 1 ) * D**A( J + 2 ) + D**1.505 / 20.) * COEF
  110 CCOST = 5000.
      IF (D .GT. 42.) GO TO 120
      IF (IDIAM .LT. 4) IDIAM = 4
      S = 2.
      IF (IDIAM .GE. 21) S = 3.
      ID = (IDIAM - 1) / S + 1.001
      DD = ID * S
      IF (IDIAM .EQ. 15) DD = 15.
      IF (DD .LE. 14.) ID = ID - 1
      IF (DD .GT. 20.) ID = ID + 4
      I = (ID - 1) * 128 + (IH - 1) * 4 + IC
      IL = (I-1) / 15 + 1
      K = (I - (IL - 1)*15 - 1) * (+4)
      IL=IL*2
      IF( K . GE . 32 )  IL=IL-1
      IF( K . GE . 32 )   K=K-32
      IL = ISHFT (M(IL),K)
      IL = IAND (IL,MSK1)
      IF (IL.EQ.0) GO TO 120
      I = 1
      IF (DD .GT. 14.) I = 2
      J = (I-1) * 18 + (IL -1) * 2
      CCOST = (B(J + 1 ) * DD**B(J  + 2) * .12 + .4 * DD**.502161)
     +* COEF
  120 IHEAD = IH * 25
      IDIAM = D + .001
      IF (COST .LE. CCOST) GO TO 130
      IDIAM = DD + .001
      COST = CCOST
  130 IF (COST .EQ. 5000.) COST = 0.
      CALL ROUND(COST)
      RETURN
      END
```

```
      SUBROUTINE ROUND(COST)
      IF(COST.GE.10.)GO TO 2
      ICOST = COST
      COS1 = ICOST
      COS2 = (COST-COS1)*10.
      ICOS1 = COS2
      COS3 = ICOS1
      COS4 = COS2-COS3
      IF(COS4.GE.0.5)COS3 = COS3 + 1.
      COST = COS1 + COS3/10.
      GO TO 999
    2 IF(COST.GE.20.)GO TO 4
      ICOST = COST
      COS1 = ICOST
      COS2 = COST-COS1
      IF(COS2.GE.0.5) COS3=1.0
      IF(COS2.LT.0.5) COS3=0.5
      IF(COS2.EQ.0.)COS3=0.
      COST=COS1+COS3
      GO TO 999
    4 ICOST = COST
      COS1=ICOST
      COS3=1.0
      COS2 = COST-COS1
      IF(COS2.LT.0.5)COS3=0.0
      COST = COS1+COS3
  999 RETURN
      END
```

```
*       DATA SET WIRIAND    AT LEVEL 003 AS OF 02/01/78
IAND     START
*               THIS FUNCTION RETURNS THE LOGICAL AND OF TWO 4-BYTE
*               ARGUMENTS IN GENERAL REGISTER 0
*               I = IAND(J,K) WHERE J AND K ARE 4 BYTE ARGUMENTS
         USING IAND,15
         ST    14,12(13)         SAVE RETURN REGISTER
         L     14,0(1)           LOAD 14 WITH ADDRESS OF 1ST ARGUMENT
         L     0,0(14)           LOAD 0 WITH 1ST ARGUMENT
         L     14,4(1)           LOAD 14 WITH ADDRESS OF 2ND ARGUMENT
         N     0,0(14)           AND IN 2ND ARGUMENT TO REGISTER 0
         L     14,12(13)         RESTORE RETURN REGISTER 14
         BR    14                RETURN
         END
*       DATA SET WIRSHIFT   AT LEVEL 011 AS OF 02/01/78
ISHFT    START
*               THIS FUNCTION RETURNS ARGUMENT 1 SHIFTED BY THE NUMBER
*               OF BITS SPECIFIED BY ARGUMENT 2 TO REGISTER 0.
*               ISHFT (J,K) WHERE J AND K ARE 4 BYTE ARGUMENTS.
         USING ISHFT,15
         ST    14,12(13)         SAVE RETURN REGISTER
         L     14,0(1)           LOAD 14 WITH ADDRESS OF 1ST ARGUMENT
         L     0,0(14)           LOAD 0 WITH 1ST ARGUMENT
         L     14,4(1)           LOAD 14 WITH ADDRESS OF 2ND ARGUMENT
         L     14,0(0,14)        LOAD REG 14 WITH # OF POSITIONS TO SHIFT
         SRL   0,0(14)           SHIFT ARGUMENT 1 BY ARGUMENT 2 # OF BITS
         L     14,12(13)         RESTORE RETURN REGISTER 14
         BR    14                RETURN
         END
```

```
C          DATA SET WIRPUMP    AT LEVEL 015 AS OF 03/08/78
C
      WRITE(6,200)
  200 FORMAT(1H1,//////////////T25,'---OUTPUT OF THE PROGRAM ''PMPCST'' -
     & PUMP COST'/)
      CALL PMPCST
      WRITE(9,2)
    2 FORMAT(//, ' THIS PROGRAM IS TERMINATED SUCCESSFULLY '///
     & ' OUTPUT OF THIS PROGRAM IS OBTAINED AT THE '//
     ' ' TERMINAL - DATA 100 LINE PRINTER'
     & ///' GOODLUCK       BYE....'/)
      STOP
      END
C   SUBROUTINE PMPCST COMPUTES THE ANNUAL COST OF A PUMPING PLANT
C   FOR THE DATA GIVEN
C
      SUBROUTINE PMPCST
C     LIST,NONE
      INTEGER ANSW
      DIMENSION A(50),PMQ(500),CTANN(500),TITLE(18),ANSW(6),WRQ(12)
      DATA CN1,CN2,CODP/3HEND,4HSKIP,4HRIVE/
  409 FORMAT('THIS PROGRAM COMPUTES PUMPING PLANT COSTS'/)
  410 FORMAT('TYPE THE FOLLOWING INFORMATION:'/
     ' ' ''READ---RIVER PUMP'' IF RIVER PUMP IS TO BE PROCESSED'/
     ' ' ''READ---FARM PUMP'' IF ON-FARM PUMP (CENTRIFUGAL OR DEEP WELL)
     ' '/'          IS TO BE PROCESSED...THEN - IDENTIFIER'/)
  411 FORMAT(/,'  TYPE DATA FOR RIVER PUMP IN THE FF ORDER'/
     & ' 1-NUMBER OF PUMPING UNITS'/
     & ' 2-TYPE OF PUMPING UNIT: CODE USED (1) FOR VERTICAL PUMP'/
     & '                                  (2) FOR HORIZONTAL PUMP'/
     & ' 3-TOTAL DYNAMIC HEAD IN FEET'/
     & ' 4-MONTH OF ESTIMATE'/
     & ' 5-YEAR OF ESTIMATE'/
     &)
  412 FORMAT(/,'  TYPE THE FF DATA:'/
     ' ' 1-CONTINGENCY COST FOR PUMPING PLANT, PERCENT'/
     ' ' 2-COST OF FOREBAY,DISCHARGE LINES, ETC. AS A PERCENT'/
     ' '    OF THE PUMP UNIT'/
     ' ' 3-COST OF POWER, CENTS PER KW-HR'/
     & ' 4-GENERAL COST INDEX, BASE YEAR IN 1976'/
     & ' 5-TYPE OF PUMPING UNIT(ACCORDING TO EYER)'/
     ' '          (1) UNATTENDED PLANT'/
     ' '          (2) SEMI-ATTENDED PLANT'/
     ' '          (3) ATTENDED PLANT'/
     ' ' 6-SEDIMENT CODE --FOR WEAR ALLOWANCE COMPUTATION:'/
     ' '       (1) CLEAR WATER'/
     ' '       (2) LIGHT SEDIMENT LOAD'/
     ' '       (3) MEDIUM SEDIMENT LOAD'/
     ' '       (4) HEAVY SEDIMENT LOAD'/)
  413 FORMAT(/,' TYPE THE FF DATA:'/
     & ' 1-LIFE OF PUMPING UNIT, YEARS'/
     & ' 2-INTEREST RATE, PERCENT'/
     & ' 3-SALVAGE VALUE OF THE UNIT, PERCENT OF THE ORIGINAL COST'/
     - ' 4-AVERAGE ESCALATION OF ENERGY, PERCENT PER YEAR'/)
  414 FORMAT(/,'  TYPE MONTHLY IRRIGATION REQUIREMENT FOR THE SEASON'/
     ' ' .....IN INCHES OR AF-FT PER MONTH'/
     &)
  415 FORMAT(' TYPE O&M DATA FOR PUMP:'/
     & ' 1-LENGTH OF OPERATING SEASON IN WEEKS '/
     & ' 2-HOURLY WAGE RATE FOR MECHANIC'/
     & ' 3-HOURLY WAGE RATE FOR PUMPING PLANT OPERATOR'/
     '' 4-AREA TO BE IRRIGATED, ACRES'/)
  416 FORMAT(/,'  TYPE STARTING Q(CFS),FINAL Q(CFS) AND Q INTERVAL'/)
  417 FORMAT(//,'  ARE THERE ANYMORE DATA TO BE PROCESSED\\\\'//
     & ' IF NO, TYPE--->   END     IF YES---'/)
      KXQ = 0
C
C   READ IN CONTROL FOR PROPER BRANCHING AND A TITLE
C   IF THE WORD BEGINNING IN COLUMN 1 IS:
C         'READ'  CONTROL IS SHIFTED TO STATEMENT 5
C         'SKIP'  CONTROL IS SHIFTED TO STATEMENT 3
C         'END'  CONTROL IS SHIFTED TO STATEMENT 98
C                STATEMENT THAT MAY BE MOVED IF DESIRED.
C   THE TITLE BEGINS IN COLUMN 8
      WRITE(9,409)
    1 CONTINUE
      WRITE(9,410)
      READ(5,150) CON, TITLE
      WRITE(9,150)CON, TITLE
  150 FORMAT (A4,3X,18A4)
      IF (CON.EQ.CN1) GO TO 98
      IF(CODP.NE.TITLE(1)) GO TO 210
C
C
```

```
C  USE THE ABOVE PROGRAM IN COMPUTING COST
      WRITE(9,411)
C
      CALL INPUT(A,NO)
C
C         ' UNITS = NUMBER OF PUMPING UNITS
C         ' TYPE  = TYPE OF PUMPING UNIT : 1--- VERTICAL PUMP
C                                            2--- HORIZONTAL PUMP
C         ' TDH   = TOTAL DYNAMIC HEAD IN FEET
C         ' MONTH = MONTH OF ESTIMATE
C         ' IYEAR = YEAR OF ESTIMATE
C
      UNITS = A(1)
      TYPE = A(2)
      TDH = A(3)
      MONTH = A(4)
      IYEAR = A(5)
C
      WRITE(9,412)
C
      CALL INPUT(A,KD)
      PCONT = A(1)/100.
      PERD = A(2)/100.
      PWCST = A(3)/ 100.
      CIDX = A(4)
      KODP = A(5)
      NSED = A(6)
C        ' PCONT = CONTINGENCY COST, PERCENT
C        ' PERD = OTHEP COST AS A PERCENT OF PUMP UNIT.
C        ' PWCST= COST OF POWER PER KW - FLAT RATE
C        ' CIDX = GENERAL COST INDEX BASE YEAR = 1976
C      ' KODP = CODE FOR TYPE OF PUMPING UNIT - FOR COMPUTING COST
C      '  PERWER = PERCENT WEAR ALLOWANCE, PERCENT OF -Q
C
      WRITE(9,502)
  502 FORMAT(/,'  TYPE DATA FOR TRANSMISSION LINE:'/
     '' 1-ACTUAL LENGTH OF TRANSMISSION LINE, MILES'/
     '' 2-TERRAIN CODE:'/
     ''      0)-FLAT TERPAIN'/
     ''      1)-SWAMPY OR MOUNTAINOUS TERRAIN'/
     '' 3-FOUNDATION CODE'/
     ''      0)-AVERAGE CONDITION'/
     ''      1)-SWAMPY OR ROCK FOUNDATION'/
     '' 4-CONTINGENCY COST FOR TRANSMISSION LINE, PERCENT'/
     '' 5-COST INDEX, TRANS. LINE, BASE IS 1976'/
     '' 6-COST INDEX, IRRIG. 0 & M, BASE IS 1976'/)
      CALL INPUT(A,NTL)
      TRLIN = A(1)
      NTER = A(2)
      NFOUN = A(3)
      TRCONT = A(4)
      TRINX = A(5)
      OMINX = A(6)
C
      WRITE(9,504)
  504 FORMAT(/,'  TYPE SWITCHING BAY DATA:'/
     '' 1-CONTINGENCY COST FOR SWITCHING BAY'/
     '' 2-COST INDEX, SWITCHING BAY, BASE IS 1976'/)
      CALL INPUT(A,NSW)
      SWCON = A(1)
      SWINX = A(2)
C
      WRITE(9,506)
  506 FORMAT(/,'  TYPE THE FF DATA:'/
     '' 1-SERVICE LIFE OF TRANSMISSION LINE AND SW BAY, YEARS'/
     '' 2-SALVAGE VALUE, PERCENT OF ORIGINAL COST'/)
      CALL INPUT(A,NYT)
      TRY = A(1)
      SVTR = A(2)
C
      WRITE(9,413)
      CALL INPUT(A,NL)
C
      TLFE = A(1)
      RINT = A(2)/100.
      SVAL = A(3)
      ESCP = A(4)/100.
C
C-----COMPUTE EQUIVALENT ANNUALIZED COST FACTOR FOR ESCALATION OF
C     POWER OVER THE LIFE OF THE SYSTEM
C
      EACF=(((1.+ESCP)**TLFE-(1.+RINT)**TLFE)/(ESCP-RINT))*RINT/
     & ((1.+RINT)**TLFE-1.)
C
```

```
C-----READ IN AVERAGE MONTHLY IRRIGATION REQUIREMENT FOR CROPS
C     THIS IS NEEDED TO DETERMINE PERCENT OF ENERGY REQUIREMENT
      WRITE(9,414)
      CALL INPUT(A,NW)
C
      DO 14 K=1,NW
   14 WRQ(K) = A(K)
C
C      SORT WRQ AND DETERMINE THE PROPORTION OF WATER VOLUME PUMPED
C      EACH MONTH TO THE WATER VOLUME PUMPED AT PEAK MONTH
C
      RAT = WRQ(1)
      DO 15 KW = 2,NW
      KW1 = KW - 1
      IF(WRQ(KW).GT.WRQ(KW1))RAT = WRQ(KW)
   15 CONTINUE
C
C
C     READ IN PARAMETERS FOR OM & R FOR RIVER PUMPS OR RELIFT PUMPS
      WRITE(9,415)
C
      CALL INPUT(A,NOM)
C
C       * T = LENGTH OF OPERATING SEASON IN WEEKS
C       * WM= HOURLY WAGE RATE FOR MECHANIC
C       * WO= HOURLY WAGE RATE FOR PUMPING PLANT OPERATOR
      T = A(1)
      WM= A(2)
      WO= A(3)
      ACFS = A(4)
C
C ---ADJUST TO BASE YEAR OF 1976
      R = CIDX * 2.0 / 0.89
C      COMPUTE APPROXIMATE VOLUME OF WATER PUMPED
C      USE 30.4 AVERAGE PUMPING DAYS PER MONTH
C
      AF = 0.
      DO 18 K= 1,NW
      IF(RAT.GT.10.) AFM = WRQ(K)
      IF(RAT.LE.10.) AFM = WRQ(K) * ACFS / (.70 * 12.)
   18 AF = AF + AFM
C
      WRITE(9,416)
C
      CALL INPUT(A,KR)
      MINQ = A(1)
      MAXQ = A(2)
      KTNQ = A(3)
C
      WRITE(6,776)TITLE
  776 FORMAT(1H1,T30,18A4)
      WRITE(6,777)
  777 FORMAT(///,T28,'PUMPING    ANNUAL EQUIV.  OPERATION    MAINTENANCE
     & REPLACEMENT   POWER       ANNUAL PUMPING'/T6,'Q            H.P.
     &PLANT COST      COST            COST          COST           COST
     & COST            COST'/T4,'(CFS) 1/   USED 2/          ($)          (
     &$/YR) 3/      ($/YR)        ($/YR)         ($/YR)        ($/YR) 4/     (
     &$/YR 5/'//)
      KX=0
C-----COMPUTE COST AT DIFFERENT Q RATES
      DO 49 LP=MINQ,MAXQ,KTNQ
      KX=KX+1
      PMQ(KX) = LP
C-----COMPUTE EXPECTED EFFICIENCY OF PUMP & MOTOR
C     USE USBR CURVES FOR PLANNING STUDIES
C
      IF(PMQ(KX).LE.5.)EFF =(47.* PMQ(KX)**0.1238) / 100.
      IF(PMQ(KX).GT.5.AND.PMQ(KX).LE.1000.)EFF=(52.*PMQ(KX)**0.052)/100.
      IF(PMQ(KX).GT.1000.)EFF = 75./100.
C
      GO TO (302,304,306,308),NSED
  302 IF(LP.LE.100)PERWER = 2.5
      IF(LP.GT.100)PERWER = 1.5
      GO TO 311
  304 IF(LP.LE.100)PERWER = 7.5
      IF(LP.GT.100)PERWER = 3.5
      GO TO 311
  306 IF(LP.LE.100)PERWER = 12.5
      IF(LP.GT.100)PERWER = 6.5
      GO TO 311
  308 IF(LP.LE.100)PERWER = 17.5
      IF(LP.GT.100)PERWER = 11.5
  311 PERWER = PERWER/100.
C        ADD WEAR ALLOWANCE--
```

```
C
      HP1=PMQW*TDH/(8.8 * EFF)
C-----HORSEPOWER IS ROUNDED TO THE NEAREST  5.0 HP
C
      HP2 = 0.
      DO 888 KJ = 1,5000
      HP2 = HP2 + 5.
      IF(HP1.LT.HP2)GO TO 890
  888 CONTINUE
  890 HP = HP2
C
C---FIND KW CAPACITY
      HPW = HP * .746
C----FIND TRANSMISSION VOLTAGE - KV
      IF(HPW.LE.700.)TKV = 13.8
      IF(HPW.GT.700.AND.HPW.LE.4000.)TKV = 34.5
      IF(HPW.GT.4000.AND.HPW.LE.15000) TKV = 69.
      IF(HPW.GT.15000.AND.HPW.LE.35000.)TKV = 115.
      IF(HPW.GT.35000.)WRITE(9,309)
  309 FORMAT(/,'  HPW IS GREATER THAN 35000. - CHECH DATA'/)
      IF(HPW.GT.35000.)GO TO 98
      IF(TKV.EQ.13.8) IVOLT = 1
      IF(TKV.EQ.34.5) IVOLT = 2
      IF(TKV.EQ.69.) IVOLT = 3
      IF(TKV.EQ.115.) IVOLT = 4
C---COMPUTE KVA
      TKVA = 1.25 * HPW
C---COMPUTE COST OF TRANSMISSION LINE AND SWITCHING BAYS
C        USE AVERAGE COST FOR EACH KV LINE
      GO TO (511,512,513,514),IVOLT
  511 TCPMIL = 17500.
      TSWB = 70000.
      GO TO 515
  512 TCPMIL = 17800.
      TSWB = 87000.
      GO TO 515
  513 TCPMIL = 25000.
      TSWB = 119000.
      GO TO 515
  514 TCPMIL = 39600.
      TSWB = 185000.
  515 CONTINUE
C---APPLY COST INDEX
      TCPMIL = TRLIN * TCPMIL * TRINX * 1.995 /0.675
      IF(NTER.EQ.1) TCP1 = TCPMIL * 0.5
      IF(NTER.NE.1) TCP1 = 0.
      IF(NFOUN.EQ.1) TCP2 = TCPMIL * .5
      IF(NFOUN.NE.1) TCP2 = 0.
      IF(TRLIN.LE.5.) TCP3 = TCPMIL * 1.
      IF(TRLIN.GT.5.) TCP3 = 0.
      IF(TRLIN.GT.5.AND.TRLIN.LE.20.)TCP4 = TCPMIL * .5
      IF(TRLIN.GT.20.)TCP4 = 0.
      SUBTLC = TCPMIL + TCP1 + TCP2 + TCP3 + TCP4
C---COMPUTE COST OF SITCHING BAY
      TSWB = TSWB * SWINX * 1.94 / 0.532
      TRSWC = TSWB * SWCON/100. + SUBTLC * TRCONT/100.
C---FILED COST TR AND SW BAY
      FTW = SUBTLC + TSWB + TRSWC
C---ASSIGN INDIRECT COST FOR TR AND SW BAY
C   USE USBR CURVES
      IF(FTW.LE.500000.)ENC = 46.25-.0000125*FTW
      IF(FTW.GT.500000.AND.FTW.LE.1000000.)ENC = 38.-.000006 * FTW
      IF(FTW.GT.1000000.AND.FTW.LE.2000000.) ENC=33.5-.0000015*FTW
      IF(FTW.GT.2000000.AND.FTW.LE.5000000.)ENC=32.5-.0000001*FTW
      IF(FTW.GT.5000000.)ENC = 29.5-.0000004*FTW
C---TOTAL COST OF TR AND SW BAY
      TSW1 = FTW * ENC/100.
      TSWEN = FTW + TSW1
C---COMPUTE ANNUAL EQUIV COST - TR AND SW BAY
      ATRAN = TSWEN*(RINT*(1.+RINT)**TRY)/(((1.+RINT)**TRY)-1.)
     *-SVTR*.01*TSWEN*RINT/(((1.+RINT)**TRY)-1.)
C
C-----COMPUTE ANNUAL COST EQUIVALENT OF PUMPING PLANT
C     USE USBR SUBROUTINE #PUMPER# TO COMPUTE COST
C
      CAP = PMQ(KX)
C
      CALL PUMPER(CAP,UNITS,TYPE,TDH,MONTH,IYEAR,IVOLT,ANSW)
      CIMP = ANSW(1)
      CWAYS = ANSW(2)
      CPMOT = ANSW(3)
      CELEC = ANSW(4)
      CMISC = ANSW(5)
      CSWIT = ANSW(6)
```

```
      PMCT = CIMP+CWAYS+CPMOT+CELEC+CMISC+CSWIT
C
C     ADD ADDITIONAL COST FOR INTAKE,DISCHARGE LINE,ETC.
      PMCT2 = CPMOT * PERD
C
      PMCST = PMCT + CPMOT * PERD
C      ADD CONTINGENCY COST
      PMCT3 = PMCST * PCONT
      PMCST = PMCST + (PCONT * PMCST)
C
C---ASSIGN PERCENT INDIRECT COST FOR PUMPING PLANT
C   USE USBR CURVES
      IF(PMCST.LE.500000.) ENP = 44.44-.00000888*PMCST
      IF(PMCST.GT.500000..AND.PMCST.LE.1500000.)ENP=41.-.000002*PMCST
      IF(PMCST.GT.1500000..AND.PMCST.LE.5000000.)ENP = 38.
      IF(PMCST.GT.5000000.)ENP=37.
      PMCT4 = PMCST * ENP/ 100.
      PMENG = PMCST + PMCT4
C
C---COMPUTE ANNUAL EQUIV COST
C
      PCOST = PMENG*(RINT*(1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.)
     &-SVAL*.01*PMENG*RINT/((((1.+RINT)**TLFE)-1.)
C
C---- DETERMINE OPERATION COST OF PUMPING PLANT
C     TYPE OF PUMPING PLANT  ?
C     CODE USED:
C        * 1 = UNATTENDED PLANTS
C        * 2 = SEMI-ATTENDED PLANTS
C        * 3 = ATTENDED PLANTS
C
C----SEE USBR PUBLICATION *PUMPING PLANT O & M COSTS* BY EYER--1965
C
      IF(KODP.EQ.1)GO TO 156
      IF(KODP.EQ.2)GO TO 158
      IF(KODP.EQ.3)GO TO 160
C
C
C-----OPERATION COST FOR UNATTENDED PLANTS
  156 IF( HP     .GT.10000.)GO TO 162
      COP=1.8*((PMQ(KX))**0.47)*(TDH**0.26)*(1.2*WO+R)*(T**0.34)
      GO TO 172
C
  162 WRITE(6,164)
  164 FORMAT(/,T15,'FOR HP GREATER THAN 10000--->USE PART 153 REC.INS.')
      KX = KX - 1
      GO TO 310
C
C-----OPERATION COST FOR SEMI-UNATTENDED PLANTS
  158 IF( HP .LT.    450.)GO TO 168
      IF( HP .GT.    15000.)GO TO 170
      COP = 5.2*(PMQ(KX)**0.05)*(TDH**0.25)*(2.80*WO + R)*T
      GO TO 172
  168 WRITE(6,174)
  174 FORMAT(T15, 'FOR HP LESS THAN 450 CFS,USE EQUATION FOR UNATTENDED
     &PLANTS')
      GO TO 156
  170 WRITE(6,176)
  176 FORMAT(/,T15,'FOR HP GREATER THAN 15000->> USE PART 153 RECL.INS')
      KX = KX -1
      GO TO 310
C
C-----OPERATION COST FOR ATTENDED PLANTS
  160 IF(  HP .LT.  450.)GO TO 168
      IF(  HP .GT.  15000.)GO TO 170
      COP = 7.0*(PMQ(KX)**0.04)*(TDH**.13)*T*(9.5*WO + R)
C
  172 CONTINUE
C
C-----COMPUTE ANNUAL MAINTENANCE COST--(COMMON TO ALL TYPES OF PLANTS)
C
      IF(HP.LT.149.) GO TO 274
      IF(HP.GT.15000.)GO TO 170
      IF(HP.LE.15000.)CMN=1.7*PMQ(KX)**.11*TDH**.41*AF**.43*(.49*WM+R)
      IF(HP.LE.6999.)CMN=2.*PMQ(KX)**.11*TDH**.41*AF**.43*(.49*WM+R )
      GO TO 186
  274 CMM=4.0*PMQ(KX) ** 0.84*TDH**.40*(.49*WM+R)
C
C
  186 CONTINUE
C
C-----COMPUTE ANNUAL REPLACEMENT COST
C     FOR   HP < 6,999  REPLACEMENT COST OF 15  HAS BEEN ADDED TO ANNUAL
C                       MAINTENANCE COST
```

```
C
      IF(HP.LE.6999.)GO TO 182
C
C-----REPLACEMENT FOR PRIME MOVERS & PUMP---USE USBR RECL. INSTR.
C-----REPLACEMENT FOR ACCESSORY ELECTRICAL EQUIPMENT
      SFF = RINT/(((1.+RINT)**35.)-1.)
      REPM = CPMOT * 0.25 * SFF
C
      RCST=REPM+RELE
      RELE = CELEC * 0.25 * SFF
      GO TO 184
  182 RCST=0
  184 CONTINUE
C
C-----DETERMINE POWER COST--->>>ASSUME FLAT RATE $/KW
C     COMPUTE MONTHLY/ANNUAL POWER CONSUMPTION
C
      TKWR = 0.
C
      DO 30 KM=1,NW
      HKWR = HP*24.*30.4*.746*WRQ(KM)/RAT
      TKWR = TKWR + HKWR
   30 CONTINUE
C-----TOTAL ANNUAL POWER COST
      TPWR = TKWR * PWCST
C
C---COMPUTE ANNUAL POWER COST-BUILDING OWN LINE
C     O AND M OF TRANS LINE
      IF(IVOLT.EQ.1)OMC = 65.
      IF(IVOLT.EQ.2)OMC = 85.
      IF(IVOLT.EQ.3.OR.IVOLT.EQ.4)OMC = 100.
      OMC = OMC * OMINX * 1.75/1.
      TOMC = TRLIN * OMC
C---O & M OF SUB
      SOMC = TKVA * .35 * OMINX * 1.75/1.
C---TOTAL O & M
      TOS = TOMC + SOMC
C---TOTAL POWER COST
      TPOW1 = ATRAN + TOS + TPWR
C---COMPUTE POWER COST---BASED ON WHEELING CHARGE
C      ASSUME 18 PERCENT OF TOTAL CONSTRUCTION COST OF POWER LINE
      TPOW2 = TSWEN * 18./100.
C---COMPUTE ANNUAL POWER COST---PRIVATE UTILITY
      CALL POWCST(CDEM,TENER,NW,WRQ,RAT,HP,LP,MINQ)
      TPOW3 = CDEM + TENER
C---FIND LEAST COST AMONG THE 3 ALTERNATIVES
      TPOW4 = TPOW1
      IF(TPOW2.LT.TPOW4)TPOW4 =TPOW2
      IF(TPOW3.LT.TPOW4)TPOW4 =TPOW3
      TPOW5=TPOW1*EACF
      TPOW6=TPOW2*EACF
      TPOW7=TPOW3*EACF
      TPOW4=TPOW4*EACF
C
C-----TOTAL ANNUAL COST
C
      CTANN(KX)= PCOST + COP + CMN + RCST + TPOW4
      IF(RCST.EQ.0.)GO TO 190
      WRITE(6,188)PMQ(KX),HP,PMENG,PCOST.COP,CMN,RCST,TPOW4,CTANN(KX)
      GO TO 49
  190 WRITE(6,192)PMQ(KX),HP.PMENG,PCOST.COP,CMN,      TPOW4,CTANN(KX)
  188 FORMAT(F7.0,F12.0,2F15.0.2F13.0,F11.0,    T87,F11.0,F17.0)
  192 FORMAT(F7.0,F12.0,2F15.0.2F13.0,T79,'---6/',T87,F11.0,F17.0)
C
   49 CONTINUE
C
  310 NO = KX
C
      WRITE(6,194)
  194 FORMAT(///,T15,'NOTE:'//T17,'1/ WEAR ALLOWANCE WAS INCLUDED.'/
     ' T17,'2/ HORSEPOWER USED WAS ROUNDED TO THE NEAREST 5 HP.'/
     ' T17,'3/ INCLUDES INDIRECT COSTS.'/
     ' T17,'4/ INCLUDES TRANS. AND SW BAY COSTS IF APPLICABLE.'/
     ' T17,'5/ ANNUAL PUMPING COST INCLUDES ANNUAL EQUIV.  COST OF PUMPI
     'NG PLANT, OM AND R, AND POWER COST.'/
     'T17,'6/ 15 PERCENT FOR REPLACEMENT WAS ADDED TO MAINTENANCE COST')
      WRITE(6,256)UNITS
  256 FORMAT(1H1,///,T15,'SUMMARY OF PUMPING PLANT DATA:'//
     &T15,'NUMBER OF PUMPING UNITS                        ',F7.0)
      IF(TYPE.EQ.1.)WRITE(6,257)
      IF(TYPE.EQ.2.)WRITE(6,258)
  257 FORMAT(T15,'TYPE OF PUMPING UNIT----VERTICAL PUMP')
  258 FORMAT(T15,'TYPE OF PUMPING UNIT----HORIZONTAL TYPE')
```

```
     +T15,'DATE OF ESTIMATE                          ',2X,I2,'/',I2/)
      WRITE(6,360)CAP.CIMP,CWAYS.CPMOT.CELEC,CMISC.CSWIT,PMCT
  360 FORMAT(//T15.'CHECK COST FOR THE LAST ''Q'' CONSIDERED:'//
     +T15,'PLANT CAPACITY, CFS                       ',F8.0//
     +T15,'STRUCTURES AND IMPROVEMENTS               ',F8.0/
     +T15.'WATERWAYS                                 ',F8.0/
     +T15.'PUMPS AND MOTORS                          ',F8.0/
     +T15,'ELECTRICAL ACCESSORIES                    ',F8.0/
     +T15.'MISCELLANEOUS EQUIPMENT                   ',F8.0/
     +T15.'SWITCHYARDS                               ',F8.0//
     +T15,'SUBTOTAL OF PUMPING PLANT             ',T56,F8.0/)
      WRITE(6,361)PMCT2,PMCT3,PMCST,PMCT4,PMENG
      WRITE(6,363)TCPMIL.TCP1,TCP2,TCP3.TCP4,SUBTLC,TSWB,TRSWC,FTW,
     ' TSW1,TSWEN
C
  363 FORMAT(
     ' T15,'TRANSMISSION LINE COST',T56.F8.0/
     ' T15,'ADD 50 PERCENT FOR MOUNTAINOUS TERRAIN',T56.F8.0/
     ' T15,'ADD 50 PERCENT FOR ROCKY/SWAMPY FOUND.',T56,F8.0/
     ' T15,'ADD 100 PERCENT FOR LINE UNDER 5 MILES',T56,F8.0/
     ' T15,'ADD 50 PERCENT FOR LINE 5 TO 20 MILES',T56,F8.0/
     ' .T15,'SUBTOTAL',T56,F8.0/
     ' T15,'SWITCHING BAY COST',T56,F8.0/
     ' T15,'CONTINGENCIES (TL AND SB)',T56,F8.0/
     ' T15,'TOTAL FIELD COSTS ',T56,F8.0/
     ' T15,'INDIRECT COST',T56,F8.0/
     ' T15,'TOTAL POWER LINE CONSTRUCTION COSTS',T56,F8.0//)
  361 FORMAT(T15,'COST OF INTAKE, DISCHARGE LINES, ETC.',T56,F8.0/
     ' T15,'CONTINGENCY COST',T56,F8.0/
     ' T15,'PUMP FIELD COST',T56.F8.0/
     ' T15,'INDIRECT COST',T56.F8.0//
     ' T15,'PUMP TOTAL CONSTRUCTION COSTS',T54,F10.0/)
      WRITE(6,365) TPOW1,TPOW5,TPOW2,TPOW6,TPOW3,TPOW7
  365 FORMAT(
     ' T56,'PRESENT RATE',T70,'INFLATED RATE OVER LIFE'/
     ' T15,'ANNUAL POWER COST---OPT 1 F.RATE,OWN LINE',T56,F8.0,T70,F8.0
     '/T15,'ANNUAL POWER COST---OPT 2 WHEELING CHARGE',T56,F8.0,T70,F8.0
     '/T15,'ANNUAL POWER COST---OPT 3 PRIVATE UTILITY',T56,F8.0,T70,F8.0
     '/)
      GO TO 222
C
C-----AT THIS POINT. READ DATA ON ON-FARM UNITS  WITH DEEP WELL
C     INSTALLATION IF DESIRED --GO TO SUBROUTINE'FARMP'
C
  210 CALL FARMP(PMQ,CTANN,NO,TITLE)
C
  222 CONTINUE
      KXQ = KXQ + 1
      IF (KXQ.LT.7) GO TO 70
      KXQ = 0
      WRITE (6,255)
  255 FORMAT('1',///)
   70 WRITE(6,260) TITLE
  260 FORMAT(   ///,10X,20A4)
C
C   DETERMINE LINEAR REGRESSION COEFFICIENTS FOR THE DATA OBTAINED
      CALL REGLIN (PMQ,CTANN,NO,AC,BC,R)
  675 CONTINUE
      WRITE(9,417)
      GO TO 1
   98 RETURN
      END

C
      SUBROUTINE FARMP(FMX,FTANN,KZ,TITLE)
C
C     SUBROUTINE FARMP COMPUTES THE ANNUAL COST OF AN ON-FARM PUMP UNIT
C     FOR A GIVEN DATA
C
      DIMENSION TITLE(18),A(75),WRQ(12),FMX(500),FTANN(500),PMQ(500)
  200 FORMAT(/,'  TYPE THE FF ON-FARM PUMP DATA IN THIS ORDER'/
     + ' 1-TOTAL DYNAMIC HEAD IN FEET'/
     + ' 2-COST INDEX FOR PUMP FACILITIES, BASE YEAR IS 1976'/
     + ' 3-CODE FOR THE TYPE OF PUMPING UNIT  (1) FOR CENTRIFUGAL'/
     + '                                      (2) FOR VERT. TURBINE'/
     + ' 4-EFFICIENCY OF PUMPING UNIT, PERCENT'/
     ' ' 5-MISC. COSTS (SUMP,DISCHARGE LINES, ETC.), PERCENT  '/
     ' '    COST OF PUMPING UNIT'/
     ' ' 6-CONTINGENCY COST. PERCENT OF FIELD COST'/)
  201 FORMAT (/,'  TYPE THE FF DATA:'/
     + ' 1-SERVICE LIFE OF PUMPING UNIT. YEARS'/
     + ' 2-INTEREST RATE, PERCENT'/
     + ' 3-SALVAGE VALUE. PERCENT OF INITIAL INVESTMENT'/
     - ' 4-OTHER EXPENSES, PERCENT OF INITIAL INVESTMENT'/
```

```
  203 FORMAT(/,' TYPE O&M AND TAX,INSURANCE AS A PERCENT OF INVESTMENT'/
     &)
  204 FORMAT(/, ' TYPE THE FOLLOWING DATA FOR DEEP WELLS, IF NONE '/
     & ' --ENTER(0., 0., 0.,0.,0.,0.)'/
     & ' 1-LIFE OF WELL, YEARS'/
     & ' 2-INTEREST RATE, PERCENT'/
     & ' 3-SALVAGE VALUE OF WELL'/
     & ' 4-TYPE OF DEEP WELL....(1) WELL IN ALLUVIUM'/
     & '                        (2) WELL IN HARD ROCK'/
     ' ' 5-MISC. COSTS (DISCHARGE LINES, HOUSING, ETC.), PERCENT'/
     ' '    COST OF PUMPING UNIT'/
     ' ' 6-CONTINGENCY COST, PERCENT OF FIELD COST'/
     ' ' 7-DEPTH OF WELL, FEET'/)
  205 FORMAT(/,'  TYPE STARTING Q(GPM), FINAL Q(GPM) AND Q INTERVAL'/)
C
C-----READ HEAD,COST INDEX,CODE,EFF
      WRITE(9,200)
      CALL INPUT(A,NF)
C
C         ' TDH = TOTAL DYNAMIC HEAD
C         ' CIDX= COST INDEX FOR PUMP FACILITIES  BASE YEAR = 1976
C         ' IPCOD=CODE FOR THE TYPE OF PUMP UNIT
C                1=CENTRIFUGAL PUMP
C                2=VERTICAL TURBINE PUMP
C         ' EFF = EFFICIENCY OF PUMP-MOTOR
C
      TDH = A(1)
      CIDX= A(2)
      IPCOD=A(3)
      EFFI = A(4)
      EFF = EFFI/100.
      XMISC = A(5)/100.
      CONTP = A(6)/100.
C
C
C-----READ LIFE,INTEREST,SALVAGE VALUE FOR PUMP
      WRITE(9,201)
      CALL INPUT(A,KL)
C
C         ' TLFE = LIFE OF PUMPING UNIT,YEARS
C         ' RINT = INTEREST RATE,PERCENT
C         ' SALV = SALVAGE VALUE,  OF INVESTMENT
C         ' ESCP = ESCALATION RATE OF POWER, PERCENT
      TLFE=A(1)
      RINT=A(2)/100.
      SVAL=A(3)
      OEXP=A(4)/100.
      ESCP=A(5)/100.
C
C-----COMPUTE EQUIVALENT ANNUALIZED COST FACTOR FOR ESCALATION OF POWER
C     OVER LIFE OF SYSTEM
C
      EACF=(((1.+ESCP)**TLFE-(1.+RINT)**TLFE)/(ESCP-RINT))*RINT/
     & ((1+RINT)**TLFE-1.)
C
C-----READ AVERAGE MONTHLY IRRIG. REQ.
      WRITE(9,202)
      CALL INPUT(A,NW)
      DO 14 K=1,NW
   14 WRQ(K)=A(K)
C
C         SORT WRQ AND DETERMINE THE PROPORTION OF WATER VOLUME PUMPED
C         EACH MONTH TO THE VOLUME PUMPED AT PEAK MONTH
C
      RAT = WRQ(1)
      DO 15 KW = 2,NW
      KW1 = KW - 1
      IF(WRQ(KW).GT.WRQ(KW1))RAT = WRQ(KW)
   15 CONTINUE
C
C
C---- READ O&M AND TAX&INS. AS A PERCENT OF INVESTMENT
      WRITE(9,203)
      CALL INPUT(A,NOM)
C         ' OMR= OPERATION & MAINTENANCE COST,  OF AVE. INV.
C         ' TAX= TAXES AND INSURANCE,    OF AVE INV.
      OMR=A(1)/100.
      TAX=A(2)/100.
C
C
C-----READ LIFE,INT,SVAL OF DEEP WELLS
      WRITE(9,204)
      CALL INPUT(A,LF)
C         ' TLFW = LIFE OF WELL
```

```
C      ' SVAW = SALVAGE VALUE
      TLFW = A(1)
      RINW = A(2)/100.
      SVAW = A(3)
      NWEL = A(4)
      WMISC = A(5)/100.
      CONTW = A(6)/100.
      DEPTH = A(7)
C---- READ RANGE OF Q CONSIDERED
       WRITE(9,205)
      CALL INPUT(A,KT)
      MINQ = A(1)
      MAXQ = A(2)
      KNTQ = A(3)
C
C     WRITE  HEADING
      WRITE(6,221)TITLE
  221 FORMAT(1H1,T30,18A4)
C
      WRITE(6,226)
  226 FORMAT(///,T43,'PUMP',T112,'WELL   PUMPING'/T6,  'Q        H.P. 1
     &/  PUMP COST 2/   FIXED COST       O & M 3/  TAXES & INS.   POWER
     & COST   WELL COST 4/ FIXED COST COST 5/',/,T4,'  (GPM)      USED
     &          ($)          ($/YR)          ($/YR)      ($/YR)
     $ ($)          ($)          ($/YR)    ($/YR)'/)
C
      KX=0
      DO 50 LP=MINQ,MAXQ,KNTQ
      KX=KX+1
      PMQ(KX)=LP
C
C       COMPUTE HORSEPOWER---PMQQ IS IN GPM
C
      HP1=PMQ(KX)*TDH/(3960.*EFF)
      HP2=0.
      DO  55 KJ=1,5000
      HP2=HP2+5.
      IF(HP1.LT.HP2)GO TO 56
   55 CONTINUE
   56 HP=HP1
C
C---- TYPE OF PUMP UNIT DESIRED ?
      IF(IPCOD.EQ.2)GO TO 57
C
C---------COST OF>>>CENTRIFUGAL PUMP
C     COST EQUATION USED BASED ON DATA SUPPLIED BY USBR
      PMCST =((1./10.97)* (TDH* PMQ(KX))**.899) * CIDX
      GO TO 58
   57 CONTINUE
C---------COST OF>>>VERTICAL TURBINE PUMP
      PMCST = (73.14*(TDH*PMQ(KX))**.3554)*CIDX
C-----ADD OTHER COST SUCH AS SUMPS,INTAKE,DISCHARGE LINES,ETC.
   58 CONTINUE
C
C
      PMCST = PMCST + PMCST*XMISC
      PMCST = PMCST + PMCST * CONTP
C-----PUMP ANNUAL COST EQUIVALENT
      PCOST = PMCST*(RINT*(1.+RINT)**TLFE)/(((1.+RINT)**TLFE)-1.)
     &-SVAL*.01*PMCST*RINT/(((1.+RINT)**TLFE)-1.)
C
C---- ANNUAL O&M COST
C     COMPUTE AVERAGE INVESTMENT
C
      AVE =(PMCST + SVAL*PMCST/100.)/2.
C
      COM = PMCST * OMR
C
C-----TAXES AND INSURANCE
      CTX = AVE * TAX
C
C-----COMPUTE WELL COST
C     TYPE OF WELL------?
      IF(NWEL.EQ.0) GO TO 63
      IF(NWEL.EQ.2)GO TO 60
C
C---- COST OF ALLUVIUM WELL WITH SCREEN
C     COST EQUATION BASED ON DATA SUPPLIED BY USBR
      CWELL =(2550.* PMQ(KX)**.239)*CIDX*DEPTH/300.
      GO TO 62
C
C-----COST OF WELL IN HARD ROCK -PARTIALLY OPEN HOLE
   60 CWELL =(3000.* PMQ(KX)**.350) * CIDX *DEPTH/300.
C
```

```
   62 CWELL = CWELL *(WMISC + 1.)
      CWELL = CWELL *(CONTW + 1.)
C
C-----ANNUAL COST EQUIVALENT OF WELL
      WELCT =CWELL *(RINW*(1.+RINW)**TLFW)/(((1.+RINW)**TLFW)-1.) -
     &SVAW *.01* CWELL*RINW/(((1.+RINW)**TLFW)-1.)
C
      GO TO 61
   63 WELCT = 0.
C
C---- COMPUTE POWER COST
C
   61 FMX(KX)= PMQ(KX)
      CALL POWCST(CDEM,TENER,NW,WRQ.RAT,HP,LP,MINQ)
      CPWR = CDEM + TENER
      TPWR = CPWR*EACF
C
C
C-----TOTAL PUMPING COST
C
      FTANN(KX) = PCOST + COM + CTX + TPWR + WELCT
C
      WRITE(6,70) PMQ(KX),HP,PMCST,PCOST,COM,CTX,TPWR,CWELL,WELCT,FTANN(
     &KX)
   70 FORMAT(F7.0,F11.0,F16.0,F13.0,F16.0,F14.0,F13.0,F11.0,F13.0,F11.0)
C
   50 CONTINUE
C
      KZ = KX
C
      WRITE(6,72)
C
   72 FORMAT(//T15,'NOTE:'//T15,'1/ HP USED WAS ROUNDED TO THE NEAREST 5
     '.0 HP'/T15,'2/ PUMP COST INCLUDES HOUSING,DISCHARGE FACILITIES,SUM
     'P,ETC.'/T15,'3/ O & M INCLUDES MINOR REPLACEMENT COST'/T15,'4/ WEL
     'L COST INCLUDES DRILLING, CASING,TESTING,SCREEN ASSEMBLY,ETC.'/
     'T15,'5/ ANNUAL PUMPING COST INCLUDES AMORTIZATION OF PUMP UNIT AND
     ' WELL, O & M, TAXES & INSURANCE AND POWER COST'/)
C
      ESCP1=ESCP*100.
      WRITE(6,150) CPWR,ESCP1,TPWR
  150 FORMAT(///,T10,'TOTAL ANNUAL PUMPING COST AT PRESENT PRICES..',T65
     -,F6.0,
     -/T10,'TOTAL ANNUAL PUMPING COST AT ENERGY INFLATION RATE OF',F6.2,
     -' PERCENT',
     -/T10,'OVER PROJECT LIFE...',T65,F6.0/)
      WRITE(6,99)TDH,EFFI
   99 FORMAT(///,T10,'TOTAL DYNAMIC HEAD, FEET.....',T45,F6.0,
     ' /T10,'PUMP-MOTOR EFF, PERCENT.....',T45,F6.0)
      RETURN
      END

C--SUBROUTINE POWCST
C
C  THIS SUBROUTINE COMPUTES POWER COST FOR ON-FARM PUMPS
C  COMPUTATION OF COST IS BASED ON THE FOLLOWING ASSUMPTIONS:
C     1. MONTHLY POWER RATE IS GIVEN AS $/KW---FOR THE FIRST XX.X KW;
C        $/KW---FOR THE NEXT XX.X KW; AND SO ON.....
C     2. MONTHLY ENERGY RATE IS GIVEN AS $ OR  /KWH---FOR THE FIRST
C        XX.X KWH;  /KWH FOR THE NEXT XX.X KWH; AND SO ON......
C        THE ENERGY RATE MAY ALSO BE BASED ON A PER KW BASIS.
C
      SUBROUTINE POWCST(CDEM,TENER,NW,WRQ,RAT,HP,LP,MINQ)
C/    LIST,NONE
C/    LIST,NONE
      DIMENSION A(30),DCST(10),DW(10),CKW(10),EKW(10),K(10),WRQ(10)
      DIMENSION KODE(10),SHPL(10),SHPH(10),SMOR(10)
C
      DATA YS/3HYES/
C
C
  102 FORMAT(/,' TYPE MONTHLY DEMAND RATE SCHEDULE (POWER COST) '/
     & 'DATA MUST BE ENTERED AS---XXX.X $/KW:  FIRST XXX.X KW '/
     & '                          XXX.X $/KW:  SECND XXX.X KW '/
     ' '                          ----AND SO ON.............'/
     & ' (I.E----2.53,100.,1.66.101)'/)
  104 FORMAT(/,'TYPE MONTHLY ENERGY RATE SCHEDULE'/
     & ' DATA MUST BE ENTERED AS---XX.X CENT.FIRST XX.X KWH; KODE'/
     ' '                           XX.X CENT,SECND XX.X KWH; KODE'/
     ' '                           -------AND SO ON............'/
     & ' CODE USED------(1) WHEN ENERGY RATE IS PER KW'/
     & '                (0) WHEN ENERGY RATE IS NOT BASED ON KW'/
     & ' (I.E.----2.459,100..1.  1.463,5000.,0.  1.01,50001.,0.)'/)
C
C
```

```
      WRITE(9,101)
  101 FORMAT(/,' IS DEMAND CHARGE BASED ON FLAT RATE FOR'/
     ' ' CERTAIN RANGE OF HP ---   , I.E. FOR HP 0-3, $5.00/KW/MO'/
     ' ' (YES OR NO)'/)
      READ(5,103)YSS
      WRITE(9,103)YSS
  103 FORMAT(A3)
      IF(YS.NE.YSS)GO TO 3
      WRITE(9,105)
  105 FORMAT(/,' TYPE MONTHLY DEMAND CHARGE FOR EACH RANGE OF HP'/
     ' ' DATA MUST BE ENTERED AS--- XX.X TO XX.X HP; $XX./KW/MO'/
     ' ' (I.E.---0. TO 3.  HP;  $ 5.0/KW/MO)'/)
      CALL INPUT (A,I)
      DO 107 M=3,I,3
      SHPL(M/3) = A(M-2)
      SHPH(M/3) = A(M-1)
      SMOR(M/3) = A(M)
  107 CONTINUE
      I = I/3
      GO TO 109
    3 WRITE(9,102)
C
C                   <-------------------------READ CARD-----------
C---READ MONTHLY DEMAND RATE SCHEDULE
C   DATA MUST BE ENTERED AS-- XX.X $/KW;  FIRST XX.X KW....
C
      CALL INPUT(A,ND)
      DO 2 N=2,ND,2
      DCST(N/2) = A(N-1)
      DW(N/2) = A(N)
    2 CONTINUE
      ND=ND/2
C
C                   <-------------------------READ CARD-----------
C---READ MONTHLY ENERGY RATE SCHEDULE
  109 WRITE(9,104)
C   DATA MUST BE ENTERED AS  XX.XX    , FIRST XXX.X KWK ,KODE
C        KODE = 1. WHEN ENERGY RATE IS PER KW
C        KODE = 0. WHEN ENERGY RATE IS NOT BASED ON KW
      J=1
      CALL INPUT(A,NE)
      DO 4 L=1,NE,3
      CKW(J) = A(L) / 100.
      EKW(J) = A(L+1)
      KODE(J) = A(L+2)
      K(J)=KODE(J)
      J=J+1
    4 CONTINUE
      NE=NE/3
  100 CONTINUE
C
C---COMPUTE DEMAND CHARGE
C
      ZNW = NW
      HPW=HP * 0.746
      IF(YSS.EQ.YS)GO TO 112
C
C
      DW1= HPW - DW(1)
      IF(ND.EQ.2) GO TO 11
      DW2= DW1 - DW(2)
      IF(ND.EQ.3) GO TO 12
      DW3= DW2 - DW(3)
      IF(ND.EQ.4) GO TO 13
      DW4= DW3 - DW(4)
C
      CDEM=DW(1) * DCST(1) + DW(2) * DCST(2) + DW(3) * DCST(3) +
     &     DW(4) * DCST(4) + DW4 * DCST(5)
      IF(HPW.LT.DW(1)) CDEM=HPW*DCST(1)
      IF(HPW.GT.DW(1).AND.HPW.LT.DW(2)) CDEM=DW(1)*DCST(1)+DW1*DCST(2)
      IF(HPW.GT.DW(2).AND.HPW.LT.DW(3)) CDEM=DW(1)*DCST(1)+DW(2)*DCST(2)
     & +DW2*DCST(3)
      IF(HPW.GT.DW(3).AND.HPW.LT.DW(4)) CDEM=DW(1)*DCST(1)+DW(2)*DCST(2)
     & + DW(3)*DCST(3)+DW3*DCST(4)
      GO TO 14
   13 CDEM=DW(1) * DCST(1) + DW(2) * DCST(2) + DW(3) * DCST(3) +
     *     DW3   * DCST(4)
      IF(HPW.LT.DW(1)) CDEM=HPW*DCST(1)
      IF(HPW.GT.DW(1).AND.HPW.LT.DW(2)) CDEM=DW(1)*DCST(1)+DW1*DCST(2)
      IF(HPW.GT.DW(2).AND.HPW.LT.DW(3)) CDEM=DW(1)*DCST(1)+DW(2)*DCST(2)
     & + DW2*DCST(3)
      GO TO 14
   12 CDEM=DW(1) * DCST(1) + DW(2) * DCST(2) + DW2   * DCST(3)
      IF(HPW.LT.DW(1)) CDEM=HPW*DCST(1)
```

```
      GO TO 14
   11 CDEM=DW(1) * DCST(1)  + DW1   * DCST(2)
      IF(HPW.LT.DW(1)) CDEM=HPW*DCST(1)
      GO TO 14
C
C
C---COMPUTE ENERGY COST
  112 RXX = 0.
      DO 116 M=1,I
      IF(HP.GE.SHPL(M).AND.HP.LE.SHPH(M)) RXX = SMOR(M)
      IF(RXX.NE.0)GO TO 118
  116 CONTINUE
  118 CDEM = HPW * RXX * ZNW
C
   14 TENER = 0.
      DO 30 KM = 1,NW
      HKWR = HP * 24.* 30.4 * 0.746 * WRQ(KM) / RAT
C
      IF(K(1).EQ.1)EKW1 =EKW(1)*HPW
      IF(K(1).EQ.0)EKW1 =EKW(1)
      IF(NE.EQ.1)GO TO 35
      IF(K(2).EQ.1)EKW2 =EKW(2)*HPW
      IF(K(2).EQ.0)EKW2 =EKW(2)
      IF(NE.EQ.2)GO TO 35
      IF(K(3).EQ.1)EKW3 =EKW(3)*HPW
      IF(K(3).EQ.0)EKW3 =EKW(3)
      IF(NE.EQ.3)GO TO 35
      IF(K(4).EQ.1)EKW4 =EKW(4)*HPW
      IF(K(4).EQ.0)EKW4 =EKW(4)
      IF(NE.EQ.4)GO TO 35
      IF(K(5).EQ.1)EKW5 = EKW(5) * HPW
      IF(K(5).EQ.0)EKW5 = EKW(5)
C
   35 CONTINUE
      IF(HKWR.GT.EKW1) GO TO 32
      CENER = HKWR*CKW(1)
      GO TO 36
   32 IF(NE.EQ.2)GO TO 33
      IF(HKWR.GT.(EKW1+EKW2))GO TO 34
   33 CENER = CKW(1)* EKW1 + CKW(2)*(HKWR-EKW1)
      GO TO 36
   34 IF(NE.EQ.3) GO TO 37
      IF(HKWR.GT.(EKW1+EKW2+EKW3))GO TO 38
   37 CENER=EKW1*CKW(1)+EKW2*CKW(2)+(HKWR-EKW1-EKW2)*CKW(3)
      GO TO 36
   38 IF(NE.EQ.4)GO TO 39
      IF(HKWR.GT.(EKW1+EKW2+EKW3+EKW4))GO TO 40
   39 CENER=EKW1*CKW(1)+EKW2*CKW(2)+EKW3*CKW(3)+
     ↰(HKWR-EKW1-EKW2-EKW3)*CKW(4)
      GO TO 36
   40 IF(NE.EQ.5)GO TO 41
      IF(HKWR.GT.(EKW1+EKW2+EKW3+EKW4+EKW5))GO TO 42
   41 CENER=EKW1*CKW(1)+EKW2*CKW(2)+EKW3*CKW(3)+EKW4*CKW(4)    +
     ↰(HKWR-EKW1-EKW2-EKW3-EKW4)*CKW(5)
      GO TO 36
   42 CENER=EKW1*CKW(1)+EKW2*CKW(2)+EKW3*CKW(3)+EKW4*CKW(4)+EKW5*CKW(5)
     ↰ + (HKWR-EKW1-EKW2-EKW3-EKW4-EKW5)*CKW(6)
C
   36 CONTINUE
      TENER = TENER + CENER
C
C
C
   30 CONTINUE
C
      RETURN
      END
```

```
     +(W,X,Y,Z,MONTH,IYEAR,IVOLT,A)
      INTEGER A
      REAL INFLAT
      DIMENSION IB(4),IX(30,4),A(6),B(4)
      DATA  IB/104,101,103,102/
      DATA  IX/83,83,83,83,85,87,89,90,92,96,98,101,104,108,111,116,
     +121,129,134,141,145,150,153,158,163,173,192,211,216,225,
     +90,92,94,94,96,96,96,97,97,99,99,101,101,104,105,108,110,113,
     +117,121,126,130,133,138,142,159,181,190,197,200,
     +82,84,84,84,86,88,89,90,92,96,98,102,103,108,111,117,122,131,
     +136,143,147,152,156,160,165,176,190,198,202,209,
     +85,85,85,85,85,86,88,90,92,96,98,101,102,105,107,111,114,120,
     +125,130,133,136,139,142,146,159,179,190,194,199/
      NI = 30
      YR = 62.
      INFLAT = 1.035
C
C     INDEX
C
      YEAR = (MONTH - 1) / 12. + IYEAR
      K = (YEAR - YR) * 2. + 1.001
      DO 120 I=1,4
        IF (K .LT. NI) GO TO 100
        LOW = IX(NI,I) * INFLAT**(K-NI)
        HIGH = IX(NI,I) * INFLAT**(K-NI+1)
        GO TO 110
  100   LOW = IX(K,I)
        HIGH = IX(K+1,I)
  110   B(I) = ((YEAR - (K-1) / 2. - YR) * (HIGH - LOW) * 2. + LOW)
     +  / IB(I)
  120 CONTINUE
C
C     CALC COSTS FROM APPENDIX A
C
      IF (Y .GT. 1)  GO TO 130
      PUMPS = (((8.05961E-6*Z-.007599)*Z+7.75271) * Z + 606.894) * W
      Y = 1
      GO TO 140
  130 PUMPS = (((4.24579E-6 * Z - 1.18664E-3) * Z
     ++ 3.40044) * Z + 611.183) * W
      Y = 2
  140 IF (PUMPS .GT. 1.5E5)  GO TO 150
      BLDG = .9533*PUMPS**(23.2/21.8)
      GO TO 160
  150 BLDG = 27.559*PUMPS**(23.6/30.1)
  160 QH = W * Z
      ANUM = X
      ELECT = (12.9-7.1*ANUM+86.2*ANUM**.5)*QH**(27.2/41.5)
      EQUIP = 11.8107*PUMPS**(.43337+1.3858E-2*ALOG(PUMPS))
      PWR = .1625*QH
      GO TO (170,180,190,200),IVOLT
  170 YARD = 15022.6+613.187*SQRT(PWR)
      GO TO 210
  180 YARD = 19428.8+630.611*SQRT(PWR)
      GO TO 210
  190 YARD = 26616+670.354*SQRT(PWR)
      GO TO 210
  200 YARD = 47116.2+702.84*SQRT(PWR)
  210 A(1) = BLDG * B(2)
      A(2) = PUMPS * (.3 * B(1) + .2 * B(3))
      A(3) = PUMPS * B(1)
      A(4) = ELECT * B(3)
      A(5) = EQUIP * B(3)
      A(6) = YARD * B(4)
      DO 220 I=1,6
        CALL IROUND (A(I))
  220 CONTINUE
      RETURN
      END

      SUBROUTINE IROUND(JA)
      B=JA/1000.
      IB=B
      IA=IB*1000
      C=JA-IA
      IF(C.GT.100.) IA=IA+1000
      JA=IA
      RETURN
      END
```

```
C
C
C
C     ////////////////////////////////////////////////////////////////////
C     /                                                                  /
C     /                                                                  /
C     /                                                                  /
C     /                        *** DYNAMIC PROGRAM ***                   /
C     /                                                                  /
C     /                                                                  /
C     /                                                                  /
C     ////////////////////////////////////////////////////////////////////
C     /                                                                  /
C     /                                                                  /
C     /                                                                  /
C     /        THIS PROGRAM IS USED TO COMPUTE FEASIBLE IRRIGATION       /
C     /        DISTRIBUTION SYSTEM COMPONENT COMBINATIONS                /
C     /                                                                  /
C     /        COMBINATIONS ARE SELECTED ON THE BASIS OF TOTAL COSTS     /
C     /        AND CONVEYANCE EFFICIENCIES USING THE THEORY OF           /
C     /        DYNAMIC OPTIMIZATION                                      /
C     /                                                                  /
C     /                                                                  /
C     /                                                                  /
C     ////////////////////////////////////////////////////////////////////
C
C
C
C
C     --- DEPT AGRICULTURAL ENGINEERING - UNIV. IDAHO ---
C            ....R.G.ALLEN......J.R.BUSCH....
C
C
C     ...THIS PROGRAM CAN MANIPULATE, AT THE PRESENT TIME, A WATER
C        CONVEYANCE SYSTEM WITH AS MANY AS 12 SECTIONS OR REACHES
C        AND AS MANY AS SIX COMPONENT ALTERNATIVES PER SECTION...
C     ...A TOTAL OF SIX HUNDRED COMPONENT COMBINATIONS CAN BE CARRIED
C        BY THIS PROGRAM...
C
C     ...IF MORE SECTIONS OR COMBINATIONS ARE REQUIRED, MANY OF THE
C        FOLLOWING DIMENSIONAL ARRAYS WILL NEED TO BE EXPANDED...
C
C
C
      INTEGER*2 CC(1800,12),CB(1800,12)
      INTEGER*2 SUFFIX(4)
      DIMENSION KPRUNE(1800)
      DIMENSION JDS(32)
      DIMENSION IDA(9)
      DIMENSION SUMA(1800),TUMA(1800),TEFF(600,12)
      DIMENSION SEFF(1800,12),DINH(1800,12)
      DIMENSION NRB(5), TEFF1(600,12)
      DIMENSION TDIH(600,12), TDINH(600,12)
      DIMENSION E(9), A(9), B(9), IN(9)
      DIMENSION CH(1800),CL(1800)
      DIMENSION SEC(12,10,10), SECT(12,10,10)
      DIMENSION DL(32), DH(32), DD(32)
      DIMENSION KCON(6,6), NTI(1800),LCST(1800),Z(10)
      DIMENSION KCOMP(6,6,6)
      DIMENSION IDS(12), AID(12), QMAX(1800),QMIN(1800)
      DIMENSION ID(6), JKJ(32)
C
C
C     INITIALIZE
C
      DATA SEC, SECT /2400*0./
      DATA ID/6*0/
      DATA KCON /36*0/
      DATA KCOMP /216*0/
      DATA CB, CC /43200*0/
      DATA TUMA, TDINH, TDIH /16200*0./
      DATA SUMA, CH, CL, SEFF, DINH /48600*0./
      DATA TEFF, TEFF1 /14400*1./
      DATA SUFFIX /2HST,2HND,2HRD,2HTH/
      DO 100 J = 1,5
      NRB(J) = 1
  100 CONTINUE
      DO 101 JJ = 1,32
      JKJ(JJ) = JJ
      DL(JJ) = 0.
      DH(JJ) = 0.
      DD(JJ) = 0.
  101 CONTINUE
C
```

```
      MDU = -1
      NDU = -1
      KDW = -1
      MDW = -1
      NDW = -1
    9 FORMAT(5X,'INPUT THE VALUE FOR EMARGN  (ALLOWABLE DIFFERENCE'./
     &        5X,'BETWEEN EFFICIENCIES OF COMBINATIONS AND STILL PRUNE)'
     &        /)
      WRITE(9,9)
      CALL INPUT(Z.ND)
      EMARGN = Z(1)
C
      WRITE(6.13) EMARGN
   13 FORMAT(5X,'EMARGN =',F10.6/)
C
C
C     .... EMARGN  IS USED TO PRUNE ADDITIONAL COMBINATIONS WHERE
C          COMBINATION COSTS MAY BE QUITE DIFFERENT, BUT THE EFFICIENCIES
C          ARE QUITE SIMILAR.   A MORE EXPENSIVE COMBINATION MUST HAVE
C          AN OVERALL CONVEYANCE EFFICIENCY HIGHER THAN EMARGIN PLUS
C          THE EFFICIENCY OF THE COMBINATION IT IS BEING COMPARED TO ....
C
C
C
    4 FORMAT(1H1,5X)
    5 FORMAT(//5X,'THIS DYNAMIC PROGRAMMING PROGRAM IS USED TO ELIMINATE
     *'/5X.'LESS EFFICIENT AND MORE COSTLY DISTRIBUTION SYSTEM'/5X,
     *'COMPONENT COMBINATIONS'/)
C
    7 FORMAT(5X,'TYPE COMPONENT (ALTERNATIVE) CODES CONSIDERED'/5X.
     *'FOR THIS SYSTEM:'/5X,
     *'USE THE FOLLOWING CODES:'/
     *'     1 - UNLINED CHANNEL'/
     *'     2 - CONCRETE LINED CHANNEL (UNREINFORCED PCC)'/
     *'     3 - GRAVITY PIPE'/
     *'     4 - CONCRETE LINED CHANNEL (REINFORCED PCC)'/
     *'     5 - ASPHALTIC LINED CHANNEL'/
     *'     6 - SHOTCRETE LINED CHANNEL'/)
C
    8 FORMAT(//,5X,'TYPE IN DATA FOR THE ',I2,A2,' SECTION ENTERED'/)
C
   10 FORMAT(//5X,'NOTE:   USE THE FOLLOWING STEPS AS A GUIDE FOR DATA '
     *,'ENTRY:',//
     *5X,'1.  SECTIONS (REACHES) MAY BE NUMBERED IN ANY PATTERN PREFERED
     * BY THE USER.'
     */9X,'(I.E., ID NUMBERS OF SECTIONS MAY BE OF ANY ORDER)...'/
     */
     *5X,'2.  SECTIONS MUST, HOWEVER, FOLLOW A SEQUENTIAL PATTERN OF'/
     *9X,'ENTRY INTO THIS PROGRAM...'/
     */
     *5X,'3.  ENTER SECTION DATA, STARTING WITH THE SECTION NEAREST'/
     *9X,'THE POINT OF THE SYSTEM DIVERSION, WORKING FROM THE SYSTEM'/
     *9X,'DIVERSION POINT TO THE TIP OF THE MAIN BRANCH...'/
     */
     *5X,'4.  ENTER ALL DATA FOR SECTIONS BRANCHING FROM THE MAIN'/
     *9X,'BRANCH AS THEY ARE ENCOUNTERED.  (SEE FIGURE 1)...'/)
   11 FORMAT(5X,'5.  ON EACH SPECIFIC SECTION, ENTER ONLY THE COMPONENT'
     */9X,'CODES CONSIDERED FOR THAT PARTICULAR SECTION...'/
     */
     *5X,'6.  IDENTIFY THE SUPPLYING SOURCE OF THE FIRST SECTION'/
     *9X,'(I.E., THE DIVERSION SOURCE) AS SECTION # 0 (ZERO)'///)
C
    3 FORMAT(///,1H1,////5X,/
     *'            10 (8)                                            '/,
     *'          .←←←←←←←.                                           '/,
     *'                  !                                           '/,
     *'                  ! 9                                         '/,
     *'                  !                                           '/,
     *'                  !(7)                                        '/,
     *'                  !                                           '/,
     *'                  !                                           '/,
     *'    5 (10)  4 (9) ! 3 (6)  2 (3)   1 (1)                      '/,
     *'  .←←←←←←←.←←←←←←←.←←←←←←←.←←←←←←←.←←←←←←←. DIVERSION (SOURCE)'/,
     *'                          !       !                           '/,
     *'                          ! 7     ! 6                         '/,
     *'                          !       !                           '/,
     *'                          !(4)    !(2)                        '/,
     *'                          !       !                           '/,
     $'                    8 (5) !       !                           '/,
     $'                  .←←←←←←←.       .                           '/,
     *//////,5X/)
C
    6 FORMAT(///,2X.'FIGURE 1. '.
     *' SECTIONS MAY BE IDENTIFIED AS SHOWN ABOVE.  NUMBERS IN'
     */13X.'PARENTHESIS DEPICT THE ORDER OF ENTRY INTO THIS PROGRAM.'
```

```
     *///////////)
C
   12 FORMAT(//,5X,'PROCESS SECTION NUMBER -----',I2,/)
C
   14 FORMAT(/5X,'TYPE THE FF DATA:'/
     *'  1 - SECTION IDENTIFICATION NUMBER'/
     *'  2 - MAXIMUM RATE OF DIVERSION FROM SECTION'/
     *'  3 - MINIMUM RATE OF DIVERSION FROM SECTION'/
     *'  4 - ID NUMBER OF SECTION SUPPLYING THE SECTION BEING READ IN'/
     *)
C
C
   16 FORMAT(/5X,'TYPE THE FF DATA'/
     *' 1 - COMPONENT CODE CORRESPONDING TO THE ABOVE TABLE'/
     *' 2 - Y-INTERCEPT OF COST FUNCTION'/
     *' 3 - SLOPE OF COST FUNCTION'/
     *' 4 - EFFICIENCY OF COMPONENT PERCENT'/
     *' 5 - IF COMPONENT(S) OF THE SUPPLYING SECTION'/
     *'            ARE NOT ALLOWED TO SUPPLY THIS SECTION,
     *'/9X,'   TYPE IN THE APPROPRIATE ID NUMBERS'/
     *'    NOTE: IF ALL COMPONENTS HAVE BEEN ENTERED'/
     *'    TYPE ---- ''NEXT'' IF ANOTHER SECTION FOLLOWS'/
     *'         ---- ''0.0'' IF THIS IS THE LAST SECTION TO PROCESS'/)
C
C
      WRITE(6,4)
      WRITE(6,5)
      WRITE(9,5)
C
C
C                 ////// READ IN GENERAL SECTION DATA //////
C
C
C         READ IN THE TABLE OF SECTION TYPES AND ASSOCIATED ID'S
C         ----- A TOTAL OF SIX (6) DIFFERENT COMPONET TYPES MAY BE
C               USED FOR ALL SECTIONS
C         ----- ENTER THE ID IN COLUMN 1 AND THE DESCRIPTIVE TITLE
C               BEGINNING IN COLUMN 2
C         ----- A BLANK CARD SIGNALS THE END OF INPUT
C
      WRITE(6,7)
      WRITE(9,7)
      CALL INPUT(Z,NR)
      IF(NR.EQ.0) Z(1) = 0.
      DO 102 KK = 1,NR
      ID(KK) = Z(KK)
  102 CONTINUE
C
C
C         .......  ALL SECTION DATA IS READ INTO THIS PROGRAM BEFORE
C                  ANY COMPUTATION IS PERFORMED..........
C
C
      WRITE(6,10)
      WRITE(6,3)
      WRITE(6,6)
      WRITE(9,10)
      WRITE(9,3)
      WRITE(9,6)
C
C
C                 ////// READ IN SECTION DATA /////
C
C
C         READ IN SECTION IDENTIFIER CARD
C         IDS ---- SECTION ID NUMBER
C         DH ----- MAXIMUM RATE OF DIVERSION FROM SECTION
C         DL ----- MINIMUM RATE OF DIVERSION FROM SECTION (I.E. FOR
C           LOW C.U. CROP WITH EFFICIENT APPLICATION SYSTEM)
C
C         TO TERMINATE THE PROGRAM, A ZERO (0) IS ENTERED FOR IDS
C
C         ... USE A POSITIVE INTEGER TO REFERENCE THE FIRST SECTION.
C             DO NOT USE ZERO ...
C
      NRC = 0
  103 NRC = NRC + 1
      NUME = NRC
      IF(NRC.GT.4) NUME = 4
      WRITE(6,8) NRC, SUFFIX(NUME)
      WRITE(9,8) NRC, SUFFIX(NUME)
      WRITE(9,14)
      CALL INPUT(Z,NO)
```

```
  104 SEC(NRC,K,1) = Z(K)
      WRITE(6,51) (Z(I5),I5=1,NO)
   51 FORMAT(//5X,'SECTION ',F3.0,'  DMAX =',F10.4, '  DMIN =',F10.4,
     *'  SUPPLYING SECT =',F3.0,5F2.0/)
C
C
C                 ////// READ IN COMPONENT DATA //////
C
C       ... USE A 'NEXT' CARD TO END DATA FOR A SPECIFIC SECTION ...
C
C       ... END THE COMPONENT DATA OF THE LAST SECTION TO BE ENTERED WITH
C           A 0.0 IN COL 2-3 ...
C
      WRITE(9,16)
      DO 106 K = 1,6
      CALL INPUT(Z,NO)
      IF(NO.EQ.0) Z(1) = 0.
      JCOM = K + 4
      DO 105 J = 1,NO
      SEC(NRC,JCOM,J+1) = Z(J)
  105 CONTINUE
      SEC(NRC,JCOM,1) = NO
      IF(Z(1).EQ.0.) GO TO 107
  106 CONTINUE
  107 IF(NO.EQ.1) GO TO 108
      GO TO 103
C
C
C         REVERSE THE ORDER OF SECTIONS SO THAT COMPUTATION MAY
C         BEGIN WITH THE LAST BRANCH
C
C
  108 DO 109 K = 1,NRC
      J = NRC - K + 1
      DO 109 L = 1,10
      DO 109 M = 1,10
  109 SECT(J,L,M) = SEC(K,L,M)
      NSC = NRC
C
C         NS ----- NUMBER OF SECTIONS AT PRESENT TIME OF COMPUTATION
C                  IN PRESENT BRANCH
C         NC ----- NUMBER OF COMBINATIONS AT START OF PRESENT SECTION
C         KS ----- SECTION COUNTER
C         NRC ---- NUMBER OF SECTION READ IN AND PROCESSED
C
      NRC = 0
      NS = 0
      NB = 1
      KS = 0
      IDU = 0
      WRITE(6,70)
      WRITE(9,70)
   70 FORMAT(/////,1H1,5X,'THE FOLLOWING SECTIONS LISTED BELOW HAVE'/
     *5X,' BEEN RENUMBERED INTERNALLY IN THE PROGRAM... '/
     *5X,' THEY MAY OR MAY NOT CORRESPOND WITH THEIR ACTUAL ID NUMBERS.'
     */////)
C
  110 NS = NS + 1
      NRC = NRC + 1
      WRITE(6,12) NRC
      WRITE(9,12) NRC
C
C
C
C     ///// BEGIN PROCESSING SECTIONS, BEGINNING WITH THE SECTION /////
C     ///// FURTHEST FROM THE SYSTEM DIVERSION POINT              /////
C
C     ...THIS PROGRAM BUILDS COMBINATIONS STARTING WITH THE LAST
C        SECTION ENTERED INTO THE PROGRAM.  THE FINAL SECTION TO BE
C        ADDED TO THE COMBINATIONS IS THE MAIN DIVERSION SECTION
C        (SECTION # 1)...
C
      KSAME = 0
      KFIRST = 0
C
      KMERG = 0
C
      LDU = IDU
C
      DO 112 J = 1,4
      Z(J) = SECT(NRC,J,1)
  112 CONTINUE
C
      IDS(NRC) = Z(1)
      DH(NRC) = Z(2)
```

```
      DL(NRC) = Z(3)
      IDU = Z(4)
C
      IF(Z(1).EQ.0.) GO TO 705
C
C
C     ...DETERMINE IF THIS IS THE FIRST SECTION PROCESSED...
C
      IF(NRC.EQ.1) KFIRST = 1
C
C     ...DETERMINE IF PRESENT SECTION IS DIRECTLY UPSTREAM OF THE LAST
C        SECTION PROCESSED...
C
      IF (LDU.EQ.Z(1)) KSAME = 1
C
      IF(KSAME.EQ.0.AND.NDU.NE.-1) KDU = NDU
      IF(KSAME.EQ.0.AND.NDU.NE.-1) KDW = NDW
      IF(KSAME.EQ.0.AND.MDU.NE.-1) NDU = MDU
      IF(KSAME.EQ.0.AND.MDU.NE.-1) NDW = MDW
      IF(KSAME.EQ.0) MDU = LDU
      IF(KSAME.EQ.0) MDW = NRC
C
      IF (KFIRST.EQ.1) MDU = -1
C
C     ...DETERMINE IF THE SECTION MERGES WITH A SECTION PREVIOUSLY
C        PROCESSED...
C
      IF(MDU.EQ.IDU) KMERG = 1
C
C        KDW, MDW, AND NDW ARE SECTION # INDICATORS, USED TO DEFINE
C        THE FIRST AND LAST SECTION ID #'S OF PROCESSED BRANCHES,
C        FOR PROPER MERGING OF THE BRANCHES
C        --- MDW = THE FIRST SECTION OF THE PRESENT BRANCH
C        --- NDW = THE FIRST SECTION OF THE MAIN BRANCH
C        --- KDW = OVERFLOW FOR MDW AND NDW
C
C        KDU, MDU, AND NDU ARE USED TO DEFINE THE ID #'S OF SUPPLYING
C        SECTIONS SO THAT PROPER MERGING OF SECTIONS MAY BE ATTAINED
C        --- MDU = THE SUPPLYING SECTION OF THE PRESENT BRANCH
C            MDU = -1 IF ALL BRANCHES PROCESSED HAVE BEEN MERGED
C        --- NDU = THE SUPPLYING SECTION OF THE MAIN BRANCH
C        --- KDU = OVERFLOW FOR MDU AND NDU
C        --- LDU = THE SUPPLYING SECTION OF THE DOWNSTREAM SECTION
C
C
C
C      ////// RESET THE COMPATABILITY CODE FOR THE NEXT SECTION //////
C
C
C         --- KCON IS THE COMPATABILITY CODE OF THE SECTION BEING
C             PROCESSED
C         --- KCOMP IS AN ARRAY FOR SECTION COMPATABILITY STORAGE
C
  120 DO 130 J1 = 1,6
      DO 130 J2 = 1,6
      IF(KSAME.EQ.1) GO TO 125
      DO 124 J4 = 1,5
      J3 = 7 - J4
      KCOMP(J3,J1,J2) = KCOMP(J3-1,J1,J2)
  124 CONTINUE
  125 KCOMP(1,J1,J2) = KCON(J1,J2)
  130 KCON(J1,J2) = 0
C
C
C
C              ////// REASSIGN THE COMPONENT DATA //////
C
C
C
C         REDEFINE DATA FOR INDIVIDUAL COMPONENTS IN THE SECTION
C         IDA ----- COMPONENT ID NUMBER CORRESPONDING WITH THE TABLE
C         A ------- Y-INTERCEPT OF COST FUNCTION
C         B ------- SLOPE OF COST FUNCTION
C         E ------- EFFICIENCY OF COMPONENT IN PERCENT
C         IDQ ----- ID OR ID'S OF ONE OR MORE COMPONENTS OF SUPPLYING
C                   SECTION NOT ALLOWED TO SUPPLY PRESENT SECTION
C
C
C     JA --------- COMPONENT (ALTERNATIVE) COUNTER
C
      JA = 0
C
  136 CONTINUE
      JT = 4
```

```
C
      DO 135 J4 = 1,9
      IDA(J4) = 0
      A(J4) = 0.
      B(J4) = 0.
      E(J4) = 0.
  135 CONTINUE
C
  140 JT = JT + 1
      SE = SECT(NRC,JT,1) + .00001
      NO = SE
      DO 150 JB = 1,9
  150 Z(JB) = SECT(NRC,JT,JB + 1)
C
      IF(NO.EQ.0.OR.Z(1).EQ.0.) GO TO 170
      JA = JA + 1
      IDA(JA) = Z(1)
      A(JA) = Z(2)
      B(JA) = Z(3)
      E(JA) = Z(4) / 100
C
      WRITE(6,73) IDA(JA),Z(2),Z(3),Z(4)
   73 FORMAT(//5X,'COMPONENT =',I2,2X,'A =',F10.3,2X,'B =',F10.3,2X,'E =
     *',F7.3)
C
C
      IF(NO.LE.4) GO TO 140
C
C
C                       ////// ESTABLISH COMPATABILITY CODE //////
C
      DO 160 KX = 5,NO
      KY = KX - 4
  160 KCON (Z(1),KY) = Z(KX)
      KCON(6,6) = NRC
      KCON(6,5) = IDU
      GO TO 140
C
  170 IF(KFIRST.NE.0) GO TO 180
      GO TO 190
C
  180 NC = 0
  190 IF(KSAME.EQ.1) GO TO 300
C
C
C        SET UP NEW SECTION AND COMBINATION INDICATORS IF A NEW,
C        NONSUPPLYING BRANCH HAS BEEN READ IN (KSAME = 0)
C
C
C     ...ONLY 3 BRANCHES CAN BE LEFT UNMERGED AT ANY ONE TIME...
C
C
      IF(KDU.NE.-1) NRB(4) = NRB(3)
      IF(NDU.NE.-1) NRB(3) = NRB(2)
      JOS = NS - 1
      NS = 1
      NRB(2) = NRB(1)
      NB = NC + 1
      NC = NC + 1
      NRB(1) = NB
C
C
C
C        ////// COMPUTATION OF COSTS, Q'S, AND EFFICIENCIES //////
C
C
C
C        COMPUTE THE COMPOSITE EFFICIENCIES AND THE COSTS FOR MAXIMUM
C        AND MINIMUM DIVERSIONS
C
C        NA = # OF COMPONENT ALTERNATIVES / SECTION
C        SEFF() = THE COMPSITE EFFICIENCY OF A SPECIFIC SECTION IN A
C        SPECIFIC COMBINATION
C        SUMA = THE COMPOSITE SUM OF THE Y-INTERCEPTS FOR A SPECIFIC
C            COMBINATION
C        DINH = THE COMPOSITE SUM OF (B'S/E'S)*D FOR A SPECIFIC SECTION
C        IN A SPECIFIC COMBINATION FOR THE MAXIMUM DIVERSION RATE(D)
C        IN THE SPECIFIC SECTION
C        DINL = SAME AS DINH FOR MINIMUM DIVERSION RATE OF A SECTION
C
C        DDH = SUMMATION OF (D*SIGMA(B/PI(E'S))) FOR MAXIMUM DIVERSION
C        DDL = SAME AS DDH, EXCEPT FOR MINIMUM DIVERSION
C        CH = TOTAL COMBINATION COST FOR MAXIMUM D
C        CL = TOTAL COMBINATION COST FOR MINIMUM D
C
```

```
C         NS = # SECTIONS IN COMBINATIONS AFTER THE PRESENT SECTION
C                HAS BEEN PROCESSED
C         NC = # OF TOTAL UNPRUNED SYSTEM COMBINATIONS AT START OF
C                PRESENT SECTION
C
  300 NNS = NS + MDW - 1
C         NNS = THE ID # OF THE PPESENT SECTION BEING PROCESSED
C         J --- THE # OF SYSTEM COMBINATIONS REPROCESSED IN THIS CYCLE
C
C
      DO 330 KN = 1,JA
      KNQ = IDA(KN)
C
      DO 330 KP = NB,NC
C
C         NC + (JA-1) * (NC - NB + 1) = # OF TOTAL SYSTEM COMBINATIONS
C         AFTER THE PRESENT SECTION HAS BEEN PROCESSED
C
      J = KP + (KN-1) * (NC-NB+1)
C
C     NB = NC MINUS # OF COMBINATIONS IN SPECIFIC BRANCH BEING
C          PROCESSED, AT START OF PRESENT SECTION
C
      SUMA(J) = TUMA(KP) + A(KN)
      DDH = 0.
      DDL = 0.
      CH(J) = 0.
      CL(J) = 0.
C
C       CALCULATE THE D*B/E TERM OF THE COST EQUATIONS FOR
C       THE BRANCH CONSIDERED
C
C       MDW MUST BE THE LOWEST SECTION ID # IN THE BRANCH BEING
C           PROCESSED
C
      QMAX(J) = 0.
      QMIN(J) = 0.
C
      DO 320 JN = MDW,NNS
C
      SEFF(J,JN) = TEFF(KP,JN) * E(KN)
      DINH(J,JN) = TDINH(KP,JN) + DH(JN) * B(KN) / SEFF(J,JN)
      QMAX(J) = QMAX(J) + DH(JN) / SEFF(J,JN)
      QMIN(J) = QMIN(J) + DL(JN) / SEFF(J,JN)
      CC(J,JN) = CB(KP,JN)
      IF(JN.EQ.NNS) CC(J,JN) = KNQ
      DDH = DDH + DINH(J,JN)
      IF(DH(JN).EQ.0.) GO TO 320
      DDL = DDL + DINH(J,JN) * DL(JN) / DH(JN)
  320 CONTINUE
C
      CH(J) = SUMA(J) + DDH
      CL(J) = SUMA(J) + DDL
  330 CONTINUE
C
C
C
C      -- COMPUTE A NEW VALUE FOR NC
C
      NC = NC + (JA-1) * (NC - NB + 1)
C
C      -- COMPUTE MINIMUM AND MAXIMUM VALUES FOR DIVERSIONS OF SYSTEM
      DIVH = 0.
      DIVL = 0.
      DO 350 JN = MDW,NNS
      DIVH = DIVH + DH(JN)
      DIVL = DIVL + DL(JN)
  350 CONTINUE
C
C         IC = # OF COMBINATIONS AFTER THE ADDITION OF THE PRESENT BRANCH
C
C         RLC = MINIMUM COST OF FIRST UNRANKED COMBINATION FOUND
C
C         RC = MINIMUM COST OF COMBINATION BEING COMPARED WITH RLC
C
C         NTI = 1 IF COMBINATION HAS CURRENTLY BEEN RANKED
C
C         LCST IS THE RANK OF THE COMBINATIONS
C
C
C
C                     ////// RANK THE COMBINATIONS //////
C
C
```

```
      DO 403 JMH = 1,NC
      LCST(JMH) = 0
      NTI(JMH) = 0
  403 CONTINUE
C
      DO 430 I = 1,IC
C
C
C          FIND THE LOWEST UNRANKED MINIMUM COMBINATION COST
C
      DO 405 K = NB,NC
      IF(NTI(K).EQ.1) GO TO 405
      RLC = CL(K)
      K1 = K
      GO TO 410
  405 CONTINUE
C
C
C         RANK FROM THE LOWEST TO HIGHEST MINIMUM COST VALUE
C
  410 DO 420 J = NB,NC
      RC = CL(J)
      IF(NTI(J).EQ.1) GO TO 420
      IF(RC.GE.RLC) GO TO 420
      RLC = RC
      LCST(I) = J
  420 CONTINUE
      IF(LCST(I).EQ.0) LCST(I) = K1
      NTI(LCST(I)) = 1
  430 CONTINUE
C
C
C
C                          ////// PRUNING SECTION //////
C
C
C          ...PRUNE ANY COMBINATIONS IN WHICH THE LAST SECTION
C             COMPONENT IS INCOMPATABLE WITH THE COMPONENT OF THE
C             DOWNSTREAM SECTION
C
      NUMC = 0
      DO 432 J1 = 1,NC
  432 KPRUNE(J1) = 0
C
      DO 440 J1 = 1,6
      NSECT = KCOMP(J1,6,5)
      MSECT = KCOMP(J1,6,6)
      IF(NSECT.NE.IDS(NRC)) GO TO 440
      NUMC = NUMC + 1
C
      DO 438 J2 = 1,5
C
      DO 436 J3 = 1,5
      IF(KCOMP(J1,J2,J3).EQ.0) GO TO 436
C
      DO 434 J = 1,NC
      IF(CC(J,NRC).EQ.KCOMP(J1,J2,J3).AND.CC(J,MSECT).EQ.J2) KPRUNE(J)=1
C
  434 CONTINUE
  436 CONTINUE
  438 CONTINUE
  440 CONTINUE
C
      IF(NUMC.LE.1) GO TO 446
      NUMD = NUMC - 1
C
      DO 445 JAC = 1,NUMD
      DO 445 J1 = 1,5
      DO 445 J2 = 1,6
      DO 445 J3 = 1,6
      KCOMP(J1,J2,J3) = KCOMP(J1+1,J2,J3)
  445 CONTINUE
C
C
C               ////// PRUNE THE NONFEASIBLE COMBINATIONS //////
C
C
  446 DO 480 J = 1,IC
      K = LCST(J)
      EFFHK = DIVH / QMAX(K)
      EFFLK = DIVL / QMIN(K)
      IF(KPRUNE(K).EQ.1) GO TO 480
      NRAT = J + 1
      IF(NRAT.GT.IC) GO TO 480
C
```

```
      DO 470 J1 = NRAT,IC
      L = LCST(J1)
      EFFHL = DIVH / QMAX(L)
      EFFLL = DIVL / QMIN(L)
      IF(KPRUNE(L).EQ.1) GO TO 470
      EFFMX = EFFHL - EFFHK
      EFFMN = EFFLL - EFFLK
C
C
C        ... COMPARE COSTS AND EFFICIENCIES ...
C
C
      IF(CH(K).LE.CL(L).AND.EFFMX.LE.EMARGN.AND.EFFMN.LE.EMARGN)GOTO 460
C
      IF(CH(K).GT.CH(L)) GO TO 455
C
      COSTK = 0.
      COSTL = 0.
C
C         DELTK = THE CHANGE IN THE TOTAL COST OF COMBINATION K IF THE
C         DIVERSION RATE OF THE JN SECTION IS INCREASED FROM THE
C         MINIMUM RATE TO THE MAXIMUM RATE
C
C         DELTL = THE SAME AS DELTK, ONLY FOR COMBINATION L
C
C         COSTK = THE SUMMATION OF ALL DELTK'S GREATER THAN
C         THE CORRESPONDING DELTL'S
C         COSTL = THE SUMMATION OF ALL DELTL'S LESS THAN
C         THE CORRESPONDING DELTK'S
C
      DO 450 JN = MDW,NNS
      IF(DH(JN).EQ.0.) GO TO 450
C
      RATIO = 1 - DL(JN)/DH(JN)
      DELTK = DINH(K,JN) * RATIO
      DELTL = DINH(L,JN) * RATIO
      IF(DELTK.LE.DELTL) GO TO 450
C
      COSTK = COSTK + DELTK
      COSTL = COSTL + DELTL
C
  450 CONTINUE
C
      IF(CL(K) + COSTK.GT.CL(L) + COSTL) GO TO 455
      IF(EFFMX.LE.EMARGN.AND.EFFMN.LE.EMARGN) GO TO 460
C
C       ...THE COST LINES OF K & L CROSS.  PRUN L IF ITS EFFICIENCY IS
C         LESS THAN THE EFFICIENCY OF K + EMARGN...
  455 IF(EFFMX.LE.EMARGN.AND.EFFMN.LE.EMARGN) GO TO 460
C
      GO TO 470
C
  460 KPRUNE(L) = 1
C
  470 CONTINUE
  480 CONTINUE
C
C
C                   ////// SORT OUT PRUNED COMBINATIONS //////
C
C
      NCC = NC
      L = NB - 1
      NRATS = NC
C
      DO 550 K = 1,IC
      J = LCST(K)
      IF(KPRUNE(J).EQ.1) GO TO 550
C
C        -- RETAIN RANKING STATUS
C
C        -- USE TEFF1 ARRAY FOR TEMPORARY STORAGE
C
      L = L + 1
      TUMA(L) = SUMA(J)
      TEFF1(L,1) = QMIN(J)
      TEFF1(L,2) = QMAX(J)
      TEFF1(L,3) = CL(J)
      TEFF1(L,4) = CH(J)
C
      DO 520 JN = MDW,NNS
      TEFF(L,JN) = SEFF(J,JN)
      TDINH(L,JN) = DINH(J,JN)
      CB(L,JN) = CC(J,JN)
```

```
C
      NC = L
  550 CONTINUE
C
C       -- RESET ARRAYS BACK TO PROPER NAMES AND ELEMENTS
C
      DO 570 I = NB,NC
      QMIN(I) = TEFF1(I,1)
      QMAX(I) = TEFF1(I,2)
      CL(I) = TEFF1(I,3)
      CH(I) = TEFF1(I,4)
      DO 570 JN = MDW,NNS
      CC(I,JN) = CB(I,JN)
  570 CONTINUE
C
C         ...REINITIALIZE THE ARRAY SPACE OF PRUNED COMBINATIONS...
C
      NRAT = NC +1
      DO 590 L = NRAT,NCC
      TUMA(L) = 0.
C
      DO 590 JN = MDW,NNS
      CC(L,JN) = 0
      CB(L,JN) = 0
      IF(L.GT.200) GO TO 590
      TEFF(L,JN) = 1.
      TDINH(L,JN) = 0.
  590 CONTINUE
C
C
      IF(KMERG.EQ.1) GO TO 600
C
      GO TO 700
C
C
C                       ////// MERGE SECTION //////
C
C
C         ...SET SECTION AND COMBINATION INDICATORS...
C
C
  600 NSP = NDW
      NSQ = MDW
      NSR = NRC
      IF(NSP.EQ.-1) NSP = 1
      NB = NRB(2)
      IF(NDU.NE.-1) GO TO 610
      MDU = -1
      MDW = 1
      GO TO 630
C
  610 MDU = NDU
      MDW = NDW
      IF(KDU.NE.-1) GO TO 620
      NDU = -1
      NDW = 1
      GO TO 630
C
  620 NDU = KDU
      NDW = KDW
  630 KDU = -1
      KDW = 1
C
C
C         NSP    = STARTING SECTION OF MAIN BRANCH BEING MERGED WITH
C         NSQ     = STARTING SECTION OF MERGING BRANCH
C         NSR     = LAST SECTION OF MERGING BRANCH
C         NRB(1) = FIRST COMBINATION OF MERGING BRANCH
C         NC      = LAST COMBINATION OF MERGING BRANCH
C         NRB(2) = FIRST COMBINATION OF MAIN BRANCH
C
C
C     ...RELABEL COMBINATIONS OF MERGING BRANCH, AND THE CORRESPONDING
C        CHARACTERISTIC ARRAYS...
C
      LBK = 0
      NRAT = NRB(1)
      DO 650 L = NRAT,NC
      LBJ = 0
      LBK = LBK + 1
      SUMA(LBK) = TUMA(L)
      DO 650 M = NSQ,NSR
      LBJ = M
      CB(LBK,LBJ) = CC(L,M)
      TEFF1(LBK,LBJ) = TEFF(L,M)
```

```
      TDIH (LBK,LBJ) = TDINH(L,M)
  650 CONTINUE
C
C     N1 = THE # OF THE COMBINATION IN THE MERGING
C           BRANCH BEING MULTIPLIED INTO THE MAIN BRANCH
C     J1 = THE # OF COMBINATIONS IN THE MERGING BRANCH
C
      N1 = NRB(1) - 1
      J1 = NC - NRB(1) + 1
C
C
C                         ////// MERGE BRANCHES //////
C
C
C         ADD THE COMPONENT COMBINATIONS OF THE MERGING BRANCH TO THE
C         COMBINATIONS OF THE MAIN BRANCH
C
C         ALSO COMBINE THE SUMMATED EFFICIENCIES, AND
C         THE SUMMATED  D*(B'S/E'S) ARRAYS OF THE BRANCHES
C
C         THE NEW TOTAL OF COMBINATIONS = MM, WHICH = # OF COMBINATIONS
C           IN THE MAIN BRANCH * THE # OF COMBINATIONS IN THE
C           MERGING BRANCH
      MM = (NRB(1) - NRB(2)) * (NC - NRB(1) + 1)
C
      NRAT = NRB(2)
      NRATS = NRB(1) - 1
C
      DO 660 M1 = 2,J1
      DO 660 L1 = NRAT,NRATS
      N1 = N1 + 1
      TUMA(N1) = TUMA(L1) + SUMA(M1)
      DO 660 N2 = NSP,NSR
      IF(N2.GE.NSQ) GO TO 655
      CC(N1,N2) = CC(L1,N2)
      TEFF(N1,N2) = TEFF(L1,N2)
      TDINH(N1,N2) = TDINH(L1,N2)
      GO TO 660
C
  655 CC(N1,N2) = CB(M1,N2)
      TEFF(N1,N2) = TEFF1(M1,N2)
      TDINH(N1,N2) = TDIH(M1,N2)
  660 CONTINUE
C
      DO 670 L1 = NRAT,NRATS
      TUMA(L1) = TUMA(L1) + SUMA(1)
      DO 670 N2 = NSQ,NSR
      CC(L1,N2) = CB(1,N2)
      TEFF(L1,N2) = TEFF1(1,N2)
      TDINH(L1,N2) = TDIH(1,N2)
      M2 = N2
  670 CONTINUE
C
      N2 = M2
      WRITE(6,72)
      WRITE(9,72)
   72 FORMAT(//5X,'SECTION HAS BEEN MERGED'//)
C
C         COMPUTE NEW VALUES FOR NC AND NS
C
      NC = MM + (NRB(2) - 1)
      NS = NS + JOS
C
C         EQUATE COMBINATION IDENTIFICATION ARRAYS CB AND CC
C
      DO 675 L1 = 1,NC
      DO 675 M1 = 1,NSR
  675 CB(L1,M1) = CC(L1,M1)
C
C
C         RESET THE COMBINATION INDICATORS FOR NEWLY FORMED MAIN BRANCH
C
      DO 680 L1 = 1,4
      NRB(L1) = NRB(L1 + 1)
  680 CONTINUE
  700 CONTINUE
      IF(NRC.GT.NSC) GO TO 705
      GO TO 710
C
C
C         ...STOP PROGRAM IF THINGS ARE NOT WORKING OUT RIGHT...
C
  705 WRITE(6,22) NRC,Z(1),NO
      WRITE(9,22) NRC,Z(1),NO
```

```
     *' , COMPONENT ',I2,' . '/5X,
     *'THE NUMBER OF TERMS READ BY THE INPUT = ',I2/)
C
      GO TO 780
C
C
C                      ////// OUTPUT //////
C
C     --- REARRANGE ARRAYS FOR OUTPUT --C
  710 CONTINUE
C
      IF(NRC.LT.NSC) WRITE(6,33) NC,NNS
      IF(NRC.LT.NSC) WRITE(9,33) NC,NNS
   33 FORMAT(///5X,'THE NUMBER OF COMBINATIONS =',I3,//5X,
     *'THE NUMBER OF SECTIONS PER COMBINATION = ',I3,/)
      IF(NRC.LT.NSC) GO TO 110
C
C         ... REGROUP THE SECTIONS IN THE ORDER WITH WHICH
C               THEY ARE NUMBERED (ID NUMBER ) ...
      DO 715 J = 1,NRC
      NTI(J) = 0
  715 JDS(J) = 0
      DO 730 KK = 1,NRC
      DO 720 J = 1,NRC
      IF(NTI(J).EQ.1) GO TO 720
      LN = IDS(J)
      K = J
      GO TO 724
  720 CONTINUE
  724 DO 725 L = 1,NRC
      LLN = IDS(L)
      IF(NTI(L).EQ.1) GO TO 725
      IF(LLN.GE.LN) GO TO 725
      LN = LLN
      JDS(KK) = L
  725 CONTINUE
      IF(JDS(KK).EQ.0) JDS(KK) = K
      NTI(JDS(KK)) = 1
  730 CONTINUE
C
      WRITE(6,28) NC,NNS,NR
      WRITE(9,28) NC,NNS,NR
      WRITE(6,34)
      WRITE(9,45)
      WRITE(6,29)
      WRITE(6,35) (JKJ(J),J=1,NNS)
      WRITE(9,35) (JKJ(J),J=1,NNS)
      WRITE(6,34)
      WRITE(9,45)
   34 FORMAT(1X,120('-'),/)
   35 FORMAT('+',5X,32(I2,1X))
   45 FORMAT(1X,75('-'),/)
C
      DO 745 J = 1,NC
      DO 745 L = 1,NNS
      K = JDS(L)
      CB(J,L) = CC(J,K)
  745 CONTINUE
C
      DO 750 J = 1,NC
      AEFF = DIVH / QMAX(J) * 100
      BEFF = DIVL / QMIN(J) * 100
      WRITE(6,30) (CB(J,JN),JN = 1,NNS)
      WRITE(9,30) (CB(J,JN),JN = 1,NNS)
      WRITE(6,31) CL(J), CH(J), QMIN(J), QMAX(J), BEFF, AEFF
  750 CONTINUE
C
   28 FORMAT(///1H1,15X,'******* DYNAMIC OUTPUT *******',10X,////
     *,5X,'SECTION COMPONENT ID''S ARE OUTPUT IN SAME ORDER AS ENTERED'/
     *,5X,'(I.E., FROM THE WATER SOURCE TO THE ENDING BRANCH)'////
     *,5X,'THE NUMBER OF COMBINATIONS = ',I3,//,5X,
     *'THE NUMBER OF SECTIONS PER COMBINATION = ',I3,//,5X,
     *'THE NUMBER OF ALTERNATIVES = ',I3,//)
C
   29 FORMAT(/T50,'MIN COST',3X,'MAX COST',3X,'MIN Q',3X,'MAX Q',3X,'EFF
     *. MIN DIV',3X,'EFF. MAX DIV')
   30 FORMAT(/,5X,32(I2,1X))
   31 FORMAT('+',T50,F8.0,3X,F8.0,1X,F7.3,1X,F7.3,4X,F6.2,8X,F6.2)
C
  780 CONTINUE
C
C
C       .... WRITE OUTPUT TO TAPE 8 ....
C
      XNS = NNS
```

```
      XNR = NR
      WRITE(8,36) XNS,XNR
   36 FORMAT(' NO OF SECTIONS = ',F5.0,' NO OF ALTERNATIVES =',F5.0)
C
      WRITE(8,37)
   37 FORMAT(' SLOPE OF COST FUNCTION  .')
      DO 810 J = 1,NNS
      I = JDS(J)
      M = 4
      DO 805 N = 1,NR
      M = M + 1
      B(N) = SECT(I,M,4)
      IF(SECT(I,M,2).EQ.ID(N)) GO TO 805
      B(N) = 0.
      M = M - 1
  805 CONTINUE
  810 WRITE(8,38) (B(N),N = 1,NR)
   38 FORMAT(6F15.4)
C
      WRITE(8,39)
   39 FORMAT(' Y-INTERCEPT OF COST FUNCTION  ,')
      DO 820 J = 1,NNS
      I = JDS(J)
      M = 4
      DO 815 N = 1,NR
      M = M + 1
      A(N) = SECT(I,M,3)
      IF(SECT(I,M,2).EQ.ID(N)) GO TO 815
      A(N) = 0.
      M = M - 1
  815 CONTINUE
  820 WRITE(8,38) (A(N),N=1,NR)
C
      WRITE(8,40)
   40 FORMAT(' CONVEYANCE EFFICIENCY  ,')
      DO 830 J = 1,NNS
      I = JDS(J)
      M = 4
      DO 825 N = 1,NR
      M = M + 1
      E(N) = SECT(I,M,5)
      IF(SECT(I,M,2).EQ.ID(N)) GO TO 825
      E(N) = 0.
      M = M -1
  825 CONTINUE
  830 WRITE(8,38) (E(N),N=1,NR)
C
      DO 840 KC = 1,NC
      WRITE(8,41) (CB(KC,KS),KS = 1,NNS)
   41 FORMAT(15I1)
      IF(KC.EQ.NC) GO TO 850
      WRITE(8,42)
  840 CONTINUE
  850 WRITE(8,43)
   42 FORMAT('YES')
   43 FORMAT('NO')
      ENDFILE 8
      WRITE (6,32)
      WRITE(9,32)
   32 FORMAT(/////,5X,' ****** END OF DYNAMIC PROGRAM ******'/////
     *,5X,'      BYE  ')
      STOP
      END
```

```
C          DATA SET WIRREADN   AT LEVEL 007 AS OF 03/09/78
      SUBROUTINE INPUT(D,N,NP)
      INTEGER C,A,AST
      DIMENSION D(10)
      DIMENSION A(7),C(80),B(15),IPT(15)
      EQUIVALENCE (B(1),IPT(1))
      DATA A/1H0,1H9,1H ,1H,,1H+,1H-,1H./,AST/1H*/
C
C-----THIS IS AN INPUT ROUTINE TO DO FREE FORM DATA INPUT
C
C-----RULES FOR USE OF INPUT
C
C      1--DATA VALUES MUST BE SEPARATED BY A BLANK OR A COMMA
C      2--ALL 80 COLUMNS MAY BE USED FOR DATA EXCEPT THAT IF DATA IS TO B
C         CONTINUED,EACH CARD TO BE CONTINUED MUST HAVE A COMMA IN COLUMN
C         NO 80
C      3--DATA VALUES ARE STORED IN THE VECTOR ARRAY D
C      4--N WILL RETURN TO THE NUMBER OF VALUES PLACED IN THE VECTOR
C         ARRAY  D. VALUES ARE PLACED  IN D  BEGINNING IN POSITION NUMBER
C         ONE
C      5--ANY AMOUNT OF DESCIDTIVE INFORMATION MAY BE INCLUDED WITH THE
C         DATA
C      6--A TYPICAL CALL STATEMENT MIGHT BE CALL INPUT(D,N)
C         WHERE  D IS A REAL ARRAY
C      6A-ALTERNATE FORMS OF THE CALL STATEMENT MIGHT BE - CALL GET1(D1)
C        -OR CALL GET2(D1,D2) --- TO  CALL GET15(D1,D2,D3---,D15)
C         FOR THE INPUT SCALAR VALUES.  NO DIMENSION IS REQUIRED IN THE
C         CALLING PROGRAM WHEN ONLY SCALAR VALUES ARE TO BE STORED AND
C         THE ARGUMENTS D1,D2,D3,ETC. MAY BE EITHER MODE (FIXED OR FLOATI
C         AND THE VALUE IS ALWAYS RETURNED ACCORDING TO THE MODE (WITHOUT
C         DECIMAL-FIXED  WITH DECIMAL- FLOATING) WITHOUT DECIMAL-FIXED)
C         OF THE NUMERIC VALUE OF THE DATA CARD
C      7--MULTIPLE DATA MAYBE ENTERED AS 50*0MEANING 50 ZERO VALUES
C         ANY VALUE MAYBE ENTERED THIS WAY 12*2 MEANS 12 2'S
C         THE * MUST INNEDIATELY FOLLOW THE MULTIPLIER OR THE * WILL BE
C         IGNORED
C
      IP=1
      NP=5
  200 MC=0
      MODE=1
      N=0
      READ (5,1000)C
      WRITE(9,1000)C
 1000 FORMAT(80A1)
C
C-----START DATA SCAN
C
    9 IS=0
      ID=0
      GO TO 10
    1 IS=IS+1
C
C-----TEST FOR END OF CARD
C
      IF(IS.GT.80)GO TO 2
C
C-----TEST FOR BLANK OR COMMA
C
    3 IF(C(IS).NE.A(3).AND.C(IS).NE.A(4))GO TO 1
   10 IS=IS+1
      IF(IS.GT.80)GO TO 2
C
C-----SET SIGN TO POSITIVE
C
      S=1
C-----CHECK FOR NEGATIVE SIGN
      IF(C(IS).NE.A(6))GO TO 4
C-----SET SIGN TO NEGATIVE
      S=-1
      GO TO 5
C-----CHECK FOR POSITIVE SIGN BEING PUNCHED
    4 IF(C(IS).NE.A(5))GO TO 11
    5 IS=IS+1
      IF(IS.GT.80)GO TO 2
   11 IB=IS
C-----TEST FOR A DIGIT
    6 IF(C(IS).GE.A(1).AND.C(IS).LE.A(2))GO TO 7
C-----TEST FOR A DECIMAL POINT
      IF(C(IS).NE.A(7))GO TO 8
C-----KEEP LOCATION OF DECIMAL
      ID=IS
    7 IS=IS+1
      IF(IS.GT.80)GO TO 8
      GO TO 6
C-----CHECK TO SEE IF NUMBER HAS ANY DIGITS
```

```
    8 IF(IS.EQ.IB)GO TO 3
C-----LOCATION OF LAST DIGIT
      IL=IS-1
C-----IF DECIMAL IS NOT PUNCHED,INSERT IT AND SET MODE
      IF(ID.GE.IB.AND.ID.LE.IL)GO TO 400
      ID=IL+1
      MODE=2
C-----COUNT DATA ITEM FOUND
  400 N=N+1
C-----CONVERT AND STORE DATA ITEM
C-----THIS ROUTINE CONVERTS FROM ALPHAMERIC CHARACTERS TO NUMERIC VALUES
      CONV=0
C-----FIND NUMBER OF POSITIONS LEFFT OF DECIMAL
      M=ID-IB
C-----TEST FOR ZERO DIGITS LEFT OF DECIMAL
      IF(M.LE.0)GO TO 33
C-----N IS POSITION OF DECIMAL
      J=ID
C-----SUM VALUES LEFT OF DECIMAL
      DO 21 I=1,M
      J=J-1
      K=(C(J)-A(1))/16777216
C-----ADD IN APPROPRIATE VALUE FOR DIGIT FOUND
   21 CONV = CONV+FLOAT(K)*10.**(I-1)
C-----FIND NUMBER OF DIGITS RIGHT OF DECIMAL
   33 M=IL-ID
C-----CHECK FOR ZERO FRACTIONAL DIGITS
      IF(M.LE.0)GO TO 25
C-----N IS POSITION OF DECIMAL
      J=ID
C-----SUM FRACTIONAL       DIGITS
      DO 24 I=1,M
      J=J+1
      K=(C(J)-A(1))/16777216
C-----ADD IN APPROPRIATE FRACTION
   24 CONV =CONV+FLOAT(K)*10.**(-I)
C-----SHOULD THE VALUES BE RETURNED AS AN ARRAY OR AS SCALARS
   25 IF(IP.EQ.1)GO TO 202
      IF(IP.EQ.2)GO TO 203
C-----STORE THE VALUES IN ARRAY D
  202 D(N)=CONV*S
      GO TO 204
C-----STORE THE VALUES TO RETURNED AS SCALARS
  203 IF(MODE.EQ.1)GO TO 250
      IF(MODE.EQ.2)GO TO 251
C-----STORE AS REAL
  250 B(N)=CONV*S
      GO TO 204
C-----STORE AS INTEGER
  251 IPT(N)=CONV*S
      MODE=1
C-----GET NEXT DATA ITEM
C-----TEST MULTIPLE DATA CODE
  204 IF(MC.NE.0) GO TO 100
C-----CHECK FOR A MULTIPLE DATA ENTRY
      IF(C(IS).NE.AST)GO TO 3
C-----MULTIPLE DATA WAS FOUND
      MC=1
      GO TO 10
C-----ENTER MULTIPLE DATA
  100 MC=0
      NB=N-1
      IF(IP.EQ.1)GO TO 401
      IF(IP.EQ.2)GO TO 402
C
  401 NME=D(NB)
      ENT=D(N)
      N=NB+NME-1
      DO 101 I=NB,N
  101 D(I)=ENT
      GO TO 3
  402 NME=IPT(NB)
      ENT=B(N)
      N=NB+NME-1
      DO 403 I=NB,N
  403 B(I)=ENT
      GO TO 3
C-----TEST FOR CONTINUATION
C
C-----TEST FOR NON-BLANK CHARACTER STARTING COLUMN 80 TO 1
C     IF THE FIRST CHARACTER  ENCOUNTERED IS A COMMA--
C     NEXT CARD IS A CONTINUATION CARD
C
```

```
    2 CONTINUE
C     IF(C(80).NE.A(4))GO TO 201
C     GO TO 209
      K=81
      DO 70 I=1.80
      K = K-1
      IF(C(K).NE.A(3)) GO TO 75
   70 CONTINUE
   75 IF(C(K).NE.A(4)) GO TO 201
C 209 CONTINUE
C
C-----READ CONTINUATION CARD
      READ (5,1000)C
      WRITE(9,1000)C
      GO TO 9
C-----IF VALUES ARE RETURNED IN ARRAY D THEN RETURN
  201 IF(IP.EQ.1)RETURN
C-----STORE THE VALUES IN THE SCALAR VARIABLES FOR RETURN
      IF(N.GE.15)GO TO 315
      GO TO (301,302,303.304,305.306,307.308,309,310,311,312,313.314),N
  315 D15=B(15)
  314 D14=B(14)
  313 D13=B(13)
  312 D12=B(12)
  311 D11=B(11)
  310 D10=B(10)
  309 D9=B(9)
  308 D8=B(8)
  307 D7=B(7)
  306 D6=B(6)
  305 D5=B(5)
  304 D4=B(4)
  303 D3=B(3)
  302 D2=B(2)
  301 D1=B(1)
      RETURN
      END
```

```
C         DATA SET WIRREGLN   AT LEVEL 002 AS OF 09/19/77
      SUBROUTINE REGLIN (X,Y,N,A,B,R)
C
C
C   SUBROUTINE REGLIN DETERMINES LINEAR REGRESSION COEFFICIENTS FOR
C   A GIVEN SET OF DATA
C         X = INDEPENDENT VARIABLE
C         Y = DEPENDENT VARIABLE
C
      DIMENSION X(500), Y(500), YE(610)
C
      XN = N
      SX = 0.
      SY = 0.
      SX2 = 0.
      SY2 = 0.
      SXY = 0.
      SYE  =0.
      SYE2 =0.
      SYYE =0.
C
      DO 10 K=1,N
      SX = SX + X(K)
      SY = SY + Y(K)
      SX2 = SX2 + X(K)*X(K)
      SY2 = SY2 + Y(K)*Y(K)
      SXY = SXY + Y(K)*X(K)
   10 CONTINUE
      SSX = SX2 - (SX*SX/XN)
      SSY = SY2 - (SY*SY/XN)
      SSXY = SXY - (SX*SY/XN)
      XM = SX/XN
      YM = SY/XN
C
      B= SSXY/SSX
      A = YM - B*XM
C
      SDYX = B*SSXY
      RESS = (SSY-SDYX)/(XN-2.)
      SB = RESS/SSX
      T = B/SB
C
C   DETERMINE CORRELATION COEFFICIENT RELATING ESTIMATED VALUES
C   TO ACTUAL VALUES
C
      DO 15 K = 1,N
      YE(K) = A + B * X(K)
      SYE = SYE + YE (K)
      SYE2 = SYE2 + YE(K)*YE(K)
   15 SYYE = SYYE + YE(K)*Y(K)
      SSYE = SYE2 - (SYE*SYE/XN)
      R = (SYYE-(SYE*SY /XN))/((SSYE*SSY)**0.5)
      WRITE(6,200) A,B,R
  200 FORMAT(  /13X,'A = ',F12.0,/13X,'B = ',F12.1,/13X,'R = ',F12.3)
      RETURN
      END
```

CONTROL PROGRAM FOR MPS/360 LINEAR PROGRAMMING ROUTINE

```
          PROGRAM
          INITIALZ
          MACRO
          SOLVE(A,B.C.D)
          MVADR(XDOPREMX,INFS)
          MOVE(XDATA.A)
          MOVE(XPBNAME,B)
          IF(IKT.GT.1.JMP)
          IKT=IKT+1
          MOVE(XOBJ.'OBJ')
          MOVE(XRHS,'RHSA')
          CONVERT('SUMMARY')
          SETUP('MIN')
          PICTURE
          GOTO(PRI)
JMP       MOVE(XOLDNAME,D)
          REVISE
          SETUP('MIN')
PRI       PRIMAL
          SOLUTION
          MOVE(XOBJ.'OBJ')
          XPARAM=0.
          XPARMAX = 15.
          XPARDELT = 3.
          MOVE(XCHROW.'CHON')
          PARAOBJ('CONT')
          SOLUTION
          MOVE(XOBJ,'OBJ')
          XPARAM = 0.
          XPARMAX = 7.0
          XPARDELT = 3.5
          MOVE(XCHROW,'CHDPD')
          PARAOBJ('CONT')
          SOLUTION
          MOVE(XOBJ.'OBJ')
          XPARAM = 0.
          XPARMAX = 1.0
          XPARDELT = .5
          MOVE(XCHROW,'CHDPB')
          PARAOBJ('CONT')
          SOLUTION
          MOVE(XOBJ,'OBJ')
          XPARAM = 0.
          XPARMAX = .5
          XPARDELT = .5
          MOVE(XCHROW,'CHSR')
          PARAOBJ('CONT')
          SOLUTION
          MOVE(XOBJ,'OBJ')
          MOVE(XCOLUMN,C)
          XPARAM = 0.
          XPARMAX = 8.
          XPARDELT = 1.
          MOVE(XCHCOL.'RHSB')
          PARACOL('CONT')
          SOLUTION
IKT       DC(1)
A         DC('ABC')
B         DC('DEF')
C         DC('GHI')
D         DC('JKL')
INFS      MEND
          SOLVE('TETON01','RUN01','SYSA121','RUN00')
          SOLVE('TETON02'.'RUN02'.'SYSB121'.'RUN01')
          SOLVE('TETON03','RUN03'.'SYSC121','RUN02')
          SOLVE('TETON04','RUN04','SYSD121','RUN03')
          SOLVE('TETON05'.'RUN05'.'SYSE121'.'RUN04')
          SOLVE('TETON06','RUN06'.'SYSF121','RUN05')
          SOLVE('TETON07'.'RUN07','SYSG121','RUN06')
          SOLVE('TETON08','RUN08','SYSH121'.'RUN07')
          SOLVE('TETON09','RUN09'.'SYSI121'.'RUN08')
          SOLVE('TETON10'.'RUN10'.'SYSJ121'.'RUN09')
          SOLVE('TETON11','RUN11'.'SYSK121'.'RUN10')
          SOLVE('TETON12'.'RUN12'.'SYSL121','RUN11')
          SOLVE('TETON13'.'RUN13','SYSM121','RUN12')
          SOLVE('TETON14','RUN14'.'SYSN121','RUN13')
          SOLVE('TETON15'.'RUN15'.'SYSO121'.'RUN14')
          SOLVE('TETON16','RUN16'.'SYSP121','RUN15')
          SOLVE('TETON17'.'RUN17','SYSQ121','RUN16')
          SOLVE('TETON18'.'RUN18'.'SYSR121'.'RUN17')
          SOLVE('TETON19','RUN19'.'SYSS121'.'RUN18')
          SOLVE('TETON20'.'RUN20'.'SYST121'.'RUN19')
          SOLVE('TETON21'.'RUN21'.'SYSU121'.'RUN20')
          SOLVE('TETON22'.'RUN22'.'SYSV121','RUN21')
          SOLVE('TETON23'.'RUN23'.'SYSW121'.'RUN22')
          EXIT
          PEND
```

APPENDIX C

COMPUTER INPUT DATA FOR SALEM IRRIGATION DISTRICT

INPUT DATA FOR APSYS ROUTINE (SURFACE SYSTEMS)

```
 4. SOIL TYPES (ANNIS;WITHERS;BLKFT&BANNOCK;HAISETON&LABENZO
80. ACRE FARMS .002 FT/FT SLOPE  SCS FAM 1.0 (ANNIS)
NO CROPS 4.
ALFALFA HAY
2.4 IN/FT  4. FT RZ 60.  RAM  19. TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
2.4 IN/FT 3.5 FT RZ 50.  RAM 12.3 TET  .20 MET  35. %CROP
MANNINGS N .10
PASTURE
2.4 IN/FT 2.5 FT RZ 50.  RAM  17. TET  .19 MET  15. %CROP
MANNINGS N .20
POTATOES
2.4 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30. %CROP
MANNINGS N .00
GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
TEST FIELD LENGTHS 1300.,1300.. 1000.,1000.. 800.,800., 600.,600., 400.,400.
ALFALFA 2. 0. 40. 0.
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
HRS FRRW LAB  .5 BORD .35 ADD FRRW 0. BORD 0. WAGE OVER LIFE 5.00
DRN .4 LINE 2.5 STRF 20. STRB 20. MISCF 40. MISCB 0. LEVELF 150. BORD 200.
LIFE FURROW EQUIP 20. BORDER 20. SALVAGE 0. INTEREST 9.5%
COST ANNUAL LAND PREP 10. LAND LOST TO PRODUCTION 250.
ANNUAL MAINT % INV 1. TAX AND INSUR .5 %
VALUE RUNOFF 0. VALUE DP 0.
NO SUBSURFACE DRAINAGE
NO ADVANCE AND RECESSION DATA FOR 1300 FT RUN
 1. HIGH EFFICIENCY
LAG TIME IS 7. MINUTES ASSUMED EFFICIENCY BORD IS 70.
ALFALFA 2. 0. 40. 0.
GRAIN 2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. EIGHT HUNDRED
GRAIN    2. 0. 40. 0.
PASTURE  2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA  2. 0. 40. 0. SIX HUNDRED
GRAIN    2. 0. 40. 0.
PASTURE  2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA  2. 0. 40. 0. FOUR HUNDRED
GRAIN    2. 0. 40. 0.
PASTURE  2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
REWORK---SOIL # 2
120. ACRE FARMS  .002 FT/FT SLOPE  SCS FAMILY 1.0 (WITHERS)
NO CROPS 4.
ALFALFA HAY
1.9 IN/FT  3. FT RZ 60.  RAM  19. TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
1.9 IN/FT  3. FT RZ 50.  RAM 12.3 TET  .20 MET  35. %CROP
MANNINGS N .10
PASTURE
2.2 IN/FT 2.5 FT RZ 50.  RAM  17. TET  .19 MET  15. %CROP
MANNINGS N .20
POTATOES
2.2 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30. %CROP
MANNINGS N .00
GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
TEST FIELD LENGTHS 1300.,1300., 1000.,1000.. 800.,800., 600.,600., 400.,400.
ALFALFA 2. 0. 40. 0.
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
HRS FRRW LAB .5 BORD .35 ADD FRRW 0. BORD 0. WAGE OVER LIFE 5.00
DRN .4 LINE 2.5 STRF 20. STRB 20. MISCF 40. MISCB 0. LEVELF 150. BORD 200.
LIFE FURROW EQUIP 20. BORDER 20. SALVAGE 0. INTEREST 9.5%
COST ANNUAL LAND PREP 2. LAND LOST TO PRODUCTION 250.
ANNUAL MAINT % INV 1. TAX AND INS .5 %
VALUE RUNOFF 0.  VALUE DP 0.
NO SUBSURFACE DRAINAGE
NO ADVANCE AND RECESSION DATA FOR 1300 FT RUN
 1. HIGH EFFICIENCY
LAG TIME IS 7. MINUTES ASSUMED EFFICIENCY BORD IS 70. %
ALFALFA  2. 0. 40. 0. ONE THOUSAND
GRAIN    2. 0. 40. 0.
```

```
POTATOES 1.  20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. EIGHT HUNDRED
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0.  SIX HUNDRED
GRAIN  2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. FOUR HUNDRED
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
REWORK---SOIL # 3
100. ACRE FARMS  .002 FT/FT SLOPE  SCS FAMILY .5 (BLKFT & BANNOCK)
NO CROPS 3.
ALFALFA HAY
2.2 IN/FT  4. FT RZ 60.  RAM  19. TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
2.2 IN/FT 3.5 FT RZ 50.  RAM 12.3 TET  .20 MET  50. %CROP
MANNINGS N .10
POTATOES
2.2 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30. %CROP
MANNINGS N 0.00
GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
TEST FIELD LENGTHS 1300.,1300., 1000.,1000., 800.,800., 600.,600., 400.,400.
ALFALFA 2. 0. 40. 0.
GRAIN   2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
HRS FRRW LAB .5 BORD .35 ADD FRRW 0. BORD 0. WAGE OVER LIFE 5.00
DRN .4 LINE 2.5 STRF 20. STRB 20. MISCF 40. MISCB 0. LEVELF 150. BORD 200.
LIFE FURROW EQUIP 20. BORDER 20. SALVAGE 0. INTEREST 9.5%
COST ANNUAL LAD PREP 2. LAND LOST TO PRODUCTION 250.
ANNUAL MAINT % INV 1. TAX AND INSUR .5 %
VALUE RUNOFF 0.  VALUE DP 0.
NO SUBSURFACE DRAINAGE
NO ADVANCE AND RECESSION DATA FOR 1300 FT RUN
 1. HIGH EFFICIENCY
LAG TIME IS 7. MINUTES  ASSUMED EFFICIENCY BORD IS 70. %
ALFALFA 2. 0. 40. 0. ONE THOUSAND
GRAIN   2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. EIGHT HUNDRED
GRAIN   2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. SIX HUNDRED
GRAIN   2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. FOUR HUNDRED
GRAIN   2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
REWORK---SOIL # 4
160. ACRE FARMS  .002 FT/FT  SCS FAMILY 2.0 (HAISETON-LABENZO)
NO CROPS 4.
ALFALFA HAY
1.4 IN/FT  3. FT RZ 60.  RAM 19. TET  .23 MET 20. %CROP
MANNINGS N .15
GRAIN
1.4 IN/FT  3. FT RZ 50.  RAM 12.3 TET  .20 MET  40. %CROP
MANNINGS N .10
PASTURE
1.6 IN/FT 2.5 FT RZ 50. RAM 17. TET  .19 MET  20 %CROP
MANNINGS N .20
POTATOES
1.6 IN/FT 2.5 FT RZ 40.  RAM 18.  TET  .28 MET  20 %CROP
MANNINGS N .00
GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
TEST FIELD LENGTHS 1300.,1300., 1000.,1000., 800.,800., 600.,600., 400.,400.
ALFALFA 2. 0. 40. 0. ONE THOUSAND
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
HRS FRRW LAB .5 BORD .35 ADD FRRW 0. BORD 0. WAGE OVER LIFE 5.00
DRN .4 LINE 2.5 STRF 20. STRB 20. MISCF 40. MISCB 0. LEVELF 150. BORD 200.
LIFE FURROW EQUIP 20. BORDER 20. SALVAGE 0. INTEREST 9.5%
```

```
ANNUAL MAINT % INV 1. TAX AND INSUR .5 %
VALUE RUNOFF 0.  VALUE DP 0.
NO SUBSURFACE DRAINAGE
NO ADVANCE AND RECESSION DATA FOR 1300 FT RUN
 1. HIGH EFFICIENCY
LAG TIME IS 7. MINUTES  ASSUMED EFFICIENCY BORD IS 70. %
ALFALFA 2. 0. 40. 0. ONE THOUSAND
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. EIGHT HUNDRED
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 20. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. SIX HUNDRED
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
ALFALFA 2. 0. 40. 0. FOUR HUNDRED
GRAIN   2. 0. 40. 0.
PASTURE 2. 0. 40. 0.
POTATOES 1. 10. 36. 0.
NO ADVANCE RECESSION DATA
END
```

```
4.  SOIL TYPES (ANNIS:WITHERS:BLKFT&HANNOCK:HAISETON&LABENZO)
80. ACRE FARMS .002 FT/FT SLOPE  SCS FAM 1.0 (ANNIS)
NO CROPS 4.
ALFALFA HAY
2.4 IN/FT  4. FT RZ 60.  RAM  19. TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
2.4 IN/FT 3.5 FT RZ 50.  RAM 12.3 TET  .20 MET  35. %CROP
MANNINGS N .10
PASTURE
2.4 IN/FT 2.5 FT RZ 50.  RAM  17. TET  .19 MET  15. %CROP
MANNINGS N .20
POTATOES
2.4 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30. %CROP
MANNINGS N .00
HANDMOVE----HAND MOVE SPRINKLER SYSTEM--ANNIS SOIL
LENGTH OF LATERAL 1300. SPACING OF LATERAL 50.
TIME TO MOVE LATERAL 75. MIN SET LENGTH TIMES 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 75. % OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE 0.8 IPH
COST OF LATERAL 1600. (PIPE&HEADS&RISERS) SYSTEM LIFE 15. INT 9.5 % .
TAX&INSURANCE 1. % SALVAGE 13. % MAINT 3. % CONTINGENCY 10. %
LATERAL MOVING LABOR RATE 5.00  TRANSPORT TIME 2.0 HR
VALUE OF DP $ 0.00 / ACRE
MAIN PIPE SIZE 8.0 INCH 600. FT $ 3.65  SIZE 6.0 LENGTH 700. COST $ 2.30
THE MAINLINE IS NOT BURIED
LIFE OF MAIN 20.  INTEREST 9.5 SALVAGE 9. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCION $ 0.00 /ACRE
SIDE ROLL---SIDE ROLL WHELL LINE SPRINKLER SYSTEM--ANNIS
LENGTH OF LATERAL 1300. FT  SPACING OF LATERAL 50. FT
TIME TO MOVE 30. MINUTES  SET TIMES  6.,8.,12.,24.,36. HOURS
OVERALL EFFICIENCY 75. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE  .8 IPH
COST OF SIDEROLL $ 5400. (THUNDERBIRD) LIFE 15. YR  INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 10. % MAINTENANCE 3. % CONTINGENCY 10. %
LABOR RATE 5.00  TRANSPORT BETWEEN IRRIG 1.0 HOURS
VALUE OF DEEP PERCOLATION  $ 0.00
MAIN PIPE SIZE 8.0 INCHES 600. FT $ 3.65 AND 6.0  700. FT $ 2.30
THE MAINLINE IS NOT BURIED
MAINLIFE IS 20. YR INTEREST 9.5 % SALVAGE 9. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION IS $ 0.00 PER ACRE
SOLID SET---SOLID SET FOR POTATOES---ANNIS SOIL
LENGTH OF LATERAL 650. FT  SPACING OF LATERALS 50. FT
TIME TO SET LATERAL 2. MINUTES  SET TIME LENGTHS 6.,8.,12.,16.,24.,36.
OVERALL EFFICIENCY 80. % OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE IS 0.8 IPH
COST OF LATERAL $ 800.  15. YR LIFE    INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINTENANCE 3. % CONTINGENCIES 10. %
NO THE LINE IS NOT BURIED
LABOR RATE $ 5.00  TRANSPORT 0.0
VALUE OF DP IS $ 0.00
MAIN PIPE SIZE 8.0 INCHES 600. FT $ 3.65  6.0  700. FT $ 2.30
THE MAINLINE IS NOT BURIED
MAINLINE LIFE 20. YR   INTEREST 9.5 %  SALVAGE 9. % ,
TAX&INS 1. % MAINTENCE 3. %
VALUE OF LAND LOST TO PRODUCTION IS $ 0.00 PER ACRE
REWORK---SOIL # 2 (WITHERS)
120. ACRE FARMS  .002 FT/FT SLOPE  SCS FAMILY 1.0  (WITHERS)
NO CROPS 4.
ALFALFA HAY
1.9 IN/FT  3. FT RZ 60.  RAM  19. TET  .23 MET  20.  %CROP
MANNINGS N .15
GRAIN
1.9 IN/FT  3. FT RZ 50.  RAM 12.3 TET  .20 MET  35. %CROP
MANNINGS N .10
PASTURE
2.2 IN/FT 2.5 FT RZ 50.  RAM  17. TET  .19 MET  15.  %CROP
MANNINGS N .20
POTATOES
2.2 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30.  %CROP
MANNINGS N .00
HANDMOVE----HAND MOVE SPRINKLER SYSTEM--WITHERS SOIL
LENGTH OF LATERAL 1300. FT  SPACING 50. FT
TIME TO MOVE LATERAL 75. MIN  SET LENGTH TIMES 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 75. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE 0.8 IPH
COST OF LATERAL 1600. (PIPE&RISERS&HEADS) SYSTEM LIFE 15.  INT 9.5 % ,
TAX&INS 1. % SALVAGE VALUE 13. % MAINT 3. % CONTINGENCY 10. %
LATERAL MOVING LABOR RATE $ 5.00  TRANSPORT TIME 2.0 HR
VALUE OF DEEP PERCOLATION $ 0.00
MAIN PIPE SIZE  10. INCH 410. FT $ 4.70  8.  900. FT  $ 3.65  6.  700. FT 2.3
THE MAINLINE IS NOT BURIED
LIFE OF MAIN 20.  INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
```

```
LENGTH OF LATERAL 1300. FT  SPACING OF LATERALS  50. FT
TIME TO MOVE LATERAL 30. MIN  SET TIME LENGTHS 6.,8..12.,24..36.
OVERALL EFFICIENCY 75. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE 0.8 IPH
COST OF SIDEROLL $ 5400. (THUNDERBIRD)  LIFE 15.  INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 10. % MAINT 3. % CONTINGENCIES 10. %
LABOR RATE $ 5.00  TRANSPORT TIME 1.0 HR
VALUE OF DP $ 0.00
MAIN PIPE SIZE 10. INCH 410. FT $ 4.70 8. 900. FT $ 3.65  6. 700. FT $ 2.30
THE MAINLINE IS NOT BURIED
MAINLIFE IS 20. YR  INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
SOLID SET---SOLID SET FOR POTATOES--WITHERS SOIL
650. FT LATERAL  50. FT SPACING
TIME TO SET LATERAL 2. MIN  SET TIME LENGTH 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 80. % OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE IS 0.8 IPH
COST OF LATERAL $ 800.  15. YR LIFE  INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINTENANCE 3. % CONTINGENCIES 10. %
NO THE LATERAL LINE IS NOT BURIED
LABOR RATE $ 5.00  TRANSPORT TIME 0.0
VALUE OF DP  $ 0.00
MAIN PIPE SIZE  10. IN 410. FT $ 4.70  8. IN 900. FT $ 3.65  6. 700. $ 2.30
THE MAINLINE IS NOT BURIED
MAINLINE LIFE IS 20. YR INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
REWORK---SOIL # 3  (BLACKFOOT AND BANNOCK)
100. ACRE FARMS  .002 FT/FT SLOPE SCS FAMILY 0.5 (BLKFT & BANNOCK)
NO CROPS 3.
ALFALFA HAY
2.2 IN/FT  4. FT RZ 60.  RAM  19. TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
2.2 IN/FT 3.5 FT RZ 50.  RAM 12.3 TET  .20 MET  50. %CROP
MANNINGS N .10
POTATOES
2.2 IN/FT 2.5 FT RZ 40.  RAM  18. TET  .28 MET  30. %CROP
MANNINGS N .00
HANDMOVE----HAND MOVE SPRINKLER SYSTEM--BLKFT&BANNOCK
LENGT OF LATERAL 1300. FT SPACING 50. FT
TIME TO MOVE LATERAL 75. MIN SET LENGTH TIMES 6.,8..12.,24.,36.
OVERALL EFFICIENCY 75. % OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE 0.5 IPH
COST OF LATERAL 1600.  (PIPE&RISERS&HEADS)  SYS LIFE 15. YR INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINT 3. % CONTINGENCIES 10. %
LATERAL MOVING LABOR RATE $ 5.00  TRANSPORT BETWEEN IRRIG 2.0 HR
VALUE OF DP $ 0.00
MAIN PIPE SIZE 8. INCH 975. FT $ 3.65  6. IN 700. FT $ 2.30
THE MAINLINE IS NOT BURIED
LIFE MAIN 20. YR INTEREST 9.5 % SALVAGE 8.5 % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.0
SIDE ROLL---SIDE ROLL WHEEL LINE SPRINKLER SYSTEM--BLKFT&BANNOCK
LENGTH OF LATERAL 1300. FT  SPACING OF LATERAL 50. FT
TIME TO MOVE 30. MIN  SET TIME LENGTHS 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 75. %  OTHER LOSSES 5 %
MAXIMUM ALLOWABLE INTAKE RATE  0.5 IPH
COST OF SIDEROLL $ 5400. (THUNDERBIRD)  LIFE 15. YR  INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 10. % MAINT 3. % CONTINGENCIES 10. %
LABOR RATE $ 5.00  TRANSPORT 1.0 HR
VALUE OF DP $ 0.00
MAIN PIPE SIZE 8.0 INCH 975. FT $ 3.65  6.0 INCH 700. FT $ 2.30
MAINLINE IS NOT BURIED
LIFE MAIN 20. YR INTEREST 9.5 % SALVAGE 8.5 % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
SOLID SET---SOLID SET FOR POTATOES--ANNIS SOIL
650. FT LATERAL  50. FT SPACING
TIME TO SET LATERAL 2. MIN  SET TIME LENGTHS 6.,8..12.,24.,36.
OVERALL EFFICIENCY 80. % OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE .5 IPH
COST OF LATERAL $ 800.  15. YR LIFE  INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINTENANCE 3. % CONTINGENCIES 10. %
NO THE LINE IS NOT BURIED
LABOR RATE $ 5.00  TRANSPORT 0.0
VALUE OF DP IS $ 0.00
MAIN PIPE SIZE 8.0 INCH 975. FT $ 3.65  6.0 INCH 700. FT $ 2.30
THE MAINLINE IS NOT BURIED
LIFE MAIN 20. YR INTEREST 9.5 % SALVAGE 8.5 % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION IS $ 0.00 /ACRE
REWORK---SOIL # 4 (HAISETON&LABENZO)
160. ACRE FARMS  .002 FT/FT  SCS FAMILY 2.0 (HAISETON-LABENZO)
NO CROPS 4.
ALFALFA HAY
1.4 IN/FT  3. FT RZ 60.  RAM  19.  TET  .23 MET  20. %CROP
MANNINGS N .15
GRAIN
```

```
1.4 IN/FT  3. FT RZ 50.  RAM 12.3 TET  .20 MET  40. %CROP
MANNINGS N .10
PASTURE
1.6 IN/FT 2.5 FT RZ 50.  RAM 17.  TET  .19 MET  20. %CROP
MANNINGS N .20
POTATOES
1.6 IN/FT 2.5 FT RZ 40.  RAM 18.  TET  .28 MET  20. %CROP
MANNINGS N .00
HANDMOVE----HANDMOVE SPRINKLER SYSTEM--HAISETON&LABENZO)
LENGTH OF LATERAL 1300.  FT   SPACING OF LATERAL 50. FT
TIME TO MOVE LATERAL 75. MIN SET LENGTH TIMES 6.,8.,12.,24.,36.
OVERALL EFFICIENCY  75. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE 1.5 IPH
COST OF LATERAL $ 1600. (PIPE&HEADS&RISERS)  LIFE 15. YR INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINT 3. % CONTINGENCIES 10. %
LATERAL MOVING LABOR RATE $ 5.00  TRANSPORT TIME  2.0 HR
VALUE OF DP $ 0.00 PER ACRE
MAIN PIPE SIZE 10. IN 1000. FT $ 4.70  8. 900. FT $ 3.65  6. 700. $ 2.30
THE MAINLINE IS NOT BURIED
LIFE MAIN 20. YR INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
SIDE ROLL---SIDE ROLL WHEEL LINE SPRINKLER SYSTEM--HAISETON&LABENZO
LENGTH OF LATERAL 1300.  SPACING OF LATERAL 50. FT
TIME TO MOVE LATERAL 30. MIN  SET TIME LENGTHS 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 75. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE  1.5 IPH
COST OF SIDEROLL $ 5400. (THUNDERBIRD) LIFE 15. INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 10. % MAINT 3. % CONTINGENCIES 10. %
LABOR RATE $ 5.00  TRANSPORT BETWEEN IRRIGATIONS 1.0 HR
VALUE OF DEEP PERCOLATION $ 0.00
MAIN PIPE SIZE 10. IN 1000. FT $ 4.70  8. IN 900. FT $ 3.65  6. 700. $ 2.30
THE MAINLINE IS NOT BURIED
LIFE MAIN 20. YR  INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
SOLID SET---SOLID SET FOR POTATOES--HAISETON&LABENZO
650. FT LATERAL  50. FT SPACING
TIME TO SET LATERAL 2. MIN  SET TIME LENGTHS 6.,8.,12.,24.,36.
OVERALL EFFICIENCY 80. %  OTHER LOSSES 5. %
MAXIMUM ALLOWABLE INTAKE RATE IS 1.5 IPH
COST OF LATERAL $ 800.  LIFE 15. YR INTEREST 9.5 % ,
TAX&INS 1. % SALVAGE 13. % MAINT 3. % CONTINGENCIES 10. %
NO THE LATERAL IS NOT BURIED
LABOR RATE $ 5.00  TRANSPORT 0.0
VALUE OF DP IS 0.0
MAIN PIPE SIZE 10. IN 1000. FT $ 4.70  8. IN 900. FT $ 3.65  6. 700. $ 2.30
THE MAINLINE IS NOT BURIED
LIFE MAIN 20. YR INTEREST 9.5 % SALVAGE 8. % TAX&INS 1. % MAINT 3. %
VALUE OF LAND LOST TO PRODUCTION $ 0.00
CENTER PIVOT-HAISETON&LABENZO
LENGTH 1298.5 FT  (VALLEY W/CORNER SYSTEM)  0. SPACING
0.0 TIME TO MOVE LATERAL  SET TIMES 20.,24.,36.,48.
OVERALL EFFICIENCY  90. %  OTHER LOSSES  0. %
MAXIMUM ALLOWABLE INTAKE RATE  1.5 IPH
SYSTEM COST (W/CORNER) $ 39000. LIFE 20. YEARS  INT 9.5 % ,
TAX&INS 1. % SALVAGE 5. % MAINT 1. % CONTINGENCIES 10. %
LABOR RATE  $ 5.00  TRANSPORT TIME 1. HOURS
VALUE OF DP IS 0.0
8. INCH MAIN (COAL TAR)  1300. FT  $ 3.75  /FT
THE MAIN LINE IS BURIED. BUT COST IS FIGURED INTO PIPE PRICE
MAINLINE LIFE 40. YR INT 9.5 % SALVAGE 0. % TAX&INS 1. % MAINT 1. %
VALUE OF LAND LOST TO PRODUCTION  $ 0.00
END
```

INPUT DATA FOR CANAL ROUTINE

```
COMMON EXC .59 COM STR 2.75 COM SIPH 2.15 COM PIP 2.75 ROCK CAN 2.75,
ROCK STR 5.30  ROCK SIPH 5.40  ROCK PIPE 5.40
BACKFILL CAN 1.20 BF STR 1.56 BF SIPH .83 BF PIPE 1.04 BP .30 COMP EM .80,
COMP BF 4.16  UHAUL .85 /YD MI
CONCRETE IN LINING 50. CON STR 150. CON SIPH 146.  STEEL .50 CEM 3.80
PIPE LAYER 10.00 EQ IN 1.2 AREA .8 HD 200.,200. MINER 9.63 SI 1.10 CI 1.0
1. THIS IS FOR A REHABILITATION OF AN EXISTING CHANNEL
READ---LINED CANAL  REACH NUMBER ONE
CONT CAN 10.  EARTH 10.  ROW 0.  LINE 5.  CI 1.06 CODE 1. UR PRT CEM
DESIGN SIDE SLOPE 1.5 OUTSIDE Z 1.5 MANNINGS .017 MINV 1.2 MAXV 7.0 D 1.0
WIDTH C BRIDGE 31.7 COST 25. WIDTH F BRIDGE 22. COST 18.
LIFE 50. INT 7.0  SAL 0.0 (NO SALVAGE DUE TO COST OF REMOVING STRS)
VALUE OF WATER LOST 0. NO OF DAYS CANAL IS OPERATING 120. OTHER LOSS 2.
SEEP COFF .2 PRESENT ROW 45.  500. SEVERANCE 0.  250. XBRW 3.0 MILES
LENGTH 6750. OUTLET ELEV 4891.4 INLET 4907.4  TO 4893.71
TURNOUTS 5. OF 2. CFS  1. OF 4. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 4. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
RW 19. Z 1.2 BH 4.4 LBW 3. RBW 3. LOZ 1.3 ROZ 3.0 EL 4910.8,4911.8,4894.8,4895.8
MIN Q= 40. MAX Q = 120. QINTERVAL= 5.0
SKIP---LINED CANAL REACH 2
SEEP COEF .2 PROW 45.  500. SEVERANCE 0.  250. XBRW 3.0 MILES
LENGTH 6490. OUTLET ELEV 4883.9 INLET 4891.4 TO 4886.8
TURNOUTS 1. OF 3.. 2. OF 4. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 4. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
BW 16. Z 1.6 BH 4.5 LBW 4. RBW 6. LOZ 2.4 ROZ 1.3 EL 4894.2,4893.6,4887.1,4886.
MIN G 30. MAX Q 90. QINTERVAL 5.0
SKIP---LINED CANAL REACH 3
SEEP COEF .2 PROW 45. 500. SEV 0. 250. XBRW 3.5 MILES
LENGTH 2700. OUTLET ELEV 4880.7 INLET 4883.9 TO 4881.1
TURNOUTS 1. OF 2., 1. OF 6. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
1. DRP 2. CHKS 0. FLUMES 0. CB 0. FB 0. SIPHON 0. TUNNEL
BW 12. Z 1.3 BH 5.4 LBW 3.5 RBW 3. LOZ 1.4 ROZ 1.7 EL 4885.2,4884.8,4882.,4881.
MIN Q 15. MAX Q 45. QINTERVAL 3.0
SKIP---LINED CANAL  REACH 4
SEEP COEF .2 PROW 45.  500. SEV 0.  250. XBRW 3.8 MILES
LENGTH 1040. OUTLET ELEV 4877.9 INLET 4880.0 TO 4879.4
TURNOUTS 1. OF 4. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 0. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
BW 12. Z 1.3 BH 5.4 LBW 3.5 RBW 3. LOZ 1.4 ROZ 1.7 E 4881.3,4880.9,4879.2,4878.
MIN Q 9. MAX Q 36. QINTERVAL 3.0
SKIP---LINED CANAL   REACH 5
SEEP COEF .2 PROW 40.  500. SEV 0.  250. XBRW 4.5 MILES
LENGTH 5700. OUTLET ELEV 4867.2 INLET 4877.9 TO 4871.7
TURNOUTS 1. OF 2., 3. OF 3. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 2. CHKS 0. FLUMES 0. CB 0. FB 0. SIPHON 0. TUNNEL
BW 10. Z 1. BH 5. LBW 1. RBW 1. LOZ 7. ROZ 3.5 E 4880.,4879.7,4871.2,4870.2
MIN Q 9. MAX Q 30. QINTERVAL 3.0
SKIP---LINED CANAL REACH 6
SEEP COEF .2 PROW 45.  500. SEV 0.  250. XBRW 5.0 MILES
LENGTH 2080. OUTLET ELEV 4862.8 INLET 4867.2 TO 4865.3
TURNOUTS 1. OF 3. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 0. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
BW 11. Z .62 BH 3.2 LBW 5. RBW 8. LOZ .57 ROZ 1. E 4868.6,4870.3,4864.2,4865.9
MIN Q 4.0 MAX Q 16.0 QINTERVAL 2.0 CFS
SKIP---LINED CANAL REACH 7
SEEP COEF .2 PROW 45.  500. SEV 0.  250. XBRW 5.5 MILES
LENGTH 2600. OUTLET ELEV 4857.8 INLET 4862.8 TO 4860.3
TURNOUTS 1. OF 2., 1. OF 3., 1. OF 4. CFS
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 2. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
BW 11. Z .62 BH 3.2 LBW 5. RBW 8. LOZ .57 ROZ 1. E 4864.2,4865.9,4859.2,4860.9
MIN Q 4.0 MAX Q 12.0 QINTERVAL 1.0 CFS
SKIP---LINED CANAL REACH 8
SEEP COEF .2 PROW 30.  500. SEV 0.  250. XBRW 3.0 MILES
LENGTH 6750. OUTLET ELEV 4889. INLET 4900. TO 4891.5
TURNOUTS 3. OF 2., 1. OF 3., 1. OF 6., AND 1. OF 12. CFS AT INLET
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 4. CHKS 0. FLUMES 0. CR 0. FB 0. SIPHON 0. TUNNEL
BW 4. Z 1. BH 4. LBW 2. RBW 2. LOZ 1. ROZ 1. E 4902.,4902.,4891.,4891.
MINQ 5.0 MAX Q 17.0 QINTERVAL 2.0 CFS
```

```
SKIP---LINED CANAL REACH 9
SEEP COEF .2 PROW 30.  500. SEV 0.  250. XBRW 3.5 MILES
LENGTH 2300. OUTLET ELEV 4877.0 INLET 4882.5 TO 4880.5
TURNOUTS 3. OF 2. CFS AND 1. OF 6. CFS AT INLET
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 2. CHKS 0. FLUMES 0. CB 0. FB 0. SIPHON 0. TUNNEL
BW 5. Z 1. BH 4. LBH 3. RBH 3. LOZ 1. ROZ 1. E 4885.5,4885.5,4880.,4880.
MIN Q 2.0 MAX Q 6.0 QINTERVAL 1.0 CFS
SKIP---LINED CANAL REACH 10
SEEP COEF .2 PROW 40.  500. SEV 0.  250. XBRW 4.0 MILES
LENGTH 5500. OUTLET ELEV 4867.5 INLET 4882.0 TO 4870.5
TURNOUTS 2. OF 2., 1. OF 5. CFS AND 1. OF 14. CFS AT INLET
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 4. CHKS 0. FLUMES 0. CB 0. FB 0. SIPHON 0. TUNNEL
BW 10. Z .96 BH 5.2 LBW 3. RBW 1. LOZ 2.3 ROZ 4.2 E 4886.3.4884.7,4871.8,4870.3
MIN Q 6.0 MAX Q 20.0 QINTERVAL 2.0 CFS
SKIP---LINED CANAL REACH 11
SEEP COEF .2 PROW 20.  500. SEV 0.  250. XBRW 4.0 MILES
LENGTH 3110. OUTLET ELEV 4874.0 INLET 4881.0 TO 4875.5
TURNOUTS 3. OF 2. CFS AND 1. OF 8. CFS AT INLET
0. 0. 0. NO DRAINAGE CROSSINGS
0. DRPS 2. CHKS 0. FLUMES 0. CB 0. FB 0. SIPHON 0. TUNNEL
BW 4. Z 1. BH 2. LBW 2. RBW 2. LOZ 1. ROZ 1. E 4882.,4882.,4875.,4875.
MIN Q 2.0 MAX Q 7.0 QINTERVAL 1.0 CFS
END OF DATA-----BYE!!!
```

INPUT DATA FOR PIPE ROUTINE (GRAVITY)

```
1.   THIS PIPE IS TO BE LAYED IN AN EXISTING CHANNEL
COMMON EXC .59 COMSTR 2.75 COMSIPH 2.15 COMPIP 2.75 ROCKCAN 2.75 ROCKSTR 5.30,
ROCK SIPH 5.40 ROCKPIPE 5.40
BACKFILL CANAL 1.20 BFSTR 1.56 BFSIPH .83 BFPIPE 1.04 BEDPREP .30 COMPEM .80,
COMPBF 4.16 OHAUL .85 /YD MI
CONCRETE IN LINING 50. CONSTR 150. CONSIPH 146. STEEL .50 CEM 3.80
READ---GRAVITY PIPE REACH NUMBER 1
WAGE PIPELAYER 10.00 EQUIP INDEX 1.0 AF 1. HD 80. HD 200. CODE 1. CIDX 1. ,
DEPTH OF FILL 4.0 HEADCLASS 15. FEET
CONTINGIENCIES EARTH 10. STEEL 15. ROW 0. CONCRETE 15. STEEL 12. PIPE 10.,
PVC HEAD CLASS 1.
50. YEAR LIFE  INTEREST 7.0 % SALVAGE VALUE 5. %
0..0.,0..0. NO STEEL TANK
LENGTH 6750. HGLO 4900.8 ELO 4887.0 HGLI 4910.8 ELI 4904.0
PIPE TYPE = 4.
WATER HAMMER = 1.0
WIDTH EASEMENT=SAME AS PRESENT= 45. CV 0. OV 0. PL 0. R 0. BRRW 3.0 MILES
TURNOUT CODE 0.  MISC=TWENTY INCH BUTTERFLY&FLANGE $ 1275.
TURNOUT SIZES IN INCHES = 5. OF 8.  INCH  1. OF 12. INCHES
BW 19. Z 1.2 BH 4.4 LBW 3. RBW 3. LOZ 1.3 ROZ 3.0 EL 4910.8,4911.8,4894.8,
4895.8, ROW 45. OELI 4907.4 OELO 4891.4
MINQ 40.  MAXQ 120.  QINTERVAL 5.0
SKIP---GRAVITY PIPE REACH 2
LENGTH 6490. HGLO 4893.0 ELO 4879.5 HGLI 4900.8 ELI 4887.0
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 45. CV 0. OV 0. PL 0. ROCK 0. BRRW 3.0 MILES
TURNOUT CODE 0.  MISC=FOURTEEN&TWENTY INCH BUTTERFLY&FLANGE $ 1850.
TURNOUT SIZE  1. OF 10. INCH  1. OF 12. INCH
BW 16. Z 1.6 BH 4.5 LBW 4. RBW 6. LOZ 2.4 ROZ 1.3 EL 4894.2,4893.6,4887.1.
4886.3.ROW 45. OELI 4891.4 OELO 4883.9
MINQ 30.  MZXQ 90.  QINTERVAL 5.0
SKIP---GRAVITY PIPE REACH 3
LENGTH 2700. HGLO 4890. ELO 4875. HGLI 4893. ELI 4879.5
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 45. CV 0. OV 0. PL 0. ROCK 0. BRRW 3.5 MILES
TURNOUT CODE 0.  0.
TURNOUT SIZE 1. OF 8. INCH  1. OF 14. INCH
BW 12. Z 1.3 BH 5.4 LBW 3.5 RBW 3.0 LOZ 1.4 ROZ 1.7 EL 4885.2.4884.8,4882.0,
4881.6 ROW 45. OELI 4883.9 OELO 4880.7
MINQ 15. MZXQ 45. QINTERVAL 3.0
SKIP---GRAVITY PIPE REACH 4
LENGTH 1040.  HGLO 4887.9 ELO 4873.0 HGLI 4890.0 ELI 4875.0
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 45. CV 0. OV 0. PL 0. ROCK 0. BRRW 3.8 MILES
TURNOUT CODE  0.  0.
TURNOUT SIZE 1. OF 12. INCH
BW 12. Z 1.3 BH 5.4 BLW 3.5 RBW 3.0 LOZ 1.4 ROZ 1.7 EL 4881.3.4880.9,4879.2,
4878.8 ROW 45. OELI 4880.0 OELO 4877.9
MINQ 9. MIZQ 36. QINTERVAL 3.0
SKIP---GRAVITY PIPE REACH 5
LENGTH 5700. HGLO 4879.2 ELO 4864.5 HGLI 4887.9 ELI 4873.0
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 40. CV 0. OV 0. PL 0. ROCK 0. BRRW 4.5 MILES
TURNOUT CODE  0.   0.
TURNOUT SIZE 1. OF 8.  3. OF 10. INCH
BW 10. Z 1.0 BH 5.0 LBW 1.0 RBW 1.0 LOZ 7.0 ROZ 3.5 EL 4880.0.4879.7,4871.2,
4870.2 ROW 40. OELI 4877.9, OELO 4867.2
MINQ 9. MAXQ 30. QINTERVAL 3.0
SKIP---GRAVITY PIPE REACH 6
LENGTH 2080. HGLO 4873.9 ELO 4859.6 HGLI 4879.2 ELI 4864.5
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 45. CV 0. OV 0. PL 0. ROCK 0. BRRW 5.0 MILES
TURNOUT CODE  0.   0.
TURNOUT SIZE 1. OF 10. INCH
BW 11. Z .62 BH 3.2 LBW 5.0 RBW 8.0 LOZ .57 ROZ 1.0 EL 4868.6,4870.3,4864.2,
4865.9, ROW 45. OELI 4867.2 OELO 4862.8
MINQ 4. MAXQ 16. QINTERVAL 2.0
SKIP---GRAVITY PIPE REACH 7
LENGTH 2600. HGLO 4868.9 ELO 4854.6 HGLI 4873.9 ELI 4859.6
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 45.  CV 0. OV 0. PL 0. ROCK 0. BRRW 5.5 MILES
TURNOUT CODE   0.   0.
TURNOUT SIZE 1. OF 8.  1. OF 10.  1. OF 12. INCHES
BW 11. Z .62 BH 3.2 LBW 5.0 RBW 8.0 LOZ .57 ROZ 1.0 EL 4864.2.4865.9.4859.2,
4860.9 ROW 45. OELI 4862.8 OELO 4857.8
MINQ 4. MAXQ 12. QINTERVAL 1.
SKIP---GRAVITY PIPE REACH
```

```
LENGTH 6750. HGLO 4897.0 ELO 4885.0 HGLI 4905.0 ELI 4896.0
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 30. CV 0. OV 0. PL 0. ROCK 0. BRRW 3.0 MILES
TURNOUT CODE     0.   0.
TURNOUT SIZE 3. OF 8.  1. OF 10.  1. OF 14. INCHES
BW 4. Z 1.0 BH 4.0 LBW 2.0 RBW 2.0 LOZ 1.0 ROZ 1.0 EL 4902..4902.,4891.,
4891. ROW 30. OELI 4900. OELO 4889.
MINQ 5.  MAXQ 17.  QINTERVAL 2.
SKIP---GRAVITY PIPE REACH 9
LENGTH 2300. HGLO 4887.5 ELO 4875.0 HGLI 4893.0 ELI 4880.5
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 30. CV 0. OV 0. PL 0. ROCK 0. BRRW 3.5 MILES
TURNOUT CODE  0.   0.
TURNOUT SIZE 3. OF 8. INCHES
BW 5. Z 1.0 BH 4.0 LBW 3.0 RBW 3.0 LOZ 1.0 ROZ 1.0 EL 4885.5,4885.5,4880.0,
4880.0 ROW 30. OELI 4882.5 OELO 4877.0
MINQ 2.0  MAXQ 6.0 QINTERVAL 1.0
SKIP---GRAVITY PIPE REACH 10
LENGTH 5500.  HGLO 4878.8 ELO 4865.4  HGLI 4893.0 ELI 4879.8
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 40. CV 0. OV 0. PL 0. ROCK 0. BRRW 4.0 MILES
TURNOUT CODE  0.  MISC=SIXTEEN INCH BUTTERFLY&FLANGE $ 890.
TURNOUT SIZE  2. OF 8.  1. OF 12.  INCHES
BW 10. Z .96 BH 5.2 LBW 3.0 RBW 1.0 LOZ 2.3 ROZ 4.7 EL 4886.3.4884.7,4871.8,
4870.3 ROW 40. OELI 4882.0 OELO 4867.5
MINQ 6.  MAXQ 20.  QINTERVAL 2.
SKIP---GRAVITY PIPE REACH 11
LENGTH 3110.  HGLO 4881. ELO 4871. HGLI 4888.7 ELI 4876.
PIPE TYPE 4.
WATER HAMMER = 1.0
EASEMENT 20. CV 0. OV 0. PL 0. ROCK 0. BRRW 4.0 MILES
TURNOUT CODE  0.  0.
TURNOUT SIZE 3. OF 8. INCHES
BW 4. Z 1.0 BH 2.0 LBW 2. RBW 2. LOZ 1. ROZ 1. EL 4882. 4882., 4875.,
4875. ROW 20. OELI 4881.0 OELO 4874.0
MINQ 2.  MAXQ 7. QINTERVAL 1.0
END  OF  DATA
```

INPUT DATA FOR PIPE ROUTINE (HIGH PRESSURE)

```
0.   THIS PIPE IS TO BE LAYED IN NATURAL TERRAIN
COMMON EXC .59 COMSTR 2.75 COMSIPH 2.15 COMPIP 2.75 ROCKCAN 2.75 ROCKSTR 5.30,
ROCKSIPH 5.40 ROCKPIPE 5.40
BACKFILL CANAL 1.20 BFSTR 1.56 BFSIPH .83 BFPIPE 1.04 BEDPREP .30 COMPEM .80,
COMPBF 4.16 OHAUL .85 /YD MI
CONCRETE IN LINING 50. CONSTR 150. CONSIPH 146. STEEL .50 CEM 3.80
READ---HIGH PRESSURE PIPE---REACH 1
WAGE PIPELAYER 10.00 EQUIP INDEX 1.2 AF 1.1 HD 80. HD 200. CODE 1. CIDX 1. ,
DEPTH OF FILL 4.0 HEADCLASS 200.
CONTINGIENCIES EARTH 10. STEEL 15. ROW 10. CONCRETE 15. STEEL 12. PIPE 10.,
PVC HEAD CLASS 3.
50. YEAR LIFE  INTEREST 7.0 % SALVAGE VALUE 5. %
TOWER HEIGHT 200. FT MIN Q 27. MAXQ 60. CFS QINT 3.
LENGTH 5060. HGLO 5036. ELO 4896. HGLI 5044. ELI 4904.
PIPE TYPE 4.
WATER HAMMER 1.0
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 3.5 MI
TURNOUT CODE 0.  MISC COSTS $ 20900.
TURNOUT SIZES (INCHES) 1. OF 12.  1. OF 14.
STATION 0.  GLE 4910.  PGE 4901.8
2000.,4907.0,4899.0
4000.,4903.7,4895.5
5060.,4902.0,4894.0
0..0..0.
MIN Q 27.  MAX Q 60.  QINTERVAL 3. CFS
SKIP---HIGH PRESSURE PIPE---REACH 2
LENGTH 8300.  HGLO 5022. ELO 4882. HGLI 5036. ELI 4896.
PIPE TYPE 4.
WATER HAMMER 1.
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 3.5
TURNOUT CODE 0.  MISC COSTS $ 28200.00
TURNOUT SIZES (INCHES) 2. OF 12.
STATION 0.  GLE. 4902. PGE 4894.2
2000.,4895.,4887.2
4000.,4889.,4881.2
6000.,4890.,4882.2
8300.,4888.,4880.2
0.,0.,0.
MINQ 21. MAXQ 48. QINTERVAL 3. CFS
SKIP---HIGH PRESSURE PIPE---REACH 3
LENGTH 2725. HGLO 5019. ELO 4879. HGLI 5022. ELI 4882.
PIPE TYPE 4.
WATER HAMMER 1.
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 3.5
TURNOUT CODE 0.   MISC COSTS $ 19000.
TURNOUT SIZES (INCHES) 1. OF 10.  1. OF 12.
STATION 0.  GLE 4888.  PGE 4881.
2000..4886.6,4879.6
2725.,4886.0,4879.0
0.,0.,0.
MINQ 10.  MAXQ 24.  QINTERVAL 2.0
SKIP---HIGH PRESSURE PIPE---REACH 4
LENGTH 2850. HGLO 5014. ELO 4874. HGLI 5019. ELI 4879.
PIPE TYPE 4.
WATER HAMMER 1.
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 4.5
TURNOUT CODE 0.  MISC COSTS $ 13600.
TURNOUT SIZES (INCHES) 1. OF 14.
STATION 0.  GLE 4886.  PGE 4879.7
2000.,4882.,4875.7
2850.,4880.,4873.7
0.,0.,0.
MINQ  8.  MAXQ  18.  QINTERVAL 1.0
SKIP---HIGH PRESSURE PIPE---REACH 5
LENGTH 7150.  HGLO 5004. ELO 4864. HGLI 5014. ELI 4874.
PIPE TYPE 4.
WATER HAMMER 1.0
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 5.0 MILES
TURNOUT CODE 0.  MISC COSTS $ 25200.
TURNOUT SIZES (INCHES) 1. OF 8.  1. OF 12.
STATION 0.  GLE 4880.  PGE 4873.6
2000.,4877..4870.6
4000..4870.,4863.6
6000.,4865..4858.6
7150.,4870.,4863.6
0..0.,0.
MINQ 5.  MAXQ 12.  QINTERVAL 1.0
SKIP---HIGH PRESSURE PIPE---REACH 6
LENGTH 2465.  HGLO 4997.  ELO 4857.  HGLI 5004.  ELI 4864.
PIPE TYPE 4.
WATER HAMMER 1.0
EASEMENT 50.  VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 5.5 MILES
TURNOUT CODE 0.  MISC COSTS $ 15200.
```

```
TURNOUT SIZES (INCHES) 1. OF 14.
STATION 0.  GLE 4870.  PGE 4864.5
2000.,4865.,4859.5
2465.,4863.,4857.5
0.,0.,0.
MINQ 2.  MAXQ 7.  QINTERVAL 1.
SKIP---HIGH PRESSURE PIPE---REACH 7
LENGTH 2725.  HGLO 5016. ELO 4876. HGLI 5022. ELI 4882.
PIPE TYPE 4.
WATER HAMMER 1.0
EASEMENT 50. VCROP 0. VOTH 0. LOTH 0. ROCK 0. BRRW 4.0 MILES
TURNOUT CODE 0.  MIC COSTS $ 7400.
TURNOUT SIZES (INCHES) 1. OF 12.
STATION 0.  GLE 4888.  PGE 4881.8
2000.,4884.5,4878.3
2725.,4882.0,4875.8
0.,0.,0.
MINQ 6.   MAXQ 12.  QINT 1.
SKIP---HIGH PRESSURE PIPE---REACH 8
LENGTH 5200. HGLO  5003. ELO 4863. HGLI 5016. ELI 4876.
PIPE TYPE 4.
WATER HAMMER 1.0
EASEMENT 50. VALUE CROPPED 0. VOTH 0. LOTH 0. ROCK 0. BRRW 4.0 MILES
TURNOUT CODE 0. MISC COSTS $ 19400.
TURNOUT SIZES (INCHES) 2. OF 12.
STATION 0.  GLE 4882.  PGE 4876.2
2000.,4877.,4871.2
4000.,4872.,4866.2
5200.,4869.,4863.2
0.,0.,0.
MINQ 4.  MAXQ 10. QINTERVAL 1. CFS
END
```

INPUT DATA FOR PUMP ROUTINE

```
READ---RIVER PUMP--CANAL TO HIGH PRESSURF PIPE--TETON ISLAND CANAL
4.  PUMPING UNITS  1. VEPTICAL TURBINE 175, FT TDH  JUNE 6. / 76,
CONTINGENCY 20. % COST FOREBAY 100. % COST OF POWER  2.65 CENTS  CI 1.07,
1.0 UNATTENDED PLANT  3.  MEDIUM SEDIMENT LOAD
LENGTH OF TRANSMISSION LINE  5.0 MILES  0, FLAT TERRAIN  0. AVE FOUNDATION 5.,
COST INDEX 1.07  COST INDEX 1.07
10 % CONTINGENCY SWITCHING BAY   1.07 COST INDEX
SERVICE LIFE OF LINE & BAY 35. YEARS  SALVAGE  25. %
LIFE OF PUMPING UNIT 40. YEARS  INTEREST 7.0 % SALVAGE 25. % ENERGY ESC 9. %
IPM .22  1.67  3.63  5.69  3.64  1.23  .09 (AVERAGE OF FOUR CROPS)
SEASON 24. WEEKS  MECHANIC WAGE 9.50  OPERATOR WAGE 10.20  AREA IRR 3150. ACR
MINQ  27.   MAXQ  60.  QINT  3. CFS
NO
3.33,100., 2.18,101.
3.235,100.,1.,
1.925,5000.,0.,
1.317,20000.,0.,
0.897,20001.,0.
READ---FARM PUMP...CANAL TO SPRINKLER--150. TDH  9.5 % INTEREST
150. TDH   CI 1.07   2. (TURBINE)  70. % EFF  5. % MISC  15. % CONT
SERVICE LIFE 15. YEARS  INTEREST 9.5 %  SALVAGE 15. % OE 0.  ENERGY ESC 9. %
IPM .22  1.67  3.63  5.69  3.64  1.23  .09 (FOUR CROPS)
3.  % O&M  3. % TAX&INS
0.,0.,0.,0.,0.,0.   WELL DATA
MINQ 100.  MAXQ 1300.  QINT  10. GPM
NO
3.33,100.,  2.18,101.
3.234,100.,1.,
1.925,5000.,0.,
1.317,20000.,0.,
0.897,20001.,0.
READ---FARM PUMP...CANAL TO SPPINKLER---175. TDH  9.5 % INTEREST
175. TDH  CI 1.07  2. TURBINE  70. % EFF  5. % MISC  15. % CONT
SERVICE LIFE  15. YEARS  INTEREST 9.5 %  SALVAGE 15. % OE 0. ENERGY ESC 9. %
IPM  .22  1.67  3.63  5.69  3.64  1.23  .09 (FOUR CROPS)
3. %   O&M  3. %  TAX&INS
0.,0.,0.,0.,0.,0.  WELL DATA
MINQ  100.  MAXQ  1300.  QINT  10. GPM
NO
3.33,100.,  2.18.101.
3.234,100.,1.,
1.925,5000.,0.,
1.317,20000.,0.,
0.897,20001.,0.
READ---FARM PUMP...CANAL TO SPRINKLER---150. TDH  7.0 % INTEREST
150. TDH  CI 1.07  2. TURBINE 70. % EFF  5. % MISC  15. % CONT
SERVICE LIFE 15. YEARS  INTEREST 7.0 % SALVAGE 15. % OE 0. ENERGY ESC 9. %
IPM  .21  1.65  3.89  5.64  3.14  .89
3. % O&M  3. % TAX&INS
0.,0.,0.,0.,0.,0.  WELL DATA
MINQ  100.  MAXQ  1300.  QINT 10.  GPM
NO
3.33,100.,  2.18,101.
3.235,100.,1.,
1.925,5000.,0.,
1.317,20000.,0.,
0.897,20001.,0.
READ---FARM PUMP...CANAL TO SPRINKLER---175, TDH  7.0 % INTEREST
175. TDH  CI 1.07  2. TURBINE 70. % EFF  5. % MISC  15. % CONT
SERVICE LIFE 15. YEARS  INTEREST 7.0 % SAL 15. % OE 0. % ENERGY ESC 9. %
IPM  .26  1.81  3.76  5.49  3.27  1.16  .12
3. %  O&M  3. % TAX&INS
0.,0.,0.,0.,0.,0.  WELL DATA
MINQ 100.  MAXQ 1300.  QINT 10.
NO
3.33,100.,  2.18,101.
3.235,100.,1.,
1.925,5000.,0.,
1.317,20000.,0.,
0.897,20001.,0.
END
```

INPUT DATA FOR DYNAMIC PROGRAMMING ROUTINE

```
EMARGN  =  0.0000
1.  UNLINED  2. LINED  3.  GRAVITY PIPE
99.  7.53  3.58  0.
1.  230.  .0001  100.
NEXT
1.  8.87  4.22  99.
1.  642.  .0001  95.7
2.  3491.  22.6  97.7
3.  12629.  161.2  100.
NEXT
8.  9.46  4.50  1.
1.  674.  .0001  89.2
2.  2180.  53.7  97.
3.  6555.  376.4   100.
NEXT
2.  9.41  4.48  1.
1.  1665.  .0001  94.9
2.  3051.  28.7  97.6
3.  10795  184.9  100.
NEXT
9.  3.32  1.58  2.
1.  275.  .0001  88.3
2.  767.  34.3  97.4
3.  1382.  135.7  100.
NEXT
10.  7.51  3.57  2.
1.  743.  .0001  86.7
2.  1888.  41.2  97.3
3.  3841.  286.2  100.
NEXT
11.  3.48  1.66  10.
1.  110.  .0001  89.8
2.  926.  48.5  97.2
3.  1822.  168.1  100.
NEXT
3.  5.67  2.7  2.
1.  676.  .0001  96.4
2.  1969.  11.7  97.8
3.  4142.  98.2  100.
NEXT
4.  3.18  1.51  3.
1.  88.  .0001  96.3
2.  683.  6.9  97.9
3.  1438.  33.3  100.
NEXT
5.  7.43  3.54  4.
1.  635.  .0001  90.6
2.  2416.  30.8  97.4
3.  6636.  219.6  100.
NEXT
6.  2.40  1.14  5.
1.  133.  .0001  94.2
2.  595.  20.2  97.7
3.  1180.  125.3  100.
NEXT
7.  6.23  2.97  6.
1.  200.  .0001  89.7
2.  924.  21.3  97.5
3.  1528.  204.7  100.
0.0
```

MATRIX INPUT DATA FOR MPS/360 LINEAR PROGRAMMING ROUTINE

```
NAME          TETON01
ROWS
 N  OBJ
 E  SOIL1P
 E  SOIL1G
 E  SOIL1A
 E  SOIL1B
 E  SOIL2P
 E  SOIL2G
 E  SOIL2A
 E  SOIL2B
 E  SOIL3P
 E  SOIL3G
 E  SOIL3A
 E  SOIL4P
 E  SOIL4G
 E  SOIL4A
 E  SOIL4B
 L  AREA1
 L  AREA2
 L  AREA3
 L  AREA4
 L  AREA5
 L  AREA6
 L  AREA7
 L  AREA8
 L  AREA9
 L  AREA10
 L  AREA11
 L  AREA12
 L  WTON
 E  VOLON
 E  DEPERB
 E  DEPERD
 E  SUROFF
 E  CONSP
 E  CONST
 E  COEM
 N  CHON
 N  CHDPB
 N  CHDPD
 N  CHSP
COLUMNS
    SUBP1     OBJ       20.520           SOIL1P    1.0000
    SUBP1     AREA1     0.0094           AREA3     0.0047
    SUBP1     AREA4     0.0084           AREA5     0.0050
    SUBP1     AREA6     0.0158           AREA7     0.0042
    SUBP1     AREA8     0.0112           AREA9     0.0041
    SUBP1     AREA10    0.0038           DEPERB     7.000
    SUBG1     OBJ       20.520           SOIL1G    1.0000
    SUBG1     AREA1     0.0093           AREA3     0.0047
    SUBG1     AREA4     0.0083           AREA5     0.0049
    SUBG1     AREA6     0.0156           AREA7     0.0041
    SUBG1     AREA8     0.0111           AREA9     0.0040
    SUBG1     AREA10    0.0037           DEPERB     7.000
    SUBA1     OBJ       20.520           SOIL1A    1.0000
    SUBA1     AREA1     0.0074           AREA3     0.0037
    SUBA1     AREA4     0.0066           AREA5     0.0039
    SUBA1     AREA6     0.0124           AREA7     0.0033
    SUBA1     AREA8     0.0088           AREA9     0.0032
    SUBA1     AREA10    0.0030           DEPERB     7.000
    SUBB1     OBJ       20.520           SOIL1B    1.0000
    SUBB1     AREA1     0.0067           AREA3     0.0034
    SUBB1     AREA4     0.0060           AREA5     0.0036
    SUBB1     AREA6     0.0113           AREA7     0.0030
    SUBB1     AREA8     0.0080           AREA9     0.0029
    SUBB1     AREA10    0.0027           DEPERB     7.000
    UNGP1     OBJ       59.010           SOIL1P    1.0000
    UNGP1     AREA1     0.0041           AREA3     0.0020
    UNGP1     AREA4     0.0036           AREA5     0.0022
    UNGP1     AREA6     0.0068           AREA7     0.0018
    UNGP1     AREA8     0.0049           AREA9     0.0018
    UNGP1     AREA10    0.0016           DEPERD    0.5800
    UNGP1     SUROFF    1.5400
    UNGG1     OBJ       37.520           SOIL1G    1.0000
    UNGG1     AREA1     0.0031           AREA3     0.0015
    UNGG1     AREA4     0.0027           AREA5     0.0016
    UNGG1     AREA6     0.0051           AREA7     0.0014
    UNGG1     AREA8     0.0036           AREA9     0.0013
    UNGG1     AREA10    0.0012           DEPERD    0.3800
    UNGG1     SUROFF    1.2000
    UNGA1     OBJ       39.270           SOIL1A    1.0000
    UNGA1     AREA1     0.0025           AREA3     0.0013
    UNGA1     AREA4     0.0023           AREA5     0.0013
```

```
UNGA1     AREA8     0.0030          AREA9     0.0011
UNGA1     AREA10    0.0010          SUROFF    1.6000
UNGB1     OBJ       42.770          SOIL1B    1.0000
UNGB1     AREA1     0.0044          AREA3     0.0022
UNGB1     AREA4     0.0039          AREA5     0.0023
UNGB1     AREA6     0.0073          AREA7     0.0019
UNGB1     AREA8     0.0052          AREA9     0.0019
UNGB1     AREA10    0.0018          DEPERD    1.4300
UNGB1     SUROFF    2.4000
IMGP1     OBJ       74.290          SOIL1P    1.0000
IMGP1     AREA1     0.0039          AREA3     0.0019
IMGP1     AREA4     0.0035          AREA5     0.0021
IMGP1     AREA6     0.0065          AREA7     0.0017
IMGP1     AREA8     0.0046          AREA9     0.0017
IMGP1     AREA10    0.0016          DEPERD    0.5800
IMGP1     SUROFF    1.5400
IMGG1     OBJ       59.450          SOIL1G    1.0000
IMGG1     AREA1     0.0018          AREA3     0.0009
IMGG1     AREA4     0.0016          AREA5     0.0009
IMGG1     AREA6     0.0030          AREA7     0.0008
IMGG1     AREA8     0.0021          AREA9     0.0008
IMGG1     AREA10    0.0007          SUROFF    0.5000
IMGA1     OBJ       61.200          SOIL1A    1.0000
IMGA1     AREA1     0.0024          AREA3     0.0012
IMGA1     AREA4     0.0021          AREA5     0.0012
IMGA1     AREA6     0.0039          AREA7     0.0010
IMGA1     AREA8     0.0028          AREA9     0.0010
IMGA1     AREA10    0.0009          DEPERD    0.0800
IMGA1     SUROFF    1.3300
IMGB1     OBJ       64.700          SOIL1B    1.0000
IMGB1     AREA1     0.0022          AREA3     0.0011
IMGB1     AREA4     0.0020          AREA5     0.0012
IMGB1     AREA6     0.0037          AREA7     0.0010
IMGB1     AREA8     0.0026          AREA9     0.0010
IMGB1     AREA10    0.0009          DEPERD    0.1100
IMGB1     SUROFF    1.3400
HMPP1     OBJ       76.880          SOIL1P    1.0000
HMPP1     AREA1     0.0024          AREA3     0.0012
HMPP1     AREA4     0.0021          AREA5     0.0013
HMPP1     AREA6     0.0040          AREA7     0.0011
HMPP1     AREA8     0.0028          AREA9     0.0010
HMPP1     AREA10    0.0010          DEPERD    0.3750
HMPG1     OBJ       65.470          SOIL1G    1.0000
HMPG1     AREA1     0.0017          AREA3     0.0009
HMPG1     AREA4     0.0015          AREA5     0.0009
HMPG1     AREA6     0.0028          AREA7     0.0008
HMPG1     AREA8     0.0020          AREA9     0.0007
HMPG1     AREA10    0.0007          DEPERD    0.2560
HMPA1     OBJ       71.500          SOIL1A    1.0000
HMPA1     AREA1     0.0020          AREA3     0.0010
HMPA1     AREA4     0.0017          AREA5     0.0010
HMPA1     AREA6     0.0033          AREA7     0.0009
HMPA1     AREA8     0.0023          AREA9     0.0008
HMPA1     AREA10    0.0008          DEPERD    0.3960
HMPB1     OBJ       71.380          SOIL1B    1.0000
HMPB1     AREA1     0.0016          AREA3     0.0008
HMPB1     AREA4     0.0014          AREA5     0.0009
HMPB1     AREA6     0.0027          AREA7     0.0007
HMPB1     AREA8     0.0019          AREA9     0.0007
HMPB1     AREA10    0.0006          DEPERD    0.3540
SRPP1     OBJ       78.940          SOIL1P    1.0000
SRPP1     AREA1     0.0024          AREA3     0.0012
SRPP1     AREA4     0.0021          AREA5     0.0013
SRPP1     AREA6     0.0040          AREA7     0.0011
SRPP1     AREA8     0.0028          AREA9     0.0010
SRPP1     AREA10    0.0010          DEPERD    0.3750
SRPG1     OBJ       74.250          SOIL1G    1.0000
SRPG1     AREA1     0.0017          AREA3     0.0009
SRPG1     AREA4     0.0015          AREA5     0.0009
SRPG1     AREA6     0.0028          AREA7     0.0008
SRPG1     AREA8     0.0020          AREA9     0.0007
SRPG1     AREA10    0.0007          DEPERD    0.2560
SRPA1     OBJ       76.690          SOIL1A    1.0000
SRPA1     AREA1     0.0020          AREA3     0.0010
SRPA1     AREA4     0.0017          AREA5     0.0010
SRPA1     AREA6     0.0033          AREA7     0.0009
SRPA1     AREA8     0.0023          AREA9     0.0008
SRPA1     AREA10    0.0008          DEPERD    0.3960
SRPB1     OBJ       76.690          SOIL1B    1.0000
SRPB1     AREA1     0.0016          AREA3     0.0008
SRPB1     AREA4     0.0014          AREA5     0.0009
SRPB1     AREA6     0.0027          AREA7     0.0007
SRPB1     AREA8     0.0019          AREA9     0.0007
SRPB1     AREA10    0.0006          DEPERD    0.3540
```

```
SSPP1      AREA1      0.0022          AREA3      0.0011
SSPP1      AREA4      0.0020          AREA5      0.0012
SSPP1      AREA6      0.0037          AREA7      0.0010
SSPP1      AREA8      0.0027          AREA9      0.0010
SSPP1      AREA10     0.0009          DEPERD     0.3000
SUBP2      OBJ        20.600          SOIL2P     1.0000
SUBP2      AREA1      0.0070          AREA2      0.0071
SUBP2      AREA3      0.0164          AREA4      0.0140
SUBP2      AREA5      0.0036          AREA7      0.0039
SUBP2      AREA10     0.0030          AREA11     0.0116
SUBP2      DEPERB      7.000
SUBG2      OBJ        20.600          SOIL2G     1.0000
SUBG2      AREA1      0.0069          AREA2      0.0070
SUBG2      AREA3      0.0162          AREA4      0.0138
SUBG2      AREA5      0.0035          AREA7      0.0038
SUBG2      AREA10     0.0030          AREA11     0.0114
SUBG2      DEPERB      7.000
SUBA2      OBJ        20.600          SOIL2A     1.0000
SUBA2      AREA1      0.0055          AREA2      0.0056
SUBA2      AREA3      0.0129          AREA4      0.0110
SUBA2      AREA5      0.0028          AREA7      0.0030
SUBA2      AREA10     0.0023          AREA11     0.0091
SUBA2      DEPERB      7.000
SUBB2      OBJ        20.600          SOIL2B     1.0000
SUBB2      AREA1      0.0050          AREA2      0.0051
SUBB2      AREA3      0.0117          AREA4      0.0100
SUBB2      AREA5      0.0026          AREA7      0.0028
SUBB2      AREA10     0.0021          AREA11     0.0083
SUBB2      DEPERB      7.000
UNGP2      OBJ        46.590          SOIL2P     1.0000
UNGP2      AREA1      0.0032          AREA2      0.0033
UNGP2      AREA3      0.0076          AREA4      0.0065
UNGP2      AREA5      0.0017          AREA7      0.0018
UNGP2      AREA10     0.0014          AREA11     0.0053
UNGP2      DEPERD     0.8700          SUROFF     1.0900
UNGG2      OBJ        29.270          SOIL2G     1.0000
UNGG2      AREA1      0.0033          AREA2      0.0033
UNGG2      AREA3      0.0077          AREA4      0.0065
UNGG2      AREA5      0.0017          AREA7      0.0018
UNGG2      AREA10     0.0014          AREA11     0.0054
UNGG2      DEPERD     1.2300          SUROFF     1.5800
UNGA2      OBJ        30.620          SOIL2A     1.0000
UNGA2      AREA1      0.0030          AREA2      0.0030
UNGA2      AREA3      0.0070          AREA4      0.0060
UNGA2      AREA5      0.0015          AREA7      0.0016
UNGA2      AREA10     0.0013          AREA11     0.0049
UNGA2      DEPERD     1.1400          SUROFF     1.9100
UNGB2      OBJ        31.960          SOIL2B     1.0000
UNGB2      AREA1      0.0032          AREA2      0.0033
UNGB2      AREA3      0.0076          AREA4      0.0065
UNGB2      AREA5      0.0017          AREA7      0.0018
UNGB2      AREA10     0.0014          AREA11     0.0053
UNGB2      DEPERD     1.7500          SUROFF     2.2400
IMGP2      OBJ        58.340          SOIL2P     1.0000
IMGP2      AREA1      0.0027          AREA2      0.0027
IMGP2      AREA3      0.0063          AREA4      0.0054
IMGP2      AREA5      0.0014          AREA7      0.0015
IMGP2      AREA10     0.0012          AREA11     0.0044
IMGP2      DEPERD     0.8700          SUROFF     1.0900
IMGG2      OBJ        47.680          SOIL2G     1.0000
IMGG2      AREA1      0.0015          AREA2      0.0016
IMGG2      AREA3      0.0036          AREA4      0.0030
IMGG2      AREA5      0.0008          AREA7      0.0008
IMGG2      AREA10     0.0007          AREA11     0.0025
IMGG2      DEPERD     0.0300          SUROFF     0.8400
IMGA2      OBJ        49.020          SOIL2A     1.0000
IMGA2      AREA1      0.0018          AREA2      0.0018
IMGA2      AREA3      0.0042          AREA4      0.0036
IMGA2      AREA5      0.0009          AREA7      0.0010
IMGA2      AREA10     0.0008          AREA11     0.0029
IMGA2      DEPERD     0.0400          SUROFF     1.2300
IMGB2      OBJ        50.370          SOIL2B     1.0000
IMGB2      AREA1      0.0017          AREA2      0.0018
IMGB2      AREA3      0.0041          AREA4      0.0035
IMGB2      AREA5      0.0009          AREA7      0.0010
IMGB2      AREA10     0.0007          AREA11     0.0029
IMGB2      DEPERD     0.1500          SUROFF     1.5600
HMPP2      OBJ        66.350          SOIL2P     1.0000
HMPP2      AREA1      0.0018          AREA2      0.0018
HMPP2      AREA3      0.0041          AREA4      0.0035
HMPP2      AREA5      0.0009          AREA7      0.0010
HMPP2      AREA10     0.0008          AREA11     0.0029
HMPP2      DEPERD     0.3750
HMPG2      OBJ        58.540          SOIL2G     1.0000
HMPG2      AREA1      0.0013          AREA2      0.0013
```

```
HMPG2     AREA3      0.0030          AREA4     0.0025
HMPG2     AREA5      0.0006          AREA7     0.0007
HMPG2     AREA10     0.0005          AREA11    0.0021
HMPG2     DEPERD     0.2560
HMPA2     OBJ        61.830          SOIL2A    1.0000
HMPA2     AREA1      0.0015          AREA2     0.0015
HMPA2     AREA3      0.0034          AREA4     0.0029
HMPA2     AREA5      0.0007          AREA7     0.0008
HMPA2     AREA10     0.0006          AREA11    0.0024
HMPA2     DEPERD     0.3960
HMPB2     OBJ        63.240          SOIL2B    1.0000
HMPB2     AREA1      0.0012          AREA2     0.0012
HMPB2     AREA3      0.0028          AREA4     0.0024
HMPB2     AREA5      0.0006          AREA7     0.0007
HMPB2     AREA10     0.0005          AREA11    0.0020
HMPB2     DEPERD     0.3540
SRPP2     OBJ        69.390          SOIL2P    1.0000
SRPP2     AREA1      0.0018          AREA2     0.0018
SRPP2     AREA3      0.0041          AREA4     0.0035
SRPP2     AREA5      0.0009          AREA7     0.0010
SRPP2     AREA10     0.0008          AREA11    0.0029
SRPP2     DEPERD     0.3750
SRPG2     OBJ        59.140          SOIL2G    1.0000
SRPG2     AREA1      0.0013          AREA2     0.0013
SRPG2     AREA3      0.0030          AREA4     0.0025
SRPG2     AREA5      0.0006          AREA7     0.0007
SRPG2     AREA10     0.0005          AREA11    0.0021
SRPG2     DEPERD     0.2560
SRPA2     OBJ        60.470          SOIL2A    1.0000
SRPA2     AREA1      0.0015          AREA2     0.0015
SRPA2     AREA3      0.0034          AREA4     0.0029
SRPA2     AREA5      0.0007          AREA7     0.0008
SRPA2     AREA10     0.0006          AREA11    0.0024
SRPA2     DEPERD     0.3960
SRPB2     OBJ        61.050          SOIL2B    1.0000
SRPB2     AREA1      0.0012          AREA2     0.0012
SRPB2     AREA3      0.0028          AREA4     0.0024
SRPB2     AREA5      0.0006          AREA7     0.0007
SRPB2     AREA10     0.0005          AREA11    0.0020
SRPB2     DEPERD     0.3540
SSPP2     OBJ        223.17          SOIL2P    1.0000
SSPP2     AREA1      0.0016          AREA2     0.0017
SSPP2     AREA3      0.0039          AREA4     0.0033
SSPP2     AREA5      0.0008          AREA7     0.0009
SSPP2     AREA10     0.0007          AREA11    0.0027
SSPP2     DEPERD     0.3000
SUBP3     OBJ        20.600          SOIL3P    1.0000
SUBP3     AREA1      0.0122          AREA2     0.0543
SUBP3     DEPERB      7.000
SUBG3     OBJ        20.600          SOIL3G    1.0000
SUBG3     AREA1      0.0121          AREA2     0.0536
SUBG3     DEPERB      7.000
SUBA3     OBJ        20.600          SOIL3A    1.0000
SUBA3     AREA1      0.0096          AREA2     0.0426
SUBA3     DEPERB      7.000
UNGP3     OBJ        46.590          SOIL3P    1.0000
UNGP3     AREA1      0.0064          AREA2     0,0282
UNGP3     DEPERD     0.3200          SUROFF    2.6600
UNGG3     OBJ        27.920          SOIL3G    1.0000
UNGG3     AREA1      0.0031          AREA2     0.0137
UNGG3     SUROFF     1.1100
UNGA3     OBJ        27.920          SOIL3A    1.0000
UNGA3     AREA1      0.0032          AREA2     0.0143
UNGA3     SUROFF     1.1200
IMGP3     OBJ        58.340          SOIL3P    1.0000
IMGP3     AREA1      0.0060          AREA2     0.0267
IMGP3     DEPERD     0.3200          SUROFF    2.6600
IMGG3     OBJ        58.340          SOIL3G    1.0000
IMGG3     AREA1      0.0023          AREA2     0.0102
IMGG3     SUROFF     0.6100
IMGA3     OBJ        46.330          SOIL3A    1.0000
IMGA3     AREA1      0.0031          AREA2     0.0138
IMGA3     DEPERD     0.0700          SUROFF    1.2200
HMPP3     OBJ        63.090          SOIL3P    1.0000
HMPP3     AREA1      0.0031          AREA2     0.0137
HMPP3     DEPERD     0.3750
HMPG3     OBJ        54.390          SOIL3G    1.0000
HMPG3     AREA1      0.0022          AREA2     0.0098
HMPG3     DEPERD     0.2560
HMPA3     OBJ        56.390          SOIL3A    1.0000
HMPA3     AREA1      0.0025          AREA2     0.0113
HMPA3     DEPERD     0.3960
SRPP3     OBJ        72.380          SOIL3P    1.0000
SRPP3     AREA1      0.0031          AREA2     0.0137
```

```
SRPG3     OBJ        60.330          SOIL3G    1.0000
SRPG3     AREA1      0.0022          AREA2     0.0098
SRPG3     DEPERD     0.2560
SRPA3     OBJ        61.130          SOIL3A    1.0000
SRPA3     AREA1      0.0025          AREA2     0.0113
SRPA3     DEPERD     0.3960
SSPP3     OBJ        226.84          SOIL3P    1.0000
SSPP3     AREA1      0.0029          AREA2     0.0128
SSPP3     DEPERD     0.3000
SUBP4     OBJ        20.750          SOIL4P    1.0000
SUBP4     AREA6      0.0035          AREA9     0.0281
SUBP4     AREA10     0.0215          AREA11    0.0027
SUBP4     AREA12     0.0108          DEPERB     7.000
SUBG4     OBJ        20.750          SOIL4G    1.0000
SUBG4     AREA6      0.0034          AREA9     0.0277
SUBG4     AREA10     0.0213          AREA11    0.0026
SUBG4     AREA12     0.0106          DEPERB     7.000
SUBA4     OBJ        20.750          SOIL4A    1.0000
SUBA4     AREA6      0.0027          AREA9     0.0220
SUBA4     AREA10     0.0169          AREA11    0.0021
SUBA4     AREA12     0.0085          DEPERB     7.000
SUBB4     OBJ        20.750          SOIL4B    1.0000
SUBB4     AREA6      0.0025          AREA9     0.0200
SUBB4     AREA10     0.0154          AREA11    0.0019
SUBB4     AREA12     0.0077          DEPERB     7.000
UNGP4     OBJ        61.010          SOIL4P    1.0000
UNGP4     AREA6      0.0014          AREA9     0.0116
UNGP4     AREA10     0.0089          AREA11    0.0011
UNGP4     AREA12     0.0044          DEPERD    1.7400
UNGP4     SUROFF     0.1900
UNGG4     OBJ        34.770          SOIL4G    1.0000
UNGG4     AREA6      0.0073          AREA9     0.0591
UNGG4     AREA10     0.0454          AREA11    0.0056
UNGG4     AREA12     0.0227          DEPERD    4.2300
UNGG4     SUROFF     5.5100
UNGA4     OBJ        38.270          SOIL4A    1.0000
UNGA4     AREA6      0.0063          AREA9     0.0590
UNGA4     AREA10     0.0391          AREA11    0.0048
UNGA4     AREA12     0.0196          DEPERD    5.3500
UNGA4     SUROFF     7.3300
UNGB4     OBJ        40.020          SOIL4B    1.0000
UNGB4     AREA6      0.0083          AREA9     0.0674
UNGB4     AREA10     0.0517          AREA11    0.0064
UNGB4     AREA12     0.0259          DEPERD    6.4800
UNGB4     SUROFF     8.2200
IMGP4     OBJ        111.48          SOIL4P    1.0000
IMGP4     AREA6      0.0013          AREA9     0.0106
IMGP4     AREA10     0.0082          AREA11    0.0010
IMGP4     AREA12     0.0041          DEPERD    2.1300
IMGG4     OBJ        78.890          SOIL4G    1.0000
IMGG4     AREA6      0.0006          AREA9     0.0052
IMGG4     AREA10     0.0040          AREA11    0.0005
IMGG4     AREA12     0.0020          SUROFF    0.4800
IMGA4     OBJ        84.720          SOIL4A    1.0000
IMGA4     AREA6      0.0007          AREA9     0.0058
IMGA4     AREA10     0.0045          AREA11    0.0006
IMGA4     AREA12     0.0022          SUROFF    0.7200
IMGB4     OBJ        87.640          SOIL4B    1.0000
IMGB4     AREA6      0.0012          AREA9     0.0094
IMGB4     AREA10     0.0072          AREA11    0.0009
IMGB4     AREA12     0.0036          DEPERD    0.4100
IMGB4     SUROFF     2.1600
HMPP4     OBJ        62.020          SOIL4P    1.0000
HMPP4     AREA6      0.0009          AREA9     0.0071
HMPP4     AREA10     0.0054          AREA11    0.0007
HMPP4     AREA12     0.0027          DEPERD    0.3750
HMPG4     OBJ        54.010          SOIL4G    1.0000
HMPG4     AREA6      0.0006          AREA9     0.0051
HMPG4     AREA10     0.0039          AREA11    0.0005
HMPG4     AREA12     0.0019          DEPERD    0.2560
HMPA4     OBJ        58.760          SOIL4A    1.0000
HMPA4     AREA6      0.0007          AREA9     0.0058
HMPA4     AREA10     0.0045          AREA11    0.0006
HMPA4     AREA12     0.0022          DEPERD    0.3960
HMPB4     OBJ        59.260          SOIL4B    1.0000
HMPB4     AREA6      0.0006          AREA9     0.0048
HMPB4     AREA10     0.0037          AREA11    0.0005
HMPB4     AREA12     0.0018          DEPERD    0.3540
SRPP4     OBJ        71.270          SOIL4P    1.0000
SRPP4     AREA6      0.0009          AREA9     0.0071
SRPP4     AREA10     0.0054          AREA11    0.0007
SRPP4     AREA12     0.0027          DEPERD    0.3750
SRPG4     OBJ        57.330          SOIL4G    1.0000
SRPG4     AREA6      0.0006          AREA9     0.0051
SRPG4     AREA10     0.0039          AREA11    0.0005
```

```
NAME          TETON02
COLUMNS
   DELETF
      SYSA11
      SYSA21
      SYSA31
      SYSA41
      SYSA51
      SYSA61
      SYSA71
      SYSA81
      SYSA91
```

```
    SRPG4     AREA12    0.0019       DEPERD    0.2560
    SRPA4     OBJ       59.270       SOIL4A    1.0000
    SRPA4     AREA6     0.0007       AREA9     0.0058
    SRPA4     AREA10    0.0045       AREA11    0.0006
    SRPA4     AREA12    0.0022       DEPERD    0.3960
    SRPB4     OBJ       59.490       SOIL4B    1.0000
    SRPB4     AREA6     0.0006       AREA9     0.0048
    SRPB4     AREA10    0.0037       AREA11    0.0005
    SRPB4     AREA12    0.0018       DEPERD    0.3540
    SSPP4     OBJ       222.28       SOIL4P    1.0000
    SSPP4     AREA6     0.0008       AREA9     0.0066
    SSPP4     AREA10    0.0051       AREA11    0.0006
    SSPP4     AREA12    0.0025       DEPERD    0.3000
    CPPP4     OBJ       60.970       SOIL4P    1.0000
    CPPP4     AREA6     0.0008       AREA9     0.0062
    CPPP4     AREA10    0.0048       AREA11    0.0006
    CPPP4     AREA12    0.0024       DEPERD    0.2250
    CPPG4     OBJ       60.970       SOIL4G    1.0000
    CPPG4     AREA6     0.0005       AREA9     0.0044
    CPPG4     AREA10    0.0034       AREA11    0.0004
    CPPG4     AREA12    0.0017       DEPERD    0.1540
    CPPA4     OBJ       60.970       SOIL4A    1.0000
    CPPA4     AREA6     0.0006       AREA9     0.0051
    CPPA4     AREA10    0.0039       AREA11    0.0005
    CPPA4     AREA12    0.0020       DEPERD    0.2380
    CPPB4     OBJ       60.970       SOIL4B    1.0000
    CPPB4     AREA6     0.0005       AREA9     0.0042
    CPPB4     AREA10    0.0032       AREA11    0.0004
    CPPB4     AREA12    0.0016       DEPERD    0.2130
    VON       VOLON     -.00528      CHON      1.0000
    VDPB      DEPERB    -1.000       CHDPB     -1.000
    VDPD      DEPERD    -1.000       CHDPD     1.0000
    VSR       SUROFF    -1.000       CHSR      1.0000
    SYSA11    OBJ       0.0001       AREA1     1.0000
    SYSA11    AREA2      -.957
    SYSA21    OBJ       0.0001       AREA2     1.0000
    SYSA21    AREA4      -.949
    SYSA31    OBJ       0.0001       AREA4     1.0000
    SYSA31    AREA6      -.964
    SYSA41    OBJ       0.0001       AREA6     1.0000
    SYSA41    AREA7      -.963
    SYSA51    OBJ       0.0001       AREA7     1.0000
    SYSA51    AREA10     -.906
    SYSA61    OBJ       0.0001       AREA10    1.0000
    SYSA61    AREA12     -.942
    SYSA71    OBJ       0.0001       AREA11     -.897
    SYSA71    AREA12    1.0000
    SYSA81    OBJ       0.0001       AREA2     1.0000
    SYSA81    AREA3      -.892
    SYSA91    OBJ       0.0001       AREA4     1.0000
    SYSA91    AREA5      -.883
    SYSA101   OBJ       0.0001       AREA4     1.0000
    SYSA101   AREA9      -.867
    SYSA111   OBJ       0.0001       AREA8      -.898
    SYSA111   AREA9     1.0000
    SYSA121   OBJ       0.0001       AREA1      -1.00
    SYSA121   WTON      1.0000       VOLON     1.0000
    SEEPAGEA  DEPERB     2679.       CONSP     1.0000
    FIXA      OBJ        6091.       CONST     1.0000
    OMCA      OBJ       23852.       COEM      1.0000
RHS
    RHSA      SOIL1P      262.       SOIL1G      306.
    RHSA      SOIL1A      175.       SOIL1B      131.
    RHSA      SOIL2P      413.       SOIL2G      482.
    RHSA      SOIL2A      276.       SOIL2B      207.
    RHSA      SOIL3P       85.       SOIL3G      141.
    RHSA      SOIL3A       56.       SOIL4P      126.
    RHSA      SOIL4G      252.       SOIL4A      126.
    RHSA      SOIL4B      126.       WTON        302.
    RHSA      CONSP     1.0000       CONST     1.0000
    RHSA      COEM      1.0000
    RHSB      WTON      1.0000
ENDATA
```

```
      SYSA101
      SYSA111
      SYSA121
      SEEPAGEA
      FIXA
      OMCA
    AFTER
      SYSB11      OBJ         0.0001          AREA1       1.0000
      SYSB11      AREA2        -.957
      SYSB21      OBJ         0.0001          AREA2       1.0000
      SYSB21      AREA4        -.949
      SYSB31      OBJ         0.0001          AREA4       1.0000
      SYSB31      AREA6        -.964
      SYSB42      OBJ           6.90          AREA6       1.0000
      SYSB42      AREA7        -.979
      SYSB51      OBJ         0.0001          AREA7       1.0000
      SYSB51      AREA10       -.906
      SYSB62      OBJ          20.20          AREA10      1.0000
      SYSB62      AREA12       -.977
      SYSB71      OBJ         0.0001          AREA11       -.897
      SYSB71      AREA12      1.0000
      SYSB81      OBJ         0.0001          AREA2       1.0000
      SYSB81      AREA3        -.892
      SYSB91      OBJ         0.0001          AREA4       1.0000
      SYSB91      AREA5        -.883
      SYSB101     OBJ         0.0001          AREA4       1.0000
      SYSB101     AREA9        -.867
      SYSB111     OBJ         0.0001          AREA8        -.898
      SYSB111     AREA9       1.0000
      SYSB121     OBJ         0.0001          AREA1        -1.00
      SYSB121     WTON        1.0000          VOLON       1.0000
      SEEPAGEB    DEPERB       2522.          CONSP       1.0000
      FIXB        OBJ          7148.          CONST       1.0000
      OMCB        OBJ         23852.          COEM        1.0000
ENDATA
NAME              TETON03
COLUMNS
    DELETE
      SYSB11
      SYSB21
      SYSB31
      SYSB42
      SYSB51
      SYSB62
      SYSB71
      SYSB81
      SYSB91
      SYSB101
      SYSB111
      SYSB121
      SEEPAGEB
      FIXB
      OMCB
    AFTER
      SYSC11      OBJ         0.0001          AREA1       1.0000
      SYSC11      AREA2        -.957
      SYSC21      OBJ         0.0001          AREA2       1.0000
      SYSC21      AREA4        -.949
      SYSC31      OBJ         0.0001          AREA4       1.0000
      SYSC31      AREA6        -.964
      SYSC41      OBJ         0.0001          AREA6       1.0000
      SYSC41      AREA7        -.963
      SYSC51      OBJ         0.0001          AREA7       1.0000
      SYSC51      AREA10       -.906
      SYSC62      OBJ          20.20          AREA10      1.0000
      SYSC62      AREA12       -.977
      SYSC72      OBJ          21.30          AREA11       -.975
      SYSC72      AREA12      1.0000
      SYSC81      OBJ         0.0001          AREA2       1.0000
      SYSC81      AREA3        -.892
      SYSC92      OBJ          34.30          AREA4       1.0000
      SYSC92      AREA5        -.974
      SYSC101     OBJ         0.0001          AREA4       1.0000
      SYSC101     AREA9        -.867
      SYSC111     OBJ         0.0001          AREA8        -.898
      SYSC111     AREA9       1.0000
      SYSC121     OBJ         0.0001          AREA1        -1.00
      SYSC121     WTON        1.0000          VOLON       1.0000
      SEEPAGEC    DEPERB       2401.          CONSP       1.0000
      FIXC        OBJ          7769.          CONST       1.0000
      OMCC        OBJ         23852.          COEM        1.0000
ENDATA
```

```
NAME          TETON04
COLUMNS
  DELETE
    SYSC11
    SYSC21
    SYSC31
    SYSC41
    SYSC51
    SYSC62
    SYSC72
    SYSC81
    SYSC92
    SYSC101
    SYSC111
    SYSC121
    SEEPAGEC
    FIXC
    OMCC
  AFTER
    SYSD11      OBJ         0.0001         AREA1       1.0000
    SYSD11      AREA2        -.957
    SYSD21      OBJ         0.0001         AREA2       1.0000
    SYSD21      AREA4        -.949
    SYSD31      OBJ         0.0001         AREA4       1.0000
    SYSD31      AREA6        -.964
    SYSD41      OBJ         0.0001         AREA6       1.0000
    SYSD41      AREA7        -.963
    SYSD51      OBJ         0.0001         AREA7       1.0000
    SYSD51      AREA10       -.906
    SYSD62      OBJ          20.20         AREA10      1.0000
    SYSD62      AREA12       -.977
    SYSD72      OBJ          21.30         AREA11        -.975
    SYSD72      AREA12      1.0000
    SYSD81      OBJ         0.0001         AREA2       1.0000
    SYSD81      AREA3        -.892
    SYSD91      OBJ         0.0001         AREA4       1.0000
    SYSD91      AREA5        -.883
    SYSD102     OBJ          41.20         AREA4       1.0000
    SYSD102     AREA9        -.973
    SYSD111     OBJ         0.0001         AREA8         -.898
    SYSD111     AREA9       1.0000
    SYSD121     OBJ         0.0001         AREA1        -1.00
    SYSD121     WTON        1.0000         VOLON       1.0000
    SEEPAGED    DEPERB       2189.         CONSP       1.0000
    FIXD        OBJ          8422.         CONST       1.0000
    OMCD        OBJ         23852.         COEM        1.0000
ENDATA
NAME          TETON05
COLUMNS
  DELETE
    SYSD11
    SYSD21
    SYSD31
    SYSD41
    SYSD51
    SYSD62
    SYSD72
    SYSD81
    SYSD91
    SYSD102
    SYSD111
    SYSD121
    SEEPAGED
    FIXD
    OMCD
  AFTER
    SYSE11      OBJ         0.0001         AREA1       1.0000
    SYSE11      AREA2        -.957
    SYSE22      OBJ          28.70         AREA2       1.0000
    SYSE22      AREA4        -.976
    SYSE31      OBJ         0.0001         AREA4       1.0000
    SYSE31      AREA6        -.964
    SYSE41      OBJ         0.0001         AREA6       1.0000
    SYSE41      AREA7        -.963
    SYSE51      OBJ         0.0001         AREA7       1.0000
    SYSE51      AREA10       -.906
    SYSE61      OBJ         0.0001         AREA10      1.0000
    SYSE61      AREA12       -.942
    SYSE71      OBJ         0.0001         AREA11        -.897
    SYSE71      AREA12      1.0000
    SYSE81      OBJ         0.0001         AREA2       1.0000
    SYSE81      AREA3        -.892
    SYSE91      OBJ         0.0001         AREA4       1.0000
    SYSE91      AREA5        -.883
    SYSE102     OBJ          41.20         AREA4       1.0000
    SYSE102     AREA9        -.973
    SYSE111     OBJ         0.0001         AREA8         -.898
    SYSE111     AREA9       1.0000
    SYSE121     OBJ         0.0001         AREA1        -1.00
    SYSE121     WTON        1.0000         VOLON       1.0000
    SEEPAGEE    DEPERB       1931.         CONSP       1.0000
    FIXE        OBJ          8622.         CONST       1.0000
    OMCE        OBJ         23852.         COEM        1.0000
ENDATA
```

APPENDIX D

SAMPLE COMPUTER OUTPUT FOR SALEM IRRIGATION DISTRICT

```
          ANNUAL COST OF IRRIGATION--------GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
          SOIL TYPE NUMBER----- 1

                            ALFALFA HAY

             FARM DATA:
      FIELD LENGTH, FT                              1300.
      LABOR REQUIRED, HR/AC/IRR                      0.35
      ADDITIONAL LABOR, HR/AC/IRR                    0.0
      LABOR RATE. $/HR                               5.00
      COST OF CONST. FARM DITCH, $/FT                0.40
      COST OF FARM DITCH LINING, $/FT                2.50
      COST OF IRRIGATION STRUC., $/AC               20.00
      COST OF MISC. EQUIPT., $/AC,                   0.0
      COST OF LEVELING, GRADING, $/AC              200.00
      COST OF LAND PREPARATION, $/AC                10.00
      COST OF LAND LOST TO PRODUCTION, $/AC        250.00


      NUMBER OF IRRIG./SEASON                          4.
      DEPLETED RAM BETWEEN IRRIGATIONS.INCHES       5.76
      FREQUENCY OF IRRIGATION AT PEAK USE.DAYS      25.

      FARM SIZE. ACRE                                 80.
      FIELD SIZE FOR THIS CROP, AC                    16.
      TOTAL INVESTMENT, $/AC                         317.

             OWNERSHIP COST ($/AC)

      DEPRECIATION (SINKING FUND)                    2.16
      INTEREST ON INITIAL INVESTMENT                30.13

      OPERATION AND MAINTENANCE COST ($/AC)
      LABOR COST                                     5.38
      MAINTENANCE AND REPAIR                        10.59
      TAXES AND INSURANCE                            0.29

             SUB TOTAL ....................         48.56
      COST OF LAND LOST TO PRODUCTION                5.77


   THE END OF THE FIELD IS BEING UNDERIRRIGATED.
 DISTRIBUTION EFFICIENCY = 88.1 PERCENT.
 APPLICATION EFFICIENCY  = 65.9 PERCENT
 UNIT FLOW RATE =0.0591 CFS
 SET TIME =      251.25 MINUTES.
 INFILTRATION AT FIELD HEAD IS    5.7600 INCHES

 INFILTRATION AT FIELD  END IS    4.7765 INCHES.

   Q AND TIME WILL BE INCREASED BY 10. PERCENT.


      COST OF WATER LOST                             0.0
      COST OF SUB-SURFACE DRAIN ($/AC)               0.0

             TOTAL ANNUAL COST ($/AC/YR)...        54.33
```

```
           BORDER IRRIGATION EFFICIENCY ESTIMATES
          SOIL TYPE NUMBER----- 1

      LENGTH OF IRRIGATION RUN, FT                           1300.
      DEPTH OF WATER APPLIED AT FIELD HEAD, IN                  6.17
      DEPTH OF WATER APPLIED AT FIELD END , IN                  5.56
      UNIT STREAM SIZE. CFS/FT                                  0.0650
      BORDER WIDTH, FT                                         40.
      FIELD SLOPE, FT/FT                                        0.0020
      TIME OF APPLICATION, MIN                                276.
      APPLICATION EFFICIENCY, PERCENT                          57.
      DISTRIBUTION EFFICIENCY, PERCENT                         94.
      VOLUME OF DEEP PERC, AC-FT/AC/YR                          0.07
      VOLUME OF RUNOFF, AC-FT/AC/YR                             1.34
```

```
               ANNUAL COST OF IRRIGATION--------GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
               SOIL TYPE NUMBER----- 1

                                     GRAIN

              FARM DATA:
      FIELD LENGTH, FT                            1300.
      LABOR REQUIRED, HR/AC/IRR                    0.35
      ADDITIONAL LABOR, HR/AC/IRR                  0.0
      LABOR RATE, $/HR                             5.00
      COST OF CONST. FARM DITCH, $/FT              0.40
      COST OF FARM DITCH LINING, $/FT              2.50
      COST OF IRRIGATION STRUC., $/AC             20.00
      COST OF MISC. EQUIPT., $/AC.                 0.0
      COST OF LEVELING, GRADING, $/AC            200.00
      COST OF LAND PREPARATION, $/AC              10.00
      COST OF LAND LOST TO PRODUCTION, $/AC      250.00


      NUMBER OF IRRIG./SEASON                        3.
      DEPLETED RAM BETWEEN IRRIGATIONS,INCHES      4.20
      FREQUENCY OF IRRIGATION AT PEAK USE,DAYS      21.

      FARM SIZE, ACRE                               80.
      FIELD SIZE FOR THIS CROP, AC                  28.
      TOTAL INVESTMENT, $/AC                       317.

              OWNERSHIP COST ($/AC)

      DEPRECIATION (SINKING FUND)                  2.16
      INTEREST ON INITIAL INVESTMENT              30.13

      OPERATION AND MAINTENANCE COST ($/AC)
      LABOR COST                                   4.04
      MAINTENANCE AND REPAIR                      10.59
      TAXES AND INSURANCE                          0.29

              SUB TOTAL ....................      47.21
      COST OF LAND LOST TO PRODUCTION              5.77


    THE END OF THE FIELD IS BEING UNDERIRRIGATED.
  DISTRIBUTION EFFICIENCY = 89.3 PERCENT.
  APPLICATION EFFICIENCY  = 66.1 PERCENT
  UNIT FLOW RATE =0.0670 CFS
  SET TIME =      161.62 MINUTES.
  INFILTRATION AT FIELD HEAD IS    4.2000 INCHES

  INFILTRATION AT FIELD  END IS    3.5444 INCHES.

     Q AND TIME WILL BE INCREASED BY 10. PERCENT.


      COST OF WATER LOST                           0.0
      COST OF SUB-SURFACE DRAIN ($/AC)             0.0

              TOTAL ANNUAL COST ($/AC/YR)...      52.98




                BORDER IRRIGATION EFFICIENCY ESTIMATES
               SOIL TYPE NUMBER----- 1

        LENGTH OF IRRIGATION RUN, FT                          1300.
        DEPTH OF WATER APPLIED AT FIELD HEAD, IN                 4.49
        DEPTH OF WATER APPLIED AT FIELD END , IN                 4.11
        UNIT STREAM SIZE, CFS/FT                                 0.0737
        BORDER WIDTH, FT                                       40.
        FIELD SLOPE, FT/FT                                       0.0020
        TIME OF APPLICATION, MIN                              178.
        APPLICATION EFFICIENCY, PERCENT                        58.
        DISTRIBUTION EFFICIENCY, PERCENT                       95.
        VOLUME OF DEEP PERC, AC-FT/AC/YR                         0.04
        VOLUME OF RUNOFF, AC-FT/AC/YR                            0.73
```

```
                  ANNUAL COST OF IRRIGATION--------GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
                  SOIL TYPE NUMBER----- 1

                                     PASTURE

                 FARM DATA:
        FIELD LENGTH, FT                              1300.
        LABOR REQUIRED, HR/AC/IRR                       0.35
        ADDITIONAL LABOR, HR/AC/IRR                     0.0
        LABOR RATE, $/HR                                5.00
        COST OF CONST. FARM DITCH, $/FT                 0.40
        COST OF FARM DITCH LINING, $/FT                 2.50
        COST OF IRRIGATION STRUC., $/AC                20.00
        COST OF MISC. EQUIPT., $/AC.                    0.0
        COST OF LEVELING, GRADING, $/AC               200.00
        COST OF LAND PREPARATION, $/AC                 10.00
        COST OF LAND LOST TO PRODUCTION, $/AC         250.00


        NUMBER OF IRRIG./SEASON                           6.
        DEPLETED RAM BETWEEN IRRIGATIONS,INCHES         3.00
        FREQUENCY OF IRRIGATION AT PEAK USE,DAYS         16.

        FARM SIZE, ACRE                                  80.
        FIELD SIZE FOR THIS CROP, AC                     12.
        TOTAL INVESTMENT, $/AC                          317.

                 OWNERSHIP COST ($/AC)

        DEPRECIATION (SINKING FUND)                     2.16
        INTEREST ON INITIAL INVESTMENT                 30.13

        OPERATION AND MAINTENANCE COST ($/AC)
        LABOR COST                                      8.08
        MAINTENANCE AND REPAIR                         10.59
        TAXES AND INSURANCE                             0.29

                 SUB TOTAL ...................         51.25
        COST OF LAND LOST TO PRODUCTION                 5.77


   RECESSION OF THE BORDER STREAM HAS BEEN DETERMINED
   TO BEGIN BEFORE THE STREAM HAS ADVANCED ACROSS THE FIELD.
   RECESSION TIME IS AT  105.93 MINUTES
   THE STREAM HAS ADVANCED TO  1170.0 FEET AT  108.17 MINUTES
   A LARGER FLOW RATE AND LONGER SET TIME WILL BE TRIED.


        COST OF WATER LOST                              0.0
        COST OF SUB-SURFACE DRAIN ($/AC)                0.0

                 TOTAL ANNUAL COST ($/AC/YR)...        57.02









                   BORDER IRRIGATION EFFICIENCY ESTIMATES
                  SOIL TYPE NUMBER----- 1

            LENGTH OF IRRIGATION RUN, FT                        1300.
            DEPTH OF WATER APPLIED AT FIELD HEAD, IN               3.39
            DEPTH OF WATER APPLIED AT FIELD END , IN               3.30
            UNIT STREAM SIZE, CFS/FT                               0.0939
            BORDER WIDTH, FT                                     40.
            FIELD SLOPE, FT/FT                                     0.0020
            TIME OF APPLICATION, MIN                            119.
            APPLICATION EFFICIENCY, PERCENT                      48.
            DISTRIBUTION EFFICIENCY, PERCENT                    100.
            VOLUME OF DEEP PERC, AC-FT/AC/YR                       0.16
            VOLUME OF RUNOFF, AC-FT/AC/YR                          1.44
```

```
           ANNUAL COST OF IRRIGATION--------GRAVITY IRRIGATION SYSTEM WITH GOOD MANAGEMENT
           SOIL TYPE NUMBER----- 1

                              POTATOES

         FARM DATA:
  FIELD LENGTH, FT                              1300.
  LABOR REQUIRED, HR/AC/IRR                     0.50
  ADDITIONAL LABOR, HR/AC/IRR                   0.0
  LABOR RATE, $/HR                              5.00
  COST OF CONST. FARM DITCH, $/FT               0.40
  COST OF FARM DITCH LINING, $/FT               2.50
  COST OF IRRIGATION STRUC., $/AC              20.00
  COST OF MISC. EQUIPT., $/AC,                 40.00
  COST OF LEVELING, GRADING, $/AC             150.00
  COST OF LAND PREPARATION, $/AC               10.00
  COST OF LAND LOST TO PRODUCTION, $/AC       250.00


  NUMBER OF IRRIG./SEASON                          8.
  DEPLETED RAM BETWEEN IRRIGATIONS,INCHES       2.40
  FREQUENCY OF IRRIGATION AT PEAK USE,DAYS         8.

  FARM SIZE, ACRE                                 80.
  FIELD SIZE FOR THIS CROP, AC                    24.
  TOTAL INVESTMENT, $/AC                         307.

         OWNERSHIP COST ($/AC)

  DEPRECIATION (SINKING FUND)                   2.90
  INTEREST ON INITIAL INVESTMENT               29.18

  OPERATION AND MAINTENANCE COST ($/AC)
  LABOR COST                                   15.38
  MAINTENANCE AND REPAIR                       10.79
  TAXES AND INSURANCE                           0.39

         SUB TOTAL ..................          58.65
  COST OF LAND LOST TO PRODUCTION               5.77


  COST OF WATER LOST                            0.0
  COST OF SUB-SURFACE DRAIN ($/AC)              0.0

         TOTAL ANNUAL COST ($/AC/YR)...        64.42
```

```
           FURROW IRRIGATION EFFICIENCY ESTIMATES
           SOIL TYPE NUMBER----- 1

     LENGTH OF IRRIGATION RUN,FT                         1300.
     DEPTH OF WATER APPLIED,IN                              2.40
     FURROW STREAM SIZE,GPM                               20.
     FURROW SPACING,IN                                    36.
     FIELD SLOPE, FT/FT                                     .00200
     TIME OF APPLICATION,MIN                             640.
     INTAKE FAMILY BASED ON SCS                           1.0
             A COEF =0.0701
             B COEF =0.7850
             C COEF =0.2750
     APPLICATION EFFICIENCY, PERCENT                      46.
     DISTRIBUTION EFFICIENCY, PERCENT                     66.
     VOLUME OF DEEP PERC, AC-FT/AC/YR                      0.81
     VOLUME OF RUNOFF, AC-FT/AC/YR                         1.10
```

```
          ANNUAL COST OF IRRIGATION-------HANDMOVE----HAND MOVE SPRINKLER SYSTEM--ANNIS SOIL
          SOIL TYPE NUMBER----- 1

                                   ALFALFA HAY

          FARM DATA:

     FIELD LENGTH, FT                          1300.
     FARM SIZE, ACRES                            80.
     NO. OF IRRIGATION                            4.
     FREQUENCY OF IRRIGATION, DAYS               25.
     GPM/LATERAL                                362.
     LABOR RATE, $/HR                            5.00

     NUMBER OF LATERALS / FARM                   2.0
     LENGTH OF LATERAL, FEET                   1300.
     LATERAL SPACING, FEET                       50.
     TIME TO MOVE LATERAL, MIN/SET               75.
     TIME OF SETTING, HRS                        12.
     TRANSPORT TIME PER ROTATION,HRS              2.
     AREA COVERED BY EACH LATERAL, ACRES        40.00

     COST PER LATERAL LINE, $                  1760.
     ALLOWABLE INTAKE RATE, IN/HR                0.80
     TOTAL LABOR, HR/AC/YR                        3.


     DEEP PERCOLATION,AF/ACRE                  0.3958
     APPLICATION EFFICIENCY,PERCENT             75.00

          MAINLINE DATA:

     TOTAL AREA SERVED BY MAINLINE, ACRES        80.
     TOTAL LENGTH OF MAINLINE, FEET            1300.

        DIAMETER(IN)      LENGTH(FT)      COST ($/FT)
            8.               600.           3.65
            6.               700.           2.30

     TOTAL COST OF MAINLINE, $                 4180.
     TOTAL INVESTMENT ($/AC)                     96.

        ANNUAL COST:                                     $/AC

     DEPRECIATION
        LATERAL                                          1.25
        MAINLINE                                         0.88
     INTEREST ON INVESTMENT
        LATERAL                                          4.18
        MAINLINE                                         4.96
     LABOR COST                                         16.63
     MAINTENANCE COST                                    2.89
     TAXES AND INSURANCE                                 0.53

                    T O T A L                           31.32

     NOTE:  TOTAL ANNUAL COST DOES NOT INCLUDE PUMP UNIT AND RESERVOIRS
```

```
         ANNUAL COST OF IRRIGATION-------HANDMOVE----HAND MOVE SPRINKLER SYSTEM--ANNIS SOIL
         SOIL TYPE NUMBER----- 1

                             GRAIN

         FARM DATA:

FIELD LENGTH, FT                           1300.
FARM SIZE. ACRES                             80.
NO. OF IRRIGATION                             3.
FREQUENCY OF IRRIGATION, DAYS                21.
GPM/LATERAL                                 264.
LABOR RATE, $/HR                            5.00

NUMBER OF LATERALS / FARM                    2.0
LENGTH OF LATERAL, FEET                    1300.
LATERAL SPACING, FEET                        50.
TIME TO MOVE LATERAL, MIN/SET                75.
TIME OF SETTING, HRS                         12.
TRANSPORT TIME PER ROTATION,HRS               2.
AREA COVERED BY EACH LATERAL, ACRES        40.00

COST PER LATERAL LINE, $                   1760.
ALLOWABLE INTAKE RATE, IN/HR                0.80
TOTAL LABOR, HR/AC/YR                         2.


DEEP PERCOLATION,AF/ACRE                  0.2562
APPLICATION EFFICIENCY,PERCENT             75.00

         MAINLINE DATA:

TOTAL AREA SERVED BY MAINLINE, ACRES         80.
TOTAL LENGTH OF MAINLINE, FEET             1300.

   DIAMETER(IN)     LENGTH(FT)      COST ($/FT)
       8.              600.             3.65
       6.              700.             2.30

TOTAL COST OF MAINLINE, $                  4180.
TOTAL INVESTMENT ($/AC)                      96.

   ANNUAL COST:                              $/AC

DEPRECIATION
    LATERAL                                  1.25
    MAINLINE                                 0.88
INTEREST ON INVESTMENT
    LATERAL                                  4.18
    MAINLINE                                 4.96
LABOR COST                                  10.59
MAINTENANCE COST                             2.89
TAXES AND INSURANCE                          0.53

               T O T A L                    25.29

NOTE:  TOTAL ANNUAL COST DOES NOT INCLUDE PUMP UNIT AND RESERVOIRS
```

```
         ANNUAL COST OF IRRIGATION-------HANDMOVE----HAND MOVE SPRINKLER SYSTEM--ANNIS SOIL
         SOIL TYPE NUMBER----- 1

                             PASTURE

         FARM DATA:

FIELD LENGTH, FT                         1300.
FARM SIZE, ACRES                           80.
NO. OF IRRIGATION                           6.
FREQUENCY OF IRRIGATION, DAYS              16.
GPM/LATERAL                               188.
LABOR RATE, $/HR                          5.00

NUMBER OF LATERALS / FARM                  2.0
LENGTH OF LATERAL, FEET                  1300.
LATERAL SPACING, FEET                      50.
TIME TO MOVE LATERAL, MIN/SET              75.
TIME OF SETTING, HRS                       12.
TRANSPORT TIME PER ROTATION,HRS             2.
AREA COVERED BY EACH LATERAL, ACRES      40.00

COST PER LATERAL LINE, $                 1760.
ALLOWABLE INTAKE RATE, IN/HR              0.80
TOTAL LABOR, HR/AC/YR                       3.


DEEP PERCOLATION,AF/ACRE                0.3542
APPLICATION EFFICIENCY,PERCENT           75.00

         MAINLINE DATA:

TOTAL AREA SERVED BY MAINLINE, ACRES       80.
TOTAL LENGTH OF MAINLINE, FEET           1300.

   DIAMETER(IN)     LENGTH(FT)     COST ($/FT)
       8.             600.            3.65
       6.             700.            2.30

TOTAL COST OF MAINLINE, $                4180.
TOTAL INVESTMENT ($/AC)                    96.

   ANNUAL COST:                               $/AC

DEPRECIATION
    LATERAL                                   1.25
    MAINLINE                                  0.88
INTEREST ON INVESTMENT
    LATERAL                                   4.18
    MAINLINE                                  4.96
LABOR COST                                   16.50
MAINTENANCE COST                              2.89
TAXES AND INSURANCE                           0.53

               T O T A L                     31.20

NOTE:  TOTAL ANNUAL COST DOES NOT INCLUDE PUMP UNIT AND RESERVOIRS
```

```
          ANNUAL COST OF IRRIGATION-------HANDMOVE----HAND MOVE SPRINKLER SYSTEM--ANNIS SOIL
          SOIL TYPE NUMBER----- 1

                              POTATOES

          FARM DATA:

      FIELD LENGTH, FT                          1300.
      FARM SIZE, ACRES                            80.
      NO. OF IRRIGATION                            8.
      FREQUENCY OF IRRIGATION, DAYS                8.
      GPM/LATERAL                                341.
      LABOR RATE, $/HR                            5.00

      NUMBER OF LATERALS / FARM                   2.0
      LENGTH OF LATERAL, FEET                   1300.
      LATERAL SPACING, FEET                       50.
      TIME TO MOVE LATERAL, MIN/SET               75.
      TIME OF SETTING, HRS                         6.
      TRANSPORT TIME PER ROTATION,HRS              2.
      AREA COVERED BY EACH LATERAL, ACRES       40.00

      COST PER LATERAL LINE, $                  1760.
      ALLOWABLE INTAKE RATE, IN/HR               0.80
      TOTAL LABOR, HR/AC/YR                        4.


      DEEP PERCOLATION,AF/ACRE                 0.3750
      APPLICATION EFFICIENCY,PERCENT            75.00

          MAINLINE DATA:

      TOTAL AREA SERVED BY MAINLINE, ACRES        80.
      TOTAL LENGTH OF MAINLINE, FEET            1300.

         DIAMETER(IN)      LENGTH(FT)      COST ($/FT)
             8.               600.            3.65
             6.               700.            2.30

      TOTAL COST OF MAINLINE, $                 4180.
      TOTAL INVESTMENT ($/AC)                     96.

         ANNUAL COST:                                   $/AC

      DEPRECIATION
          LATERAL                                       1.25
          MAINLINE                                      0.88
      INTEREST ON INVESTMENT
          LATERAL                                       4.18
          MAINLINE                                      4.96
      LABOR COST                                       22.00
      MAINTENANCE COST                                  2.89
      TAXES AND INSURANCE                               0.53

                   T O T A L                           36.70

      NOTE:  TOTAL ANNUAL COST DOES NOT INCLUDE PUMP UNIT AND RESERVOIRS
```

```
LINED CANAL  REACH NUMBER ONE

   Q         COST OF          COST OF          COST OF          COST OF            TOTAL CONST.     ANNUAL EQUI     CONVEYANCE
 (CFS)      STRUCTURE        EARTHWORK         LINING         RIGHT OF/WAY            COST             COST         EFFICIENCY

  40.          9555.           17895.          31118.               0.                58568.          4243.9           97.6
  45.          9923.           18755.          32096.               0.                60774.          4403.7           97.6
  50.         10279.           19549.          33260.               0.                63088.          4571.3           97.7
  55.         10625.           20272.          34353.               0.                65250.          4728.0           97.7
  60.         10963.           20955.          35387.               0.                67304.          4876.9           97.7
  65.         11293.           22560.          36369.               0.                70221.          5088.2           97.7
  70.         11616.           22594.          37305.               0.                71515.          5182.0           97.7
  75.         11933.           22670.          38200.               0.                72803.          5275.3           97.7
  80.         12244.           22780.          39060.               0.                74083.          5368.1           97.7
  85.         12549.           22920.          39887.               0.                75356.          5460.3           97.8
  90.         12850.           23084.          40684.               0.                76619.          5551.8           97.8
  95.         13146.           23271.          41455.               0.                77871.          5642.5           97.8
 100.         13437.           23474.          42201.               0.                79113.          5732.5           97.8
 105.         13725.           23695.          42924.               0.                80344.          5821.7           97.8
 110.         14009.           23927.          43626.               0.                81563.          5910.0           97.8
 115.         14289.           24572.          44309.               0.                83170.          6026.5           97.8

                      *****  SUMMARY OF EARTHWORK FOR REHABILATATION OF THIS REACH *****

                                      Q =    120 CFS


          COMMON EXCAVATION TOTAL                 9267.CU YD

          FILL FROM CHANNEL EXCAVATION             853.CU YD

          CHANNEL COMPACTED BACKFILL TOTAL        9054.CU YD

          COMPACTED EMBANKMENT TOTAL              7467.CU YD

          FILL FROM ADJACENT EXCAVATION           8201.CU YD

          OVERHAUL                                   0.CU YD

          AVERAGE MINIMUM RIGHT OF WAY              23.FEET


          OLD INLET AND OUTLET ELEV              4907.4        4891.4 FEET
          DESIGN INLET AND OUTLET ELEV           4907.4        4891.4 FEET



          DESIGN DEPTH OF CHANNEL                   4.3 FEET
          DESIGN WIDTH OF CHANNEL                   6.6 FEET
          LENGTH OF REACH                        6750. FEET
```

```
LINED CANAL  REACH NUMBER ONE


                        ESTIMATED COST OF STRUCTURES

                                       Q =   120 CFS

                   ESTIMATED COST OF SIPHON..........................              0.

                   ESTIMATED COST OF TUNNEL..........................              0.

                   ESTIMATED COST OF DROPS.........................                0.

                   ESTIMATED COST OF CONCRETE CHECKS...............             8333.

                   ESTIMATED COST OF MODIFIED P. FLUME.............                0.

                   ESTIMATED COST OF TURNOUTS........................           4909.

                   ESTIMATED COST OF COUNTY BRIDGE...................              0.

                   ESTIMATED COST OF FARM BRIDGE.....................              0.

                   ESTIMATED COST OF DRAINAGE CROSSINGS...........                 0.

                        CONTINGENCIES ( 10 )......................              1324.

                   TOTAL COST OF STRUCTURES FOR THIS REACH..........           14566.


                        COST SUMMARY FOR THIS #Q#

    Q        COST OF       COST OF       COST OF       COST OF        TOTAL CONST.    ANNUAL EQUI     CONVEYANCE
  (CFS)     STRUCTURE     EARTHWORK       LINING     RIGHT OF/WAY        COST            COST         EFFICIENCY

  120.        14566.        25148.        44974.          0.            84688.          6136.5           97.8


          CONVEYANCE EFFICIENCY = 97.8

          AVERAGE CANAL SEEPAGE (AF-FT/CFS OF FLOW) =   0.6391

             A =          3491.
             B =            22.6
             R =          0.991
```

```
LINED CANAL REACH 2


  Q         COST OF         COST OF          COST OF        COST OF        TOTAL CONST.    ANNUAL EQUI      CONVEYANCE
 (CFS)     STRUCTURE       EARTHWORK         LINING      RIGHT OF/WAY         COST            COST          EFFICIENCY

  30.          6655.          16552.          30522.             0.           53728.         3893.1            97.5
  35.          7051.          17017.          31876.             0.           55943.         4053.6            97.5
  40.          7431.          17473.          33113.             0.           58017.         4203.9            97.6
  45.          7799.          17918.          34198.             0.           59915.         4341.4            97.6
  50.          8155.          18352.          35451.             0.           61958.         4489.5            97.6
  55.          8501.          18728.          36629.             0.           63858.         4627.2            97.6
  60.          8839.          19324.          37742.             0.           65905.         4775.5            97.7
  65.          9169.          20086.          38799.             0.           68054.         4931.2            97.7
  70.          9492.          20797.          39807.             0.           70097.         5079.2            97.7
  75.          9809.          21449.          40772.             0.           72029.         5219.2            97.7
  80.         10120.          22065.          41697.             0.           73882.         5353.5            97.7
  85.         10425.          22637.          42588.             0.           75649.         5481.5            97.7

                        ***** SUMMARY OF EARTHWORK FOR REHABILATATION OF THIS REACH *****

                                      Q =     90 CFS


            COMMON EXCAVATION TOTAL                9521.CU YD

            FILL FROM CHANNEL EXCAVATION           6285.CU YD

            CHANNEL COMPACTED BACKFILL TOTAL       7949.CU YD

            COMPACTED EMBANKMENT TOTAL             6676.CU YD

            FILL FROM ADJACENT EXCAVATION          1664.CU YD

            OVERHAUL                                  0.CU YD

            AVERAGE MINIMUM RIGHT OF WAY             32.FEET


            OLD INLET AND OUTLET ELEV             4891.4       4883.9 FEET
            DESIGN INLET AND OUTLET ELEV          4891.4       4883.9 FEET



            DESIGN DEPTH OF CHANNEL                 4.2 FEET
            DESIGN WIDTH OF CHANNEL                 6.7 FEET
            LENGTH OF REACH                       6490. FEET
```

```
LINED CANAL REACH 2


                         ESTIMATED COST OF STRUCTURES

                                     Q =    90 CFS


                 ESTIMATED COST OF SIPHON.........................                    0.

                 ESTIMATED COST OF TUNNEL.........................                    0.

                 ESTIMATED COST OF DROPS.........................                     0.

                 ESTIMATED COST OF CONCRETE CHECKS...............                  6772.

                 ESTIMATED COST OF MODIFIED P. FLUME.............                     0.

                 ESTIMATED COST OF TURNOUTS......................                  2978.

                 ESTIMATED COST OF COUNTY BRIDGE.................                     0.

                 ESTIMATED COST OF FARM BRIDGE...................                     0.

                 ESTIMATED COST OF DRAINAGE CROSSINGS...........                      0.

                           CONTINGENCIES ( 10 )..................                   975.

                 TOTAL COST OF STRUCTURES FOR THIS REACH...........               10726.



                           COST SUMMARY FOR THIS #Q#

   Q        COST OF       COST OF        COST OF       COST OF        TOTAL CONST.    ANNUAL EQUI    CONVEYANCE
 (CFS)     STRUCTURE     EARTHWORK       LINING      RIGHT OF/WAY       COST            COST        EFFICIENCY

  90.        10726.        23175.        43446.          0.           77347.          5604.6          97.7


          CONVEYANCE EFFICIENCY = 97.7

          AVERAGE CANAL SEEPAGE (AF-FT/CFS OF FLOW) =   0.8434

             A =        3051.
             B =          28.7
             R =        1.000
```

GRAVITY PIPE REACH NUMBER 1

Q (CFS)	DIAMETER (IN)	LENGTH (FT)	PIPE COST 1/ ($)	TURNOUTS 2/ ($)	RIGHT OF WAY ($)	EARTHWORK 3/ ($)	TOTAL COST ($)	ANNUAL COST ($)	PIPE TYPE
40.	40.	6750.	202500.	12749.	0.	47734.	262982.	19029.	CONCRETE
45.	42.	6750.	202500.	12749.	0.	47917.	263165.	19042.	CONCRETE
50.	44.	6750.	218700.	12749.	0.	49073.	280522.	20298.	CONCRETE
55.	46.	6750.	243000.	12749.	0.	50265.	306014.	22142.	CONCRETE
60.	48.	6750.	243000.	12749.	0.	51558.	307306.	22236.	CONCRETE
65.	48.	6750.	243000.	12749.	0.	51558.	307306.	22236.	CONCRETE
70.	50.	6750.	267300.	12749.	0.	52866.	332915.	24088.	CONCRETE
75.	52.	6750.	291600.	12749.	0.	54191.	358540.	25942.	CONCRETE
80.	52.	6750.	291600.	12749.	0.	54191.	358540.	25942.	CONCRETE
85.	54.	6750.	291600.	12749.	0.	55532.	359881.	26039.	CONCRETE
90.	56.	6750.	315900.	12749.	0.	56889.	385538.	27896.	CONCRETE
95.	56.	6750.	315900.	12749.	0.	56889.	385538.	27896.	CONCRETE
100.	58.	6750.	340200.	12749.	0.	58614.	411563.	29778.	CONCRETE
105.	58.	6750.	340200.	12749.	0.	58614.	411563.	29778.	CONCRETE
110.	60.	6750.	340200.	12749.	0.	60393.	413342.	29907.	CONCRETE
115.	60.	6750.	340200.	12749.	0.	60393.	413342.	29907.	CONCRETE

NOTE:

1/PIPE COST INCLUDES COST OF PIPE.LAYING OF PIPE,COST OF FITTINGS.VALVES,BLOCKING,ETC.
2/TURNOUT COST INCLUDES GATE VALVE.LINE METER.PRESSURE REDUCING VALVE.CONCRETE PIPE,STEEL PIPE DELIVERY,ETC
3/EARTHWORK COST INCLUDES TRENCHING, BACKFILLING AND COMPACTING BACKFILL

```
                                    GRAVITY PIPE REACH NUMBER 1




SUMMARY FOR THIS REACH:


     COST INDEX FOR PIPE SYSTEM(B=1976)=      1.
     LENGTH OF REACH IN FEET            =  6750.
     ELEVATION OF PIPE OUTLET, FEET     =  4887.
     ELEVATION OF PIPE INLET, FEET      =  4904.
     H.G.L. REQ. AT PIPE OUTLET,FEET    =  4901.
     H.G.L. REQ. AT PIPE INLET, FEET    =  4911.
     WIDTH OF EASEMENT, FEET            =    45.
     VALUE OF EASEMENT FOR CROPPED LAND=      0.
     VALUE OF EASEMENT FOR OTHER LAND   =     0.
     PERCENT LENGTH OF OTHER EASEMENT   =     0.
     NUMBER OF TURNOUTS:


          NUMBER=  5.       SIZE (IN)=  8.

          NUMBER=  1.       SIZE (IN)= 12.




     CHECK DATA FOR .....Q =    120. CFS


     CAPACITY,CFS                   =   120.
     DIAMETER,INCHES (ROUNDED)      =    62.
     AVERAGE HEAD CLASS, FEET       =    25.
     TYPE OF COVER                  =
     PIPE COST, $/FT                =     45.00
     MISC COST, (DOLLARS)           =   1275.00


    A =        12629.
    B =         161.2
    R =         0.986
```

```
                                   Q =   120 CFS

                            V  O  L  U  M  E  S
            PIPE

REHABILITATION PLAN---LAYING PIPE IN OLD CHANNEL

TOTAL EXCAVATION =                    9757. CUBIC YARDS

TOTAL COMPACTED BACKFILL=             5027. CUBIC YARDS


TOTAL BACKFILL (OLD CHAN)=               0.CUBIC YARDS


TOTAL OVERHAUL =                         0.CUBIC YARDS


SUBSTITUTE EXCAVATION FROM AREA ADJACENT TO PIPELINE
IN PLACE OF OVERHAUL FROM OUTSIDE AREA.
ADJACENT EXCAVATION =                14831. CUBIC YARDS

TOTAL BACKFILL =                        53. CUBIC YARDS



    Q      DIAMETER   LENGTH    PIPE COST 1/    TURNOUTS 2/  RIGHT OF WAY        EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TYPE
  (CFS)      (IN)      (FT)         ($)             ($)          ($)                 ($)             ($)          ($)

  120.        62.      6750.      364500.         12749.              0.          62207.          439455.       31795.   CONCRETE
```

```
   Q      DIAMETER   LENGTH    PIPE COST 1/   TURNOUTS 2/  RIGHT OF WAY        EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TYPE
 (CFS)      (IN)      (FT)         ($)            ($)          ($)                 ($)              ($)          ($)

   30.       38.      6490.      171336.         5956.              0.           41701.          218992.       15846.   CONCRETE
   35.       40.      6490.      194700.         5956.              0.           43668.          244324.       17679.   CONCRETE
   40.       42.      6490.      194700.         5956.              0.           44801.          245457.       17761.   CONCRETE
   45.       44.      6490.      210276.         5956.              0.           45937.          262169.       18970.   CONCRETE
   50.       46.      6490.      233640.         5956.              0.           47076.          286672.       20743.   CONCRETE
   55.       48.      6490.      233640.         5956.              0.           48218.          287814.       20825.   CONCRETE
   60.       50.      6490.      257004.         5956.              0.           49363.          312323.       22598.   CONCRETE
   65.       50.      6490.      257004.         5956.              0.           49363.          312323.       22598.   CONCRETE
   70.       52.      6490.      280368.         5956.              0.           50511.          336834.       24372.   CONCRETE
   75.       54.      6490.      280368.         5956.              0.           51661.          337984.       24455.   CONCRETE
   80.       54.      6490.      280368.         5956.              0.           51661.          337984.       24455.   CONCRETE
   85.       56.      6490.      303732.         5956.              0.           52873.          362560.       26233.   CONCRETE


             NOTE:

               1/PIPE COST INCLUDES COST OF PIPE.LAYING OF PIPE,COST OF FITTINGS,VALVES,BLOCKING,ETC.
               2/TURNOUT COST INCLUDES GATE VALVE.LINE METER,PRESSURE REDUCING VALVE,CONCRETE PIPE,STEEL PIPE DELIVERY,ETC
               3/EARTHWORK COST INCLUDES TRENCHING, BACKFILLING AND COMPACTING BACKFILL



                           PIPE EARTHWORK FOR THE ABOVE REACH

                                            Q =     90 CFS

                                      V  O  L  U  M  E  S
         PIPE

REHABILITATION PLAN---LAYING PIPE IN OLD CHANNEL

TOTAL EXCAVATION =                  9959. CUBIC YARDS

TOTAL COMPACTED BACKFILL=           4327. CUBIC YARDS

TOTAL BACKFILL (OLD CHAN)=             0.CUBIC YARDS

TOTAL OVERHAUL =                       0.CUBIC YARDS

SUBSTITUTE EXCAVATION FROM AREA ADJACENT TO PIPELINE
IN PLACE OF OVERHAUL FROM OUTSIDE AREA.
ADJACENT EXCAVATION =               7389. CUBIC YARDS

TOTAL BACKFILL =                       0. CUBIC YARDS


   Q      DIAMETER   LENGTH    PIPE COST 1/   TURNOUTS 2/  RIGHT OF WAY        EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TYPE
 (CFS)      (IN)      (FT)         ($)            ($)          ($)                 ($)              ($)          ($)

   90.       58.      6490.      327096.         5956.              0.           54722.          387773.       28057.   CONCRETE
```

```
                                              GRAVITY PIPE REACH 2



SUMMARY FOR THIS REACH:


     COST INDEX FOR PIPE SYSTEM(B=1976)=        1.
     LENGTH OF REACH IN FEET               =  6490.
     ELEVATION OF PIPE OUTLET, FEET        =  4879.
     ELEVATION OF PIPE INLET, FEET         =  4887.
     H.G.L. REQ. AT PIPE OUTLET,FEET       =  4893.
     H.G.L. REQ. AT PIPE INLET, FEET       =  4901.
     WIDTH OF EASEMENT, FEET               =    45.
     VALUE OF EASEMENT FOR CROPPED LAND=        0.
     VALUE OF EASEMENT FOR OTHER LAND      =    0.
     PERCENT LENGTH OF OTHER EASEMENT      =    0.
     NUMBER OF TURNOUTS:


          NUMBER=  1.        SIZE (IN)= 10.

          NUMBER=  1.        SIZE (IN)= 12.



     CHECK DATA FOR .....Q =     90. CFS


     CAPACITY,CFS                   =     90.
     DIAMETER,INCHES (ROUNDED)      =     58.
     AVERAGE HEAD CLASS, FEET       =     25.
     TYPE OF COVER                  =
     PIPE COST, $/FT                =     42.00
     MISC COST, (DOLLARS)           =  1850.00

    A =         10795.
    B =          184.9
    R =          0.988
```

```
                              COST OF STEEL TANK


     Q          CAPACITY          WT OF TANK        HT OF TOWER        WT OF TOWER          COST OF STEEL   TOTAL COST 1/      ANNUAL COST
   (CFS)         (GAL)              (LB)               (FT)               (LB)                   ($)             ($)              ($/AN)


    27.         102350.            44634.               200.            129050.               86842.         1604842.            116089.
    30.         111500.            47105.               200.            129050.               88077.         1627668.            117740.
    33.         120650.            49575.               200.            129050.               89313.         1650496.            119392.
    36.         129800.            52046.               200.            145100.               98573.         1821625.            131770.
    39.         138950.            54516.               200.            145100.               99808.         1844452.            133422.
    42.         148100.            56987.               200.            145100.              101043.         1867280.            135073.
    45.         157250.            59457.               200.            166450.              112954.         2087381.            150994.
    48.         166400.            61928.               200.            166450.              114189.         2110209.            152646.
    51.         175550.            64398.               200.            187800.              126099.         2330310.            168567.
    54.         184700.            66869.               200.            187800.              127334.         2353137.            170218.
    57.         193850.            69339.               200.            187800.              128570.         2375965.            171870.
    60.         203000.            71810.               200.            215200.              143505.         2651968.            191835.
            N O T E :

             1/ TOTAL COST INCLUDES:  10.0    FOR FOUNDATION,VALVES,ETC.
                                       5.0    FOR UNLISTED ITEMS
                                      15.0    FOR CONTINGENCIES


            A =        48593.
            B =        2253.8
            R =         0.980
```

```
     Q      DIAMETER   LENGTH    PIPE COST 1/    TURNOUTS 2/  RIGHT OF WAY      EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TYPE
   (CFS)     (IN)      (FT)        ($)             ($)           ($)              ($)              ($)         ($)

     27.        34.     5060.     117215.         31682.               0.        42077.          190974.        13820.   STEEL
     30.        36.     5060.     124240.         31682.               0.        43447.          199370.        14427.   STEEL
     33.        38.     5060.     221643.         31682.               0.        44819.          298144.        21572.   STEEL
     36.        38.     5060.     221643.         31682.               0.        44819.          298144.        21572.   STEEL
     39.        40.     5060.     233298.         31682.               0.        46191.          311171.        22515.   STEEL
     42.        40.     5060.     233298.         31682.               0.        46191.          311171.        22515.   STEEL
     45.        42.     5060.     245154.         31682.               0.        47565.          324401.        23472.   STEEL
     48.        42.     5060.     245154.         31682.               0.        47565.          324401.        23472.   STEEL
     51.        44.     5060.     256809.         31682.               0.        48940.          337431.        24415.   STEEL
     54.        44.     5060.     256809.         31682.               0.        48940.          337431.        24415.   STEEL
     57.        46.     5060.     268665.         31682.               0.        50317.          350664.        25372.   STEEL


              NOTE:

                1/PIPE COST INCLUDES COST OF PIPE.LAYING OF PIPE.COST OF FITTINGS.VALVES.BLOCKING.ETC.
                2/TURNOUT COST INCLUDES GATE VALVE.LINE METER.PRESSURE REDUCING VALVE.CONCRETE PIPE.STEEL PIPE DELIVERY.ETC
                3/EARTHWORK COST INCLUDES TRENCHING. BACKFILLING AND COMPACTING BACKFILL
```

```
                    PIPE EARTHWORK FOR THE ABOVE REACH

                                   Q =    60 CFS

                             V  O  L  U  M  E  S
            PIPE
  STATION   DIA.         EXCAVATION   BACKFILL   C. BACKFILL   GLE-PGE    DIAM + DESIGN COVER    TRENCH WIDTH

    0.0     46.00                                                   8.20           7.83              7.46
                          4478.06      2983.00       640.17
  2000.00   46.00                                                   8.00           7.83              7.46
                          4478.06      2983.00       640.17
  4000.00   46.00                                                   8.20           7.83              7.46
                          2373.37      1580.99       339.29
  5060.00   46.00                                                   8.00           7.83              7.46
  TOTAL EXCAVATION =               11329. CUBIC YARDS

  TOTAL COMPACTED BACKFILL=         1620. CUBIC YARDS

  TOTAL OVERHAUL =                     0.CUBIC YARDS

  TOTAL BACKFILL =                  7547. CUBIC YARDS

     Q      DIAMETER   LENGTH    PIPE COST 1/    TURNOUTS 2/  RIGHT OF WAY      EARTHWORK 3/     TOTAL COST  ANNUAL COST  PIPE TYPE
   (CFS)     (IN)      (FT)        ($)             ($)           ($)              ($)              ($)         ($)

     60.        46.     5060.     268665.         31682.               0.        50317.          350664.        25372.   STEEL
```

```
                                               HIGH PRESSURE PIPE---REACH 1



       SUMMARY FOR THIS REACH:


            COST INDEX FOR PIPE SYSTEM(B=1976)=      1.
            LENGTH OF REACH IN FEET           =   5060.
            ELEVATION OF PIPE OUTLET, FEET    =   4896.
            ELEVATION OF PIPE INLET, FEET     =   4904.
            H.G.L. REQ. AT PIPE OUTLET,FEET   =   5036.
            H.G.L. REQ. AT PIPE INLET, FEET   =   5044.
            WIDTH OF EASEMENT, FEET           =     50.
            VALUE OF EASEMENT FOR CROPPED LAND=      0.
            VALUE OF EASEMENT FOR OTHER LAND  =      0.
            PERCENT LENGTH OF OTHER EASEMENT  =      0.
            NUMBER OF TURNOUTS:


                 NUMBER=  1.        SIZE (IN)= 12.

                 NUMBER=  1.        SIZE (IN)= 14.



            CHECK DATA FOR .....Q =    60. CFS


            CAPACITY,CFS                 =    60.
            DIAMETER,INCHES (ROUNDED)    =    46.
            AVERAGE HEAD CLASS, FEET     =   200.
            TYPE OF COVER                =
            PIPE COST, $/FT              =    45.38
            MISC COST, (DOLLARS)         = 20900.00

           A =         8551.
           B =         307.1
           R =         0.861
```

```
   Q       DIAMETER    LENGTH      PIPE COST 1/     TURNOUTS 2/   RIGHT OF WAY        EARTHWORK 3/       TOTAL COST   ANNUAL COST   PIPE TYPE
 (CFS)       (IN)       (FT)          ($)              ($)            ($)                 ($)               ($)           ($)

  21.         30.       8300.        169553.          38249.                  0.        62254.              270056.       19543.      STEEL
  24.         32.       8300.        181076.          38249.                  0.        64422.              283748.       20533.      STEEL
  27.         34.       8300.        192270.          38249.                  0.        66593.              297112.       21500.      STEEL
  30.         36.       8300.        203794.          38249.                  0.        68765.              310808.       22491.      STEEL
  33.         36.       8300.        203794.          38249.                  0.        68765.              310808.       22491.      STEEL
  36.         38.       8300.        363565.          38249.                  0.        70939.              472754.       34206.      STEEL
  39.         40.       8300.        382683.          38249.                  0.        73116.              494048.       35747.      STEEL
  42.         40.       8300.        382683.          38249.                  0.        73116.              494048.       35747.      STEEL
  45.         42.       8300.        402131.          38249.                  0.        75295.              515675.       37311.      STEEL


                NOTE:

                  1/PIPE COST INCLUDES COST OF PIPE.LAYING OF PIPE,COST OF FITTINGS.VALVES,BLOCKING.ETC.
                  2/TURNOUT COST INCLUDES GATE VALVE,LINE METER,PRESSURE REDUCING VALVE,CONCRETE PIPE,STEEL PIPE DELIVERY,ETC
                  3/EARTHWORK COST INCLUDES TRENCHING. BACKFILLING AND COMPACTING BACKFILL


-------------------------------------------------------------------------------------------------------------------------


                        PIPE EARTHWORK FOR THE ABOVE REACH

                                          Q =     48 CFS

                                V  O  L  U  M  E  S
              PIPE
 STATION      DIA.        EXCAVATION    BACKFILL    C. BACKFILL    GLE-PGE    DIAM + DESIGN COVER    TRENCH WIDTH

    0.0       42.00                                                    7.80          7.50              7.07
                          4087.61       2816.23        558.70
 2000.00      42.00                                                    7.80          7.50              7.07
                          4087.61       2816.23        558.70
 4000.00      42.00                                                    7.80          7.50              7.07
                          4087.61       2816.23        558.70
 6000.00      42.00                                                    7.80          7.50              7.07
                          4700.75       3238.67        642.50
 8300.00      42.00                                                    7.80          7.50              7.07
 TOTAL EXCAVATION =                  16964. CUBIC YARDS

 TOTAL COMPACTED BACKFILL=            2319. CUBIC YARDS

 TOTAL OVERHAUL =                       0.CUBIC YARDS

 TOTAL BACKFILL =                    11687. CUBIC YARDS


   Q       DIAMETER    LENGTH      PIPE COST 1/     TURNOUTS 2/   RIGHT OF WAY        EARTHWORK 3/       TOTAL COST   ANNUAL COST   PIPE TYPE
 (CFS)       (IN)       (FT)          ($)              ($)            ($)                 ($)               ($)           ($)

  48.         42.       8300.        402131.          38249.                  0.        75295.              515675.       37311.      STEEL
```

```
                                                  HIGH PRESSURE PIPE---REACH 2



 SUMMARY FOR THIS REACH:


      COST INDEX FOR PIPE SYSTEM(B=1976)=      1.
      LENGTH OF REACH IN FEET           =  8300.
      ELEVATION OF PIPE OUTLET, FEET    =  4882.
      ELEVATION OF PIPE INLET, FEET     =  4896.
      H.G.L. REQ. AT PIPE OUTLET.FEET   =  5022.
      H.G.L. REQ. AT PIPE INLET, FEET   =  5036.
      WIDTH OF EASEMENT, FEET           =    50.
      VALUE OF EASEMENT FOR CROPPED LAND=     0.
      VALUE OF EASEMENT FOR OTHER LAND  =     0.
      PERCENT LENGTH OF OTHER EASEMENT  =     0.
      NUMBER OF TURNOUTS:

           NUMBER=  2.        SIZE (IN)= 12.



      CHECK DATA FOR .....Q =     48. CFS


      CAPACITY,CFS                 =    48.
      DIAMETER,INCHES (ROUNDED)    =    42.
      AVERAGE HEAD CLASS, FEET     =   200.
      TYPE OF COVER                =
      PIPE COST, $/FT              =    41.41
      MISC COST, (DOLLARS)         = 28200.00

     A =          803.
     B =          808.3
     R =          0.933
```

```
                    RIVER PUMP--CANAL TO HIGH PRESSURE PIPE--TETON ISLAND CANAL


                       PUMPING     ANNUAL EQUIV.  OPERATION   MAINTENANCE  REPLACEMENT    POWER         ANNUAL PUMPING
            H.P.     PLANT COST        COST          COST         COST         COST        COST              COST
FS) 1/     USED 2/       ($)        ($/YR) 3/       ($/YR)       ($/YR)       ($/YR)     ($/YR) 4/         ($/YR 5/


7.          980.      1011461.        74602.        1400.        7136.     ---6/        103761.           186899.
0.         1085.      1109136.        81806.        1471.        7220.     ---6/        114529.           205026.
3.         1185.      1206610.        88996.        1539.        7296.     ---6/        124784.           222614.
6.         1290.      1300590.        95927.        1603.        7366.     ---6/        135552.           240448.
9.         1390.      1397671.       103088.        1664.        7431.     ---6/        145807.           257990.
2.         1490.      1494549.       110233.        1723.        7492.     ---6/        156062.           275510.
5.         1590.      1587955.       117122.        1780.        7549.     ---6/        166317.           292769.
8.         1690.      1681173.       123998.        1835.        7603.     ---6/        176573.           310008.
1.         1790.      1775835.       130980.        1888.        7653.     ---6/        186828.           327349.
4.         1890.      1868675.       137827.        1939.        7702.     ---6/        197083.           344551.
7.         1990.      1964576.       144901.        1989.        7748.     ---6/        207338.           361976.
0.         2090.      2055416.       151601.        2038.        7792.     ---6/        217593.           379023.


         NOTE:

           1/ WEAR ALLOWANCE WAS INCLUDED.
           2/ HORSEPOWER USED WAS ROUNDED TO THE NEAREST 5 HP.
           3/ INCLUDES INDIRECT COSTS.
           4/ INCLUDES TRANS. AND SW BAY COSTS IF APPLICABLE.
           5/ ANNUAL PUMPING COST INCLUDES ANNUAL EQUIV.  COST OF PUMPING PLANT, OM AND R, AND POWER COST.
           6/ 15 PERCENT FOR REPLACEMENT WAS ADDED TO MAINTENANCE COST

         SUMMARY OF PUMPING PLANT DATA:

         NUMBER OF PUMPING UNITS                        4.
         TYPE OF PUMPING UNIT----VERTICAL PUMP
         TOTAL DYNAMIC HEAD, FEET                     175.
         DATE OF ESTIMATE                             6/76


         CHECK COST FOR THE LAST 'Q' CONSIDERED:

         PLANT CAPACITY, CFS                           60.

         STRUCTURES AND IMPROVEMENTS               422000.
         WATERWAYS                                 112000.
         PUMPS AND MOTORS                          229000.
         ELECTRICAL ACCESSORIES                    137000.
         MISCELLANEOUS EQUIPMENT                    23000.
         SWITCHYARDS                                89000.

         SUBTOTAL OF PUMPING PLANT                1012000.

         COST OF INTAKE, DISCHARGE LINES, ETC.     229000.
         CONTINGENCY COST                          248200.
         PUMP FIELD COST                          1489199.
         INDIRECT COST                             566217.

         PUMP TOTAL CONSTRUCTION COSTS            2055416.

         TRANSMISSION LINE COST                    281457.
         ADD 50 PERCENT FOR MOUNTAINOUS TERRAIN         0.
         ADD 50 PERCENT FOR ROCKY/SWAMPY FOUND.         0.
         ADD 100 PERCENT FOR LINE UNDER 5 MILES    281457.
         ADD 50 PERCENT FOR LINE 5 TO 20 MILES          0.
         SUBTOTAL                                  562915.
         SWITCHING BAY COST                        339463.
         CONTINGENCIES (TL AND SB)                  62092.
         TOTAL FIELD COSTS                         964470.
         INDIRECT COST                             310686.
         TOTAL POWER LINE CONSTRUCTION COSTS      1275156.

                                                 PRESENT RATE  INFLATED RATE OVER LIFE
         ANNUAL POWER COST---OPT 1 F.RATE,OWN LINE 183919.        757034.
         ANNUAL POWER COST---OPT 2 WHEELING CHARGE 229528.        944766.
         ANNUAL POWER COST---OPT 3 PRIVATE UTILITY  52864.        217593.



     RIVER PUMP--CANAL TO HIGH PRESSURE PIPE--TETON ISLAND CANAL

        A =        30822.
        P =        5812.8
        R =         1.000
```

FARM PUMP...CANAL TO SPRINKLER--150. TDH 9.5 % INTEREST

Q (GPM)	H.P. 1/ USED	PUMP COST 2/ ($)	PUMP FIXED COST ($/YR)	O & M 3/ ($/YR)	TAXES & INS. ($/YR)	POWER COST ($)	WELL COST 4/ ($)	WELL FIXED COST ($/YR)	PUMPING COST 5/ ($/YR)
100.	5.	2881.	354.	86.	50.	344.	0.	0.	834.
110.	6.	2981.	366.	89.	51.	379.	0.	0.	886.
120.	6.	3074.	378.	92.	53.	413.	0.	0.	936.
130.	7.	3163.	389.	95.	55.	448.	0.	0.	985.
140.	8.	3247.	399.	97.	56.	482.	0.	0.	1034.
150.	8.	3328.	409.	100.	57.	516.	0.	0.	1082.
160.	9.	3405.	418.	102.	59.	551.	0.	0.	1130.
170.	9.	3479.	427.	104.	60.	585.	0.	0.	1177.
180.	10.	3551.	436.	107.	61.	620.	0.	0.	1224.
190.	10.	3620.	445.	109.	62.	654.	0.	0.	1270.
200.	11.	3686.	453.	111.	64.	688.	0.	0.	1315.
210.	11.	3751.	461.	113.	65.	719.	0.	0.	1357.
220.	12.	3813.	468.	114.	66.	751.	0.	0.	1400.
230.	12.	3874.	476.	116.	67.	783.	0.	0.	1442.
240.	13.	3933.	483.	118.	68.	815.	0.	0.	1484.
250.	14.	3991.	490.	120.	69.	847.	0.	0.	1525.
260.	14.	4047.	497.	121.	70.	878.	0.	0.	1567.
270.	15.	4101.	504.	123.	71.	910.	0.	0.	1608.
280.	15.	4155.	510.	125.	72.	942.	0.	0.	1649.
290.	16.	4207.	517.	126.	73.	974.	0.	0.	1689.
300.	16.	4258.	523.	128.	73.	1006.	0.	0.	1730.
310.	17.	4308.	529.	129.	74.	1037.	0.	0.	1770.
320.	17.	4357.	535.	131.	75.	1069.	0.	0.	1810.
330.	18.	4404.	541.	132.	76.	1101.	0.	0.	1850.
340.	18.	4451.	547.	134.	77.	1132.	0.	0.	1890.
350.	19.	4497.	552.	135.	78.	1161.	0.	0.	1926.
360.	19.	4543.	558.	136.	78.	1190.	0.	0.	1963.
370.	20.	4587.	563.	138.	79.	1219.	0.	0.	1999.
380.	21.	4631.	569.	139.	80.	1247.	0.	0.	2035.
390.	21.	4674.	574.	140.	81.	1276.	0.	0.	2071.
400.	22.	4716.	579.	141.	81.	1305.	0.	0.	2107.
410.	22.	4758.	584.	143.	82.	1334.	0.	0.	2143.
420.	23.	4799.	589.	144.	83.	1362.	0.	0.	2179.
430.	23.	4839.	594.	145.	83.	1391.	0.	0.	2214.
440.	24.	4879.	599.	146.	84.	1420.	0.	0.	2250.
450.	24.	4918.	604.	148.	85.	1449.	0.	0.	2285.
460.	25.	4956.	609.	149.	85.	1478.	0.	0.	2320.
470.	25.	4994.	613.	150.	86.	1506.	0.	0.	2356.
480.	26.	5032.	618.	151.	87.	1535.	0.	0.	2391.
490.	27.	5069.	623.	152.	87.	1564.	0.	0.	2426.
500.	27.	5105.	627.	153.	88.	1593.	0.	0.	2461.
510.	28.	5141.	632.	154.	89.	1621.	0.	0.	2496.
520.	28.	5177.	636.	155.	89.	1650.	0.	0.	2531.
530.	29.	5212.	640.	156.	90.	1679.	0.	0.	2565.
540.	29.	5247.	644.	157.	91.	1708.	0.	0.	2600.
550.	30.	5281.	649.	158.	91.	1736.	0.	0.	2635.
560.	30.	5315.	653.	159.	92.	1765.	0.	0.	2669.
570.	31.	5349.	657.	160.	92.	1794.	0.	0.	2704.
580.	31.	5382.	661.	161.	93.	1823.	0.	0.	2738.
590.	32.	5415.	665.	162.	93.	1851.	0.	0.	2772.
600.	32.	5447.	669.	163.	94.	1880.	0.	0.	2807.
610.	33.	5479.	673.	164.	95.	1909.	0.	0.	2841.
620.	34.	5511.	677.	165.	95.	1938.	0.	0.	2875.
630.	34.	5542.	681.	166.	96.	1966.	0.	0.	2909.
640.	35.	5573.	685.	167.	96.	1995.	0.	0.	2943.
650.	35.	5604.	688.	168.	97.	2024.	0.	0.	2977.
660.	36.	5635.	692.	169.	97.	2053.	0.	0.	3011.
670.	36.	5665.	696.	170.	98.	2081.	0.	0.	3045.
680.	37.	5695.	700.	171.	98.	2110.	0.	0.	3079.
690.	37.	5724.	703.	172.	99.	2139.	0.	0.	3113.
700.	38.	5754.	707.	173.	99.	2168.	0.	0.	3146.
710.	38.	5783.	710.	173.	100.	2196.	0.	0.	3180.
720.	39.	5812.	714.	174.	100.	2225.	0.	0.	3214.
730.	40.	5840.	717.	175.	101.	2254.	0.	0.	3247.
740.	40.	5869.	721.	176.	101.	2283.	0.	0.	3281.
750.	41.	5897.	724.	177.	102.	2312.	0.	0.	3314.
760.	41.	5924.	728.	178.	102.	2340.	0.	0.	3348.
770.	42.	5952.	731.	179.	103.	2369.	0.	0.	3381.
780.	42.	5979.	734.	179.	103.	2398.	0.	0.	3415.
790.	43.	6007.	738.	180.	104.	2427.	0.	0.	3448.
800.	43.	6033.	741.	181.	104.	2455.	0.	0.	3482.

810.	44.	6060.	744.	182.	105.	2484.	0.	0.	3515.
820.	44.	6087.	748.	183.	105.	2513.	0.	0.	3548.
830.	45.	6113.	751.	183.	105.	2542.	0.	0.	3581.
840.	45.	6139.	754.	184.	106.	2570.	0.	0.	3615.
850.	46.	6165.	757.	185.	106.	2599.	0.	0.	3648.
860.	47.	6191.	760.	186.	107.	2628.	0.	0.	3681.
870.	47.	6216.	764.	186.	107.	2657.	0.	0.	3714.
880.	48.	6241.	767.	187.	108.	2685.	0.	0.	3747.
890.	48.	6266.	770.	188.	108.	2714.	0.	0.	3780.
900.	49.	6291.	773.	189.	109.	2743.	0.	0.	3813.
910.	49.	6316.	776.	189.	109.	2772.	0.	0.	3846.
920.	50.	6341.	779.	190.	109.	2800.	0.	0.	3879.
930.	50.	6365.	782.	191.	110.	2829.	0.	0.	3912.
940.	51.	6389.	785.	192.	110.	2858.	0.	0.	3945.
950.	51.	6413.	788.	192.	111.	2887.	0.	0.	3978.
960.	52.	6437.	791.	193.	111.	2915.	0.	0.	4010.
970.	52.	6461.	794.	194.	111.	2944.	0.	0.	4043.
980.	53.	6485.	797.	195.	112.	2973.	0.	0.	4076.
990.	54.	6508.	799.	195.	112.	3001.	0.	0.	4108.
1000.	54.	6531.	802.	196.	113.	3028.	0.	0.	4138.
1010.	55.	6555.	805.	197.	113.	3055.	0.	0.	4169.
1020.	55.	6578.	808.	197.	113.	3081.	0.	0.	4200.
1030.	56.	6600.	811.	198.	114.	3108.	0.	0.	4231.
1040.	56.	6623.	814.	199.	114.	3135.	0.	0.	4262.
1050.	57.	6646.	816.	199.	115.	3162.	0.	0.	4293.
1060.	57.	6668.	819.	200.	115.	3189.	0.	0.	4323.
1070.	58.	6690.	822.	201.	115.	3216.	0.	0.	4354.
1080.	58.	6713.	825.	201.	116.	3243.	0.	0.	4385.
1090.	59.	6735.	827.	202.	116.	3270.	0.	0.	4415.
1100.	60.	6756.	830.	203.	117.	3296.	0.	0.	4446.
1110.	60.	6778.	833.	203.	117.	3323.	0.	0.	4476.
1120.	61.	6800.	835.	204.	117.	3349.	0.	0.	4506.
1130.	61.	6821.	838.	205.	118.	3376.	0.	0.	4536.
1140.	62.	6843.	841.	205.	118.	3402.	0.	0.	4566.
1150.	62.	6864.	843.	206.	118.	3429.	0.	0.	4596.
1160.	63.	6885.	846.	207.	119.	3455.	0.	0.	4626.
1170.	63.	6906.	848.	207.	119.	3482.	0.	0.	4656.
1180.	64.	6927.	851.	208.	119.	3508.	0.	0.	4686.
1190.	64.	6948.	853.	208.	120.	3535.	0.	0.	4716.
1200.	65.	6969.	856.	209.	120.	3561.	0.	0.	4746.
1210.	65.	6989.	859.	210.	121.	3588.	0.	0.	4776.
1220.	66.	7010.	861.	210.	121.	3614.	0.	0.	4806.
1230.	67.	7030.	864.	211.	121.	3641.	0.	0.	4836.
1240.	67.	7050.	866.	212.	122.	3667.	0.	0.	4866.
1250.	68.	7070.	868.	212.	122.	3693.	0.	0.	4896.
1260.	68.	7091.	871.	213.	122.	3720.	0.	0.	4926.
1270.	69.	7110.	873.	213.	123.	3746.	0.	0.	4956.
1280.	69.	7130.	876.	214.	123.	3773.	0.	0.	4986.
1290.	70.	7150.	878.	215.	123.	3799.	0.	0.	5015.
1300.	70.	7170.	881.	215.	124.	3826.	0.	0.	5045.

```
      NOTE:

      1/ HP USED WAS ROUNDED TO THE NEAREST 5.0 HP
      2/ PUMP COST INCLUDES HOUSING,DISCHARGE FACILITIES,SUMP,ETC.
      3/ O & M INCLUDES MINOR REPLACEMENT COST
      4/ WELL COST INCLUDES DRILLING, CASING,TESTING,SCREEN ASSEMBLY,ETC.
      5/ ANNUAL PUMPING COST INCLUDES AMORTIZATION OF PUMP UNIT AND WELL, O & M, TAXES & INSURANCE AND POWER COST


TOTAL ANNUAL PUMPING COST AT PRESENT PRICES..          2257.
TOTAL ANNUAL PUMPING COST AT ENERGY INFLATION RATE OF  9.00 PERCENT
OVER PROJECT LIFE...                                   3826.


TOTAL DYNAMIC HEAD, FEET.....        150.
PUMP-MOTOR EFF, PERCENT.....          70.


 FARM PUMP...CANAL TO SPRINKLER--150. TDH  9.5 % INTEREST

      A =          693.
      B =            3.4
      R =          0.999
```

```
           ****** DYNAMIC OUTPUT ******


 SECTION COMPONENT ID'S ARE OUTPUT IN SAME ORDER AS ENTERED
 (I.E.. FROM THE WATER SOURCE TO THE ENDING BRANCH)


 THE NUMBER OF COMBINATIONS = 184

 THE NUMBER OF SECTIONS PER COMBINATION =  12

 THE NUMBER OF ALTERNATIVES =   3

------------------------------------------------------------------------------------------------------------------------

                                                MIN COST   MAX COST   MIN Q    MAX Q   EFF. MIN DIV    EFF. MAX DIV
  1  2  3  4  5  6  7  8  9 10 11 12
------------------------------------------------------------------------------------------------------------------------


  1  1  1  1  1  1  1  1  1  1  1  1
                                                  6071.      6071.  42.741  89.804      82.94           82.95

  1  1  1  1  1  1  1  1  2  1  1  1
                                                  6619.      6680.  42.557  89.417      83.30           83.31

  1  1  1  1  1  2  1  1  1  1  1  1
                                                  6625.      6726.  42.519  89.339      83.37           83.38

  1  1  1  1  1  1  2  1  1  1  1  1
                                                  6860.      6931.  42.373  89.032      83.66           83.67

  1  1  1  1  1  2  1  1  2  1  1  1
                                                  7173.      7335.  42.335  88.952      83.74           83.74

  1  1  1  2  1  2  1  1  1  1  1  1
                                                  7294.      7476.  42.317  88.913      83.77           83.78

  1  1  1  1  1  1  2  1  2  1  1  1
                                                  7408.      7540.  42.189  88.645      84.03           84.03

  1  1  1  1  1  2  2  1  1  1  1  1
                                                  7408.      7575.  42.164  88.594      84.08           84.08

  1  1  1  1  1  1  1  1  1  2  1  1
                                                  7445.      7698.  41.991  88.229      84.42           84.43

  1  1  1  1  1  2  2  1  2  1  1  1
                                                  7956.      8184.  41.980  88.207      84.44           84.45

  1  1  1  1  1  1  1  1  2  2  1  1
                                                  7993.      8307.  41.807  87.842      84.79           84.80

  1  1  1  1  1  2  1  1  1  2  1  1
                                                  7999.      8353.  41.770  87.763      84.87           84.88

  1  1  1  1  1  1  2  1  1  2  1  1
                                                  8234.      8558.  41.623  87.456      85.17           85.17

  1  1  1  1  1  2  1  1  2  2  1  1
                                                  8547.      8962.  41.586  87.377      85.25           85.25

  1  1  1  2  1  2  1  1  1  2  1  1
                                                  8668.      9103.  41.567  87.338      85.28           85.29

  1  1  1  1  1  1  2  1  2  2  1  1
                                                  8782.      9167.  41.439  87.070      85.55           85.55

  1  1  1  1  1  2  2  1  1  2  1  1
                                                  8783.      9202.  41.415  87.019      85.60           85.60

  1  1  1  2  1  2  1  1  2  2  1  1
                                                  9216.      9712.  41.383  86.951      85.66           85.67

  1  1  1  1  1  2  2  1  2  2  1  1
                                                  9331.      9811.  41.231  86.632      85.98           85.98

  1  1  1  2  1  2  2  1  1  2  1  1
                                                  9449.      9947.  41.218  86.606      86.01           86.01

  1  2  1  1  1  1  1  1  1  2  1  1
                                                  9599.     10696.  41.196  86.559      86.05           86.06
```

```
1  1  1  3  1  1  2  1  1  2  1  1
                                                9928.     10630.  41.170  86.505      86.11          86.11
1  1  1  2  1  2  2  1  2  2  1  1
                                                9997.     10556.  41.034  86.219      86.39          86.40
1  1  1  1  2  2  1  1  1  2  1  1
                                               10036.     10672.  41.030  86.210      86.40          86.41
1  2  1  1  1  1  1  1  2  2  1  1
                                               10141.     11294.  41.018  86.183      86.43          86.43
1  2  1  1  1  2  1  1  1  2  1  1
                                               10147.     11339.  40.981  86.107      86.50          86.51
1  1  1  1  2  1  2  1  1  2  1  1
                                               10268.     10869.  40.893  85.924      86.69          86.69
1  2  1  1  1  1  2  1  1  2  1  1
                                               10378.     11535.  40.839  85.808      86.81          86.81
1  2  1  1  1  2  1  1  2  2  1  1
                                               10690.     11937.  40.802  85.731      86.88          86.89
1  2  1  2  1  2  1  1  1  2  1  1
                                               10810.     12077.  40.784  85.693      86.92          86.93
1  1  1  1  2  2  2  1  1  2  1  1
                                               10811.     11502.  40.700  85.517      87.10          87.10
1  2  1  1  1  1  2  1  2  2  1  1
                                               10920.     12134.  40.660  85.432      87.19          87.19
1  2  1  1  1  2  2  1  1  2  1  1
                                               10921.     12167.  40.636  85.383      87.24          87.24
1  2  1  2  1  2  1  1  2  2  1  1
                                               11353.     12675.  40.605  85.317      87.30          87.31
1  1  1  1  2  2  2  1  2  2  1  1
                                               11359.     12111.  40.515  85.131      87.50          87.50
1  2  1  1  1  2  2  1  2  2  1  1
                                               11463.     12766.  40.457  85.007      87.62          87.63
1  2  1  2  1  2  2  1  1  2  1  1
                                               11582.     12901.  40.445  84.981      87.65          87.65
1  1  1  2  2  2  2  1  2  2  1  1
                                               12021.     12848.  40.330  84.742      87.90          87.90
1  2  1  2  1  2  2  1  2  2  1  1
                                               12125.     13500.  40.266  84.605      88.04          88.04
1  2  1  1  2  2  1  1  1  2  1  1
                                               12164.     13616.  40.262  84.596      88.05          88.05
1  2  1  1  2  1  2  1  1  2  1  1
                                               12392.     13805.  40.129  84.319      88.34          88.34
1  2  1  1  2  2  1  1  2  2  1  1
                                               12707.     14214.  40.083  84.220      88.44          88.45
1  2  1  2  2  2  1  1  1  2  1  1
                                               12823.     14345.  40.076  84.206      88.46          88.46
1  2  1  1  2  2  2  1  1  2  1  1
                                               12930.     14428.  39.941  83.923      88.76          88.76
1  2  1  2  2  2  1  1  2  2  1  1
                                               13366.     14944.  39.897  83.831      88.85          88.86
1  2  1  1  2  2  2  1  2  2  1  1
                                               13473.     15026.  39.762  83.547      89.16          89.16
1  2  1  2  2  2  2  1  1  2  1  1
                                               13587.     15154.  39.761  83.545      89.16          89.16
1  2  1  3  2  1  2  1  1  2  1  1
                                               14054.     15810.  39.715  83.449      89.26          89.26
1  2  1  2  2  2  2  1  2  2  1  1
                                               14130.     15752.  39.582  83.169      89.56          89.56
1  2  1  3  2  2  2  1  1  2  1  1
                                               14587.     16422.  39.533  83.068      89.67          89.67
1  2  1  1  2  2  2  2  1  2  1  1
                                               14685.     16457.  39.517  83.032      89.71          89.71
```

```
1 2 1 2 2 2 2 1 2 2 2 1          15019.    16720.  39.427  82.844     89.91         89.92
1 2 1 3 2 2 2 1 2 2 1 1          15129.    17020.  39.354  82.691     90.08         90.08
1 2 1 1 2 2 2 2 2 2 1 1          15228.    17056.  39.338  82.656     90.12         90.12
1 2 1 2 2 2 2 2 1 2 1 1          15343.    17183.  39.337  82.654     90.12         90.12
1 2 1 3 2 1 2 2 1 2 1 1          15809.    17840.  39.291  82.558     90.22         90.23
1 2 1 2 2 2 2 2 2 2 1 1          15885.    17782.  39.158  82.278     90.53         90.53
1 2 1 3 2 2 2 2 1 2 1 1          16342.    18451.  39.109  82.176     90.64         90.65
1 2 1 2 2 2 2 2 2 2 2 1          16774.    18750.  39.003  81.953     90.89         90.89
1 2 1 3 2 2 2 2 2 2 1 1          16885.    19050.  38.930  81.800     91.06         91.06
1 2 1 3 2 2 2 2 3 2 1 1          17657.    19996.  38.885  81.705     91.17         91.17
1 2 1 3 2 2 2 2 2 2 2 1          17773.    20018.  38.776  81.476     91.42         91.43
1 2 2 3 2 2 2 2 2 2 1 1          18319.    20639.  38.736  81.392     91.52         91.52
1 2 1 3 2 2 2 2 3 2 2 1          18546.    20964.  38.730  81.381     91.53         91.53
2 2 1 2 2 2 2 1 2 2 2 1          18661.    21237.  38.693  81.303     91.62         91.62
2 2 1 3 2 2 2 1 2 2 1 1          18770.    21533.  38.622  81.153     91.79         91.79
2 2 1 1 2 2 2 2 2 2 1 1          18869.    21568.  38.606  81.118     91.83         91.83
2 2 1 2 2 2 2 2 1 2 1 1          18983.    21695.  38.605  81.116     91.83         91.83
1 2 2 3 2 2 2 2 2 2 2 1          19207.    21608.  38.581  81.067     91.88         91.89
2 2 1 3 2 1 2 2 1 2 1 1          19448.    22350.  38.560  81.022     91.93         91.94
2 2 1 2 2 2 2 2 2 2 1 1          19522.    22286.  38.429  80.748     92.25         92.25
2 2 1 3 2 2 2 2 1 2 1 1          19977.    22953.  38.382  80.648     92.36         92.36
2 2 1 2 2 2 2 2 2 2 2 1          20407.    23247.  38.278  80.430     92.61         92.61
2 2 1 3 2 2 2 2 2 2 1 1          20516.    23543.  38.207  80.280     92.78         92.79
2 2 1 3 2 2 2 2 3 2 1 1          21288.    24487.  38.163  80.167     92.89         92.90
2 2 1 3 2 2 2 2 2 2 2 1          21401.    24504.  38.055  79.962     93.15         93.16
2 2 2 3 2 2 2 2 2 2 1 1          21946.    25123.  38.016  79.880     93.25         93.25
2 2 1 3 2 2 2 2 3 2 2 1          22173.    25448.  38.011  79.869     93.26         93.27
2 2 1 3 2 3 2 2 2 2 2 1          22412.    25983.  37.945  79.731     93.42         93.43
2 2 2 3 2 2 2 2 2 2 2 1
```

```
                                                22831.     26084.   37.864   79.562      93.62           93.63
2 2 1 3 2 3 3 2 2 2 2 1
                                                23540.     27687.   37.860   79.552      93.63           93.64
2 2 2 3 2 2 2 2 3 2 2 1
                                                23603.     27028.   37.820   79.469      93.73           93.74
2 2 2 3 2 3 2 2 2 2 2 1
                                                23841.     27561.   37.756   79.334      93.89           93.89
2 2 2 3 2 3 2 2 3 2 2 1
                                                24612.     28505.   37.712   79.241      94.00           94.00
2 2 2 3 2 3 2 2 2 2 3 1
                                                24928.     28859.   37.704   79.226      94.02           94.02
2 2 2 3 2 3 3 2 2 2 2 1
                                                24968.     29263.   37.672   79.158      94.10           94.10
2 2 2 3 2 3 2 2 3 2 3 1
                                                25700.     29803.   37.660   79.133      94.13           94.13
2 2 2 3 2 3 3 2 3 2 2 1
                                                25740.     30207.   37.628   79.065      94.21           94.21
2 2 3 3 2 2 2 2 2 2 2 1
                                                26045.     30444.   37.576   78.955      94.34           94.34
2 2 3 3 2 2 2 2 3 2 2 1
                                                26817.     31388.   37.531   78.862      94.45           94.46
2 2 3 3 2 3 2 2 2 2 2 1
                                                27047.     31903.   37.469   78.732      94.61           94.61
2 2 3 3 2 3 2 2 3 2 2 1
                                                27818.     32847.   37.425   78.639      94.72           94.72
2 2 3 3 2 3 2 2 2 2 3 1
                                                28134.     33201.   37.418   78.624      94.74           94.74
2 2 3 3 2 3 3 2 2 2 2 1
                                                28167.     33591.   37.387   78.560      94.82           94.82
2 2 3 3 2 3 2 2 3 2 3 1
                                                28906.     34145.   37.374   78.531      94.85           94.85
2 2 3 3 2 3 3 2 3 2 2 1
                                                28939.     34535.   37.343   78.467      94.93           94.93
2 2 3 3 2 3 3 2 2 2 3 1
                                                29255.     34889.   37.336   78.452      94.95           94.95
2 2 3 3 2 3 3 2 3 2 3 1
                                                30026.     35833.   37.292   78.359      95.06           95.06
2 2 3 3 2 3 2 2 3 3 2 1
                                                31050.     37488.   37.272   78.316      95.11           95.11
2 2 3 3 2 3 2 2 2 3 3 1
                                                31355.     37818.   37.266   78.304      95.13           95.13
2 2 3 3 2 3 3 2 2 3 2 1
                                                31399.     38232.   37.234   78.237      95.21           95.21
2 2 3 3 2 3 2 2 3 3 3 1
                                                32126.     38762.   37.221   78.211      95.24           95.24
2 2 3 3 2 3 3 2 3 3 2 1
                                                32171.     39176.   37.190   78.144      95.32           95.32
2 2 3 3 2 3 3 2 2 3 3 1
                                                32475.     39505.   37.184   78.132      95.34           95.34
2 2 3 3 2 3 3 2 3 3 3 1
                                                33247.     40449.   37.139   78.039      95.45           95.45
2 2 3 3 3 3 3 2 3 2 2 1
                                                34559.     41695.   37.129   78.018      95.48           95.48
2 2 3 3 3 3 3 2 2 2 3 1
                                                34875.     42048.   37.122   78.002      95.50           95.50
2 2 3 3 3 3 3 2 3 2 3 1
                                                35647.     42992.   37.078   77.910      95.61           95.61
2 3 2 3 2 3 3 2 2 2 2 1
                                                36409.     44773.   37.071   77.896      95.63           95.63
```

```
2 2 3 3 3 3 2 2 3 3 2 1      36685.    44677.  37.055  77.862    95.67      95.67
2 2 3 3 3 3 2 2 2 3 3 1      36989.    45007.  37.049  77.850    95.68      95.68
2 2 3 3 3 3 3 2 2 3 2 1      37020.    45392.  37.020  77.788    95.76      95.76
2 3 3 3 2 2 2 2 2 2 2 1      37472.    45924.  36.977  77.698    95.87      95.87
3 2 2 3 2 3 2 2 2 2 2 1      37589.    46385.  36.970  77.682    95.89      95.89
2 2 3 3 3 3 3 2 2 3 3 1      38096.    46665.  36.970  77.683    95.89      95.89
2 3 3 3 2 2 2 2 3 2 2 1      38237.    46854.  36.934  77.607    95.98      95.98
3 2 2 3 2 3 2 2 3 2 2 1      38355.    47317.  36.927  77.591    96.00      96.00
2 3 3 3 2 3 2 2 2 2 2 1      38457.    47350.  36.874  77.481    96.14      96.14
2 3 3 3 2 3 2 2 3 2 2 1      39222.    48280.  36.831  77.390    96.25      96.25
2 3 3 3 2 3 2 2 2 2 3 1      39537.    48632.  36.823  77.375    96.27      96.27
2 3 3 3 2 3 3 2 2 2 2 1      39566.    49012.  36.794  77.313    96.35      96.35
3 2 3 3 2 2 2 2 2 2 2 1      39769.    49217.  36.794  77.312    96.35      96.35
2 3 3 3 2 3 2 2 3 2 3 1      40302.    49562.  36.780  77.285    96.38      96.38
2 3 3 3 2 3 3 2 3 2 2 1      40331.    49943.  36.751  77.222    96.46      96.46
3 2 3 3 2 2 2 2 3 2 2 1      40535.    50148.  36.750  77.221    96.46      96.46
2 3 3 3 2 3 3 2 2 2 3 1      40646.    50294.  36.743  77.207    96.48      96.48
3 2 3 3 2 3 2 2 2 2 2 1      40756.    50646.  36.690  77.094    96.62      96.62
3 2 3 3 2 3 2 2 3 2 2 1      41521.    51577.  36.647  77.004    96.73      96.74
3 2 3 3 2 3 2 2 2 2 3 1      41837.    51929.  36.640  76.989    96.75      96.75
3 2 3 3 2 3 3 2 2 2 2 1      41866.    52310.  36.610  76.926    96.83      96.83
3 2 3 3 2 3 2 2 3 2 3 1      42602.    52860.  36.596  76.898    96.87      96.87
3 2 3 3 2 3 3 2 3 2 2 1      42631.    53242.  36.567  76.836    96.95      96.95
3 2 3 3 2 3 3 2 2 2 3 1      42946.    53594.  36.560  76.821    96.96      96.97
3 2 3 3 2 3 3 2 3 2 3 1      43712.    54525.  36.516  76.730    97.08      97.08
3 2 3 3 2 3 2 2 3 3 2 1      44733.    56175.  36.497  76.688    97.13      97.13
3 2 3 3 2 3 2 2 2 3 3 1      45037.    56503.  36.491  76.676    97.15      97.15
3 2 3 3 2 3 3 2 2 3 2 1      45077.    56908.  36.460  76.611    97.23      97.23
3 2 3 3 2 3 2 2 3 3 3 1      45802.    57434.  36.448  76.586    97.26      97.26
```

```
3 2 3 3 2 3 3 2 3 3 2 1
                                   45843.     57839.   36.417  76.520      97.35          97.35
3 2 3 3 2 3 3 2 2 3 3 1
                                   46146.     58167.   36.411  76.508      97.36          97.36
3 2 3 3 2 3 3 2 3 3 3 1
                                   46912.     59099.   36.368  76.418      97.48          97.48
3 2 3 3 3 3 3 2 3 2 2 1
                                   48223.     60341.   36.357  76.396      97.50          97.50
3 2 3 3 3 3 3 2 2 2 3 1
                                   48538.     60693.   36.350  76.382      97.52          97.52
3 2 3 3 3 3 3 2 3 2 3 1
                                   49303.     61624.   36.307  76.291      97.64          97.64
3 3 2 3 2 3 3 2 2 2 2 1
                                   50065.     63403.   36.301  76.278      97.66          97.66
3 2 3 3 3 3 2 2 3 3 2 1
                                   50338.     63303.   36.285  76.245      97.70          97.70
3 2 3 3 3 3 2 2 2 3 3 1
                                   50642.     63630.   36.280  76.233      97.71          97.71
3 2 3 3 3 3 3 2 2 3 2 1
                                   50669.     64007.   36.251  76.172      97.79          97.79
3 3 3 3 2 2 2 2 2 2 2 1
                                   51115.     64527.   36.209  76.084      97.90          97.90
3 2 3 3 3 3 3 2 3 3 2 1
                                   51434.     64939.   36.207  76.081      97.91          97.91
3 2 3 3 3 3 3 2 2 3 3 1
                                   51738.     65266.   36.202  76.069      97.92          97.92
3 3 3 3 2 2 2 2 3 2 2 1
                                   51874.     65445.   36.167  75.996      98.02          98.02
3 3 3 3 2 3 2 2 2 2 2 1
                                   52086.     65924.   36.108  75.872      98.18          98.18
3 3 3 3 2 3 2 2 3 2 2 1
                                   52846.     66842.   36.066  75.783      98.29          98.29
3 3 3 3 2 3 2 2 2 2 3 1
                                   53160.     67191.   36.059  75.769      98.31          98.31
3 3 3 3 2 3 3 2 2 2 2 1
                                   53184.     67564.   36.030  75.706      98.39          98.39
3 3 3 3 2 3 2 2 3 2 3 1
                                   53919.     68109.   36.017  75.680      98.43          98.43
3 3 3 3 2 3 3 2 3 2 2 1
                                   53943.     68482.   35.988  75.619      98.51          98.51
3 3 3 3 2 3 3 2 2 2 3 1
                                   54257.     68831.   35.981  75.605      98.53          98.53
3 3 3 3 2 3 3 2 3 2 3 1
                                   55017.     69749.   35.938  75.516      98.64          98.64
3 3 3 3 2 3 2 2 3 3 2 1
                                   56035.     71393.   35.919  75.475      98.69          98.69
3 3 3 3 2 3 2 2 2 3 3 1
                                   56338.     71719.   35.914  75.464      98.71          98.71
3 3 3 3 2 3 3 2 2 3 2 1
                                   56374.     72115.   35.883  75.400      98.79          98.79
3 3 3 3 2 3 2 2 3 3 3 1
                                   57097.     72637.   35.871  75.375      98.82          98.83
3 3 3 3 2 3 3 2 3 3 2 1
                                   57133.     73032.   35.841  75.311      98.91          98.91
3 3 3 3 2 3 3 2 2 3 3 1
                                   57436.     73358.   35.835  75.300      98.92          98.92
3 3 3 3 2 3 3 2 3 3 3 1
                                   58195.     74276.   35.793  75.211      99.04          99.04
3 3 3 3 3 3 3 2 3 2 2 1
```

```
                                                59504.     75516.  35.783  75.191     99.07          99.07
 3  3  3  3  3  3  3  2  2  2  3  1
                                                59818.     75865.  35.776  75.176     99.09          99.09
 3  3  3  3  3  3  3  2  3  2  3  1
                                                60577.     76783.  35.734  75.067     99.20          99.20
 3  3  3  3  3  3  2  2  3  3  2  1
                                                61609.     78455.  35.713  75.043     99.26          99.26
 3  3  3  3  3  3  2  2  2  3  3  1
                                                61912.     78781.  35.707  75.031     99.28          99.28
 3  3  3  3  3  3  3  2  2  3  2  1
                                                61934.     79149.  35.679  74.971     99.36          99.36
 3  3  3  3  3  3  2  2  3  3  3  1
                                                62671.     79699.  35.665  74.942     99.40          99.40
 3  3  3  3  3  3  3  2  3  3  2  1
                                                62693.     80067.  35.637  74.883     99.48          99.48
 3  3  3  3  3  3  3  2  2  3  3  1
                                                62996.     80393.  35.631  74.871     99.49          99.49
 3  3  3  3  3  3  3  2  3  3  3  1
                                                63755.     81311.  35.589  74.783     99.61          99.61
 3  3  3  3  3  3  2  3  3  3  2  1
                                                67406.     85820.  35.574  74.750     99.65          99.65
 3  3  3  3  3  3  2  3  2  3  3  1
                                                67709.     86146.  35.568  74.738     99.67          99.67
 3  3  3  3  3  3  3  3  2  3  2  1
                                                67731.     86514.  35.540  74.679     99.75          99.75
 3  3  3  3  3  3  2  3  3  3  3  1
                                                68468.     87064.  35.526  74.650     99.79          99.79
 3  3  3  3  3  3  3  3  3  3  2  1
                                                68491.     87431.  35.498  74.590     99.87          99.87
 3  3  3  3  3  3  3  3  2  3  3  1
                                                68793.     87758.  35.492  74.579     99.88          99.88
 3  3  3  3  3  3  3  3  3  3  3  1
                                                69552.     88675.  35.450  74.490    100.00         100.00


****** END OF DYNAMIC PROGRAM ******



    BYE
```