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# Planning Flood Control Measures by Digital Computer


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PLANNING FLOOD CONTROL MEASURES  
BY DIGITAL COMPUTER

James Norris Cline

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University of Kentucky Water Resources Institute  
Lexington, Kentucky

Project Number A-001-KY  
Dr. L. Douglas James, Principal Investigator

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## INTRODUCTION

"Planning Flood Control Measures by Digital Computer" is based on research performed as part of a project entitled "Economic Analysis of Alternative Flood Control Measures" (OWRR Project No. A-001-KY) sponsored by the University of Kentucky Water Resources Institute and supported in part by funds provided by the United States Department of Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379. Special thanks must also be extended to the Louisville District office of the U. S. Army Corps of Engineers for help in data gathering and the University of Kentucky Computing Center for use of their facilities.

The research goal is a practical means for economic evaluation of alternative combinations of structural and nonstructural measures for flood control for use in flood control project formulation. The result has been a pair of computer programs designed to ease the computational burden of comparing measure combinations by reproducing the mathematical steps in the design process. The programs are described in a series of four reports.

1. Rachford, Thomas M., "Economic Analysis of Alternative Flood Control Measures by Digital Computer," Research Report No. 1

2. Villines, James R., "Economic Analysis of Flood Detention Storage by Digital Computer," Research Report No. 9
3. Dempsey, Clyde R., "The Effects of Geographical and Climatic Setting on the Economic Advantages of Alternative Flood Control Measures," Research Report No. 10
4. Cline, James Norris, "Planning Flood Control Measures by Digital Computer," Research Report No. 11

The last three of these reports may be read as a unit for a thorough understanding of the research results.

The computer program as described is continuously being revised and updated as new experience is gained by applying it in different circumstances. Any comments or suggestions the reader may have will be sincerely appreciated and should be addressed to L. Douglas James, Project Director.

## ABSTRACT

The purpose of this study was to develop adequate guidelines whereby those interested in flood control planning would be able to apply a pair of digital computer programs known as the University of Kentucky Flood Control Planning Programs to ease the computational burden of evaluating specific flood control situations. Program II determines the economically optimum combination of channel improvement, land use restriction, and flood proofing for flood damage abatement. Program III also incorporates reservoir storage into the planning process. The Programs are not intended to provide a finished design but rather to select the optimum combination of flood control measures and residual flooding with regard to both time and space.

Application of Computer Programs to flood control planning is guided by presenting first a general description of the application process then a detailed description of the input required and the output produced by the Planning Programs. Input was developed and results interpreted to determine the optimum flood control plan for the upper reaches of the North Fork of the Kentucky River near Hazard, Kentucky.

## TABLE OF CONTENTS

	Page
INTRODUCTION . . . . .	iii
ABSTRACT . . . . .	v
LIST OF TABLES . . . . .	xi
LIST OF ILLUSTRATIONS . . . . .	xiii
Chapter	
I. SELECTING ALTERNATIVE FLOOD CONTROL MEASURES	
Introduction . . . . .	1
Measure Evaluation . . . . .	2
Flood Damage . . . . .	4
Structural Measures . . . . .	10
Nonstructural Measures . . . . .	14
Dynamic Analysis . . . . .	18
Methodology of Analysis . . . . .	20
II. COMPUTER PROGRAMS DEVELOPED FOR FLOOD MEASURE ANALYSIS	
Program II . . . . .	23
Program III . . . . .	31
III. APPLICATION OF COMPUTER PROGRAMS TO SOLVING A FLOOD CONTROL PROBLEM	
Problem Definition . . . . .	33
Alternative Methods of Analysis . . . . .	36
Planning Situations . . . . .	38
Varying Controls . . . . .	44
Limitations . . . . .	46

TABLE OF CONTENTS  
(Continued)

Chapter	Page
IV. DEVELOPMENT OF INPUT DATA	
Introduction . . . . .	49
The Study Area . . . . .	50
The Data Collection Process . . . . .	56
Program Control Parameters . . . . .	57
Physical Characteristics of Drainage Area and Channels . . . . .	62
Hydrology . . . . .	67
Flood Damages . . . . .	79
General Design Variables . . . . .	95
Design Data for Subwatershed Measures . . . . .	98
Urbanization and Land Value Projections . . . . .	121
Design Data for Dam and Reservoir . . . . .	125
V. INTERPRETATION OF OUTPUT	
Program II . . . . .	156
Program III . . . . .	167
Kentucky River Analysis . . . . .	184
VI. SUMMARY OF FINDINGS	
Significance of Findings . . . . .	197
Nature of Application . . . . .	198
Potential for Expansion . . . . .	199
Appendix	
A. FORTRAN IV LISTING OF THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II . . . . .	
	200
B. DICTIONARY OF VARIABLES USED IN THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAMS . . . . .	
	254



TABLE OF CONTENTS  
(Continued)

Appendix	Page
C. INPUT DATA FOR THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II . . . .	290
D. INPUT DATA FOR THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM III . . . .	296
LIST OF REFERENCES . . . . .	309

## LIST OF TABLES

Table	Page
1. Agricultural Land Use in Perry County . . . . .	87
2. Percent of Total Crop Value Destroyed by Flooding . . . . .	89
3. Relative Flood Threat by Month . . . . .	89
4. Annual Cost of Land Use Management . . . . .	158
5. Flood Plain Measures Considered . . . . .	159
6. Alternative Flood Plain Measure Combinations . . . . .	160
7. Stage Analysis Summary . . . . .	160
8. Summary of Channel Improvements . . . . .	162
9. Summary of Flood Proofing Measures . . . . .	163
10. Summary of Location Measures . . . . .	164
11. Summary of Right-of-Way Preserved for Future Channel Construction in Stage 2 . . . . .	165
12. Average Annual Cost Over All Stages . . . . .	166
13. Flood Hydrograph . . . . .	165
14. Hydrograph Parameters . . . . .	169
15. Flow and Water Surface Elevation at Flood Beginning . . . . .	170
16. Reservoir Outflow . . . . .	171
17. Reservoir Data Used in Routing Procedure . . . . .	172
18. Reservoir Routing Table . . . . .	173
19. Dam Quantities . . . . .	174

LIST OF TABLES  
(Continued)

Table		Page
20.	Trial Flow Depths . . . . .	175
21.	Stilling Basin Quantities . . . . .	175
22.	Emergency Spillway Quantities . . . . .	176
23.	Principal Spillway Quantities . . . . .	177
24.	Dam and Reservoir Cost Summary . . . . .	178
25.	Dam Design Details . . . . .	179
26.	Subwatershed Flood Peaks . . . . .	179
27.	On Line Cost Summary . . . . .	180
28.	Summary for Reservoir Trial . . . . .	181
29.	Cost of Justified Reservoir . . . . .	182
30.	Description of Computer Runs . . . . .	186
31.	Dam and Reservoir Data (Program III) . . . . .	188
32.	Dam and Reservoir Data (Corps of Engineers) . . . . .	189
33.	Reservoir Effect on 200-Year Flood Peak at Hazard . . . . .	190
34.	Benefit Cost Analysis of Reservoir Alternatives . . . . .	192
35.	Optimum Flood Proofing Program . . . . .	195

## LIST OF ILLUSTRATIONS

Figure		Page
1.	General Location Map . . . . .	51
2.	Specific Location Map . . . . .	52
3.	Variation of Crop Damage with Depth of Flooding . . .	90
A.	Emergency Spillway Profile . . . . .	306
B.	Dam Cross Section . . . . .	307
C.	Spillway Cross Section . . . . .	308

## Chapter I

### SELECTING ALTERNATIVE FLOOD CONTROL MEASURES

#### INTRODUCTION

The people of the United States suffer an average of roughly \$1,000,000,000 in flood damage each year. In Kentucky, the average annual damage is between \$10,000,000 and \$12,000,000 (21, p. 9). These figures, large as they are, do not satisfactorily portray the full economic impact of flood events. Flood damages do not occur in uniform annual amounts equally distributed over the population; instead, they come unexpectedly in amounts which vary from year to year from minor annoyance to major disasters, and they afflict a relatively small number of people. The impact of a major flood can be seen from the event of January, 1957, when approximately 6,000 residents of the area around Hazard, Kentucky, an area already suffering an economic and population decline, suffered \$6,813,300 in flood damages, more than \$1,000 per capita or 40 per cent of the median annual per capita income (21, p. 11). In 1937, 60 per cent of the city of Louisville was inundated by flood waters from the Ohio River (28, p. 2).

The more than \$10,000,000,000 that has been spent for structural measures to confine flood waters since passage of the

Flood Control Act of 1936 has certainly reduced flood damages below what they would have been otherwise. However, the expected annual flood damage is still increasing every year. The most promising approach to reverse the rising trend in flood damages is incorporation of nonstructural measures into flood control projects.

In explanation, flood damages result from an interaction between two factors. The streamflow must exceed the stream's carrying capacity, and damageable property must be located in the area flooded. A flood damage mitigation program may work on changing either of the two factors.

Measures designed to change the first factor, hence to prevent the stream from leaving its channel, are called structural measures, the most common examples being reservoir storage and channel improvement. The second type of flood damage abatement measures, the nonstructural measures, are designed to reduce the damage caused by the flood water that leaves the channel. This is accomplished by either modifying damageable flood plain property so that it suffers less damage during inundation (flood proofing) or by keeping potentially damageable property from the flood plain (land use management).

#### MEASURE EVALUATION

Following a report by the Task Force on Federal Flood Control Policy in 1966 (25), the President issued Executive Order 11296

requiring federal agencies to determine the optimum combination of structural and nonstructural measures for application in each flood plain studied.

Both broad categories of measures reduce flood damages, but both have economic costs associated with their implementation. Flood control planning seeks that combination of measures, each specified by area and level of implementation, that will yield the maximum flood control benefits net of the cost of the measures. Another way of describing this optimum flood control program is to say that it is the combination of measures, specified by area and level of implementation, that minimizes the sum of the cost of the damage reduction measures and flood damage residual to these measures.

"Level of protection" is the magnitude of the maximum flood event a flood control measure is designed to handle, usually expressed as the probability of the design flood occurring in any given year or as a return period, the long-term average interval between such floods. For example, a channel improvement providing a one per cent level of protection physically prevents flood water from spilling into the flood plain during all floods not exceeding the largest flood expected to occur, over an indefinitely long period of time, an average of once each 100 years.

Project planners are required to search for the optimum combination of structural and nonstructural measures for application in each watershed they study. They can only do so by evaluating the damage reduction each measure produces and the cost installation of each measure requires.

### FLOOD DAMAGE

Four flood damage categories are generally recognized: direct damages, indirect damages, secondary damages, and intangible damages. More recent research has suggested uncertainty damage as a fifth category.

Intangible damages, as the name implies, are those consequences of flooding that cannot be assigned a monetary value, hence can only be considered qualitatively in flood control planning. Loss of life and health, the temporary interruption of essential services during flood periods, and the insecurity from living under perpetual flood threat are examples.

Secondary damages result from economic rather than physical or technological linkages. For example, damage inflicted by a flood may prevent a family from being financially able to purchase a new automobile. Some automobile dealer loses a potential sale and thus suffers a secondary damage. Some auto manufacturer also loses a sale - more secondary damage. Such damages are difficult



to quantify and are at least partially offset by secondary benefits (for example, those realized by the suppliers of the building materials and new furniture to the flooded family).

For many water-resource project purposes, the favorable secondary effects are experienced locally while the unfavorable effects are dispersed over a wide area. A project whose local secondary benefits equal widely dispersed adverse secondary consequences may be regarded favorably because of a desirable income redistribution. However, this effect may not be as significant for flood control as for other project purposes because damage prevention shifts local expenditure from one group of merchants to another. In any event, the net secondary economic effect is usually close to zero from the national viewpoint.

Indirect damages are inflicted by some physical or technological linkage other than direct physical contact with the flood water. A good example of an indirect damage is the extra cost required to transport goods around a flooded area. The time and expense necessary to trace and evaluate indirect damages is seldom justified for planning individual projects. Consequently, indirect damages are usually taken as the fixed percentage of direct damages determined by pilot studies. For example, the Soil Conservation Service has developed the following values (37, p. 25):

Agricultural damages	5 to 10 per cent
Residential damages	10 to 15 per cent
Commercial and industrial damages	15 to 20 per cent

Direct damages result from direct physical contact of damage-able property with flood water. Direct urban damages are taken as the cost of restoring damaged property to its condition before it was inundated or its loss in market value if restoration is not worthwhile. The damage to totally destroyed property is its market value at the time of the loss.

While the damages caused by a flood of given severity to structures, contents, and surrounding landscaping vary greatly among individual properties, a relationship may be derived for planning purposes to express the average damage inflicted by shallow flooding ( $C_f$ ) in dollars per foot of flood depth per dollar of structure market value for a representative composite combination of residential, industrial, and commercial property. A representative value for  $C_f$  of 0.052 has been determined (13, pp. 85-88) for estimating total damage in the flood plain by the equation:

$$\$ _u = C_f M_s d \quad (1)$$

where  $\$ _u$  is the urban flood damage in dollars per acre,  $M_s$  is the market value of structures in dollars per acre, and  $d$  is the average depth of flooding in feet. Total urban and structural damage is the product of  $\$ _u$ , the total acres flooded, and fraction of the

area flooded subject to urban or structural damage. Higher values of  $C_f$  should be used for flood flows of high velocity or sediment content. The value may also be modified to include indirect or secondary damages by using an appropriate percentage increase or through a more exhaustive analysis where warranted. For flood depths exceeding four or five feet, flood damage no longer increases linearly with depth as indicated by eq. 1, and a curved relationship should be substituted (1).

Crop damage depends on the productivity and distribution of various soil types within the flood plain, the value of the crops grown and their susceptibility to flood damage at various times during the year, the relative probability of flooding at various times of the year, and the depth of flooding.

The damage wrought by a flood of given frequency is determined by summing the various kinds of damage. However, in determining the economic feasibility of a flood damage abatement measure, the benefits to be realized must be compared with the cost of the measure. To be comparable, the benefits and costs must be determined on the same time basis, for example, average annual values. The average annual benefits from a damage abatement measure is the difference in the average annual damage with and without the measure.

The frequency with which floods of various magnitudes (hence various depths and areas flooded) occur can be determined by hydrologic analysis (13, pp. 10-15). From relationships between flood magnitude and frequency and others relating flood magnitude and damage, damage can be plotted as a function of frequency. The average annual damage is the area under the damage-frequency curve.

Hydrologic studies can be used to determine how the flood frequency relationship varies with such other factors as the degree of urbanization of the tributary drainage area and the amount of channel improvement in the upstream channels (4). The change in average annual flood damage with time is caused partly by upstream urban development and channel improvement and partly by changes in flood plain land use. The increase in downstream flood damage induced by channel improvement is an important consideration in project planning.

Several years with no flooding at all may be followed by a year with extremely high damage. Due to their psychological aversion to not knowing in advance when a flood will occur and their financial aversion to very large infrequent damages, most people would be willing to pay an annual "flood damage bill" in excess of the average annual damage they suffer to be free from the

uncertainty. This excess may be called the uncertainty damage, and its reduction may be considered another goal of flood control measures. H. A. Thomas (5, pp. 150-152) developed a procedure for quantifying this aversion to uncertainty, and Bhavnagri and Bugliarello (1, pp. 149-173) showed how Thomas' method (called the Thomas Uncertainty Fund method) could be applied to flood control project formulation.

The Thomas Uncertainty Fund is a hypothetical sinking fund into which is deposited annually an amount of money large enough to cover expected flood damages with a fixed probability of having the fund exhausted by a series of unexpectedly large floods. In years of below average flood damage, the fund grows. In years of greater damage, the fund is depleted. If the probability of having the fund run out is set at less than 50 per cent, which will be the case if there is any aversion to uncertainty, the annual Thomas Uncertainty Fund payment will be more than the average annual flood damage. This excess is the uncertainty damage suffered by flood victims solely because of the variability of flood damages from year to year.

The uncertainty damage may be calculated by the equation:

$$C_u = (V_\alpha) (\sigma) / \sqrt{2r} \quad (2)$$

where  $C_u$  is the present worth of the uncertainty damage,  $V_\alpha$  is

the normal deviate with a probability  $\alpha$  of being exceeded,  $\alpha$  is the probability of having the hypothetical fund exhausted,  $\sigma$  is the standard deviation of the flood damage time series, and  $r$  is the project discount rate. Higher levels of protection by structural or nonstructural measures will cause a decrease in  $\sigma$ , which in turn decreases  $C_u$ . If  $C_u$  is included in the total measure and residual damage cost that is minimized in the optimum project, the decrease in uncertainty helps to justify flood control measures that cause the decrease. Selection of a low value of  $\alpha$  for calculating uncertainty damage can be used to increase the optimum level of protection above that specified by the reduction in average annual damages where believed warranted because of intangible considerations.

### STRUCTURAL MEASURES

Structural measures are designed to prevent the stream from leaving its banks. Reservoir storage prevents floods by holding floodwater within upstream reservoirs to dampen downstream flood peaks. Channel improvement prevents floods by increasing the flood peak required to overtop the stream bank.

In determining what (if any) level of protection should be supplied by reservoir storage, it is necessary to estimate average annual damage were no measures used at all. Then various levels of protection by reservoir detention may be assumed, beginning

with no flood control storage and proceeding to the highest level of protection to be considered. For each storage amount, the economically optimum combination and levels of protection of the downstream measures used to complement detention storage may be determined as that having the smallest total cost, including the costs of structural and nonstructural measures, residual flooding, and uncertainty. The optimum reservoir storage is associated with the minimum sum of reservoir and downstream cost. Should no combination be found whose total cost is lower than the damages if no measures are implemented, the optimum policy is to bear the damages.

Detention storage can be economically justified only when the downstream flood plain suffers relatively large damages and a reservoir site providing substantial low cost storage can be found. The cost of detention storage is comprised mainly of the dam cost, the cost of relocations, and of right-of-way. Consequently, detention storage can be used to the greatest advantage when the dam site provides maximum storage for a given dam size and has a suitable foundation and emergency spillway site and when the upstream area to be inundated by the reservoir has relatively few highways, railroads, transmission lines, etc., that would require relocation, and is relatively sparsely populated, thus avoiding expulsion of many people from their homes at a high social and

financial right-of-way cost.

Annual storage benefits are taken as the difference in the annual cost of the optimum combination of the other measures considered (including residual damages and uncertainty) with and without detention storage. The initial storage cost is evaluated from unit costs and quantities used in dam construction (including materials, engineering, design, and contingencies), relocations, and right-of-way. The initial cost is distributed over the project design life, using the project discount rate, and is added to the annual maintenance to determine the total annual cost. The right-of-way cost includes, in addition to the financial cost of acquiring real property, additional cost components to account for the difference between the project discount rate and the private interest rate (7) and the social and psychological cost of forcing unwilling residents to sell and leave their homes and farms (11).

The second means of keeping streamflows from leaving the channel, hence a structural measure, is by increasing the capacity of the channel. This can be accomplished by channel enlargement accompanied by lining or drop structures as required to prevent excessive scour by high flow velocities.

The capacity for uniform flow in an open channel, an index of its ability to dispose of flood water as efficiently and safely as



possible, is given by the Manning equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad (3)$$

where Q is the discharge in cfs, n is the Manning roughness coefficient, A is the cross sectional area of the stream, R is the hydraulic radius of the stream, and S is the slope of the hydraulic gradient which can be assumed, for our purposes, to equal the slope of the channel bottom. From this equation, it can be seen that enlarging the channel increases its capacity by increasing A and R and that lining the channel also increases its capacity by reducing the Manning roughness coefficient.

Annual benefits from a proposed channel improvement are taken as the difference in the average annual damages with and without the measure in place. Determination of the annual cost of channel improvement is analogous to that for reservoir detention storage, both being the sum of products of quantities and unit costs. Channel improvement reduces the dampening effect of flood plain storage. Consequently it makes the downstream flood peaks more severe. To account for this effect, the damage increase in downstream reaches or the cost of improving the downstream channel to handle the increased flow, whichever is smaller, should be calculated and treated as a negative benefit.

Channel improvement is likely to be found advantageous where there is a considerable amount of urbanization to provide potential benefits, particularly when a reservoir is not feasible upstream. The flood plain must be wide enough so that the right-of-way required will not be an excessively large fraction of the flood plain. In cases where right-of-way is relatively inexpensive, channel enlargement is most likely to be utilized. With increasingly urban areas abutting the stream, thus placing higher premiums on right-of-way, trapezoidal and then rectangular lined channels will become advantageous, their higher construction costs being offset by savings in right-of-way required.

#### NONSTRUCTURAL MEASURES

Nonstructural measures make no attempt to prevent floods - only to reduce the damage inflicted by floods when they do occur. These are the measures that have been too often overlooked in planning flood control projects. A major cause of their neglect has probably been the difficulty involved in determining their effect on flood damages and their costs.

Those nonstructural measures designed to reduce the flood damage to property located in the flood plain are called flood proofing measures. Only those flood proofing measures involving structural modification of buildings lend themselves to economic

analysis. Examples include sealing of foundation cracks to keep water out, removable bulkheads for doors and windows to reduce water entry and glass breakage, elevation or covering of damageable equipment, and use of building materials that are not particularly susceptible to flood damage. Flood proofing, unlike structural measures, can be implemented by individuals acting alone or on a community-wide basis as has been done in Bristol, Tennessee-Virginia. The average cost of flood proofing a large number of buildings (13, pp. 110-115) may be estimated by the equation:

$$C_P = C_p M_s h \quad (4)$$

where  $C_p$  is the installation cost of the measures,  $M_s$  is the market value of the structures, and  $h$  is the flood proofing design depth.  $C_p$  is an average cost of flood proofing that must be estimated from flood proofing measures designed for a large number of buildings and is analagous in units to  $C_f$  in eq. 1.

In determining flood proofing benefits, the damage residual to flood proofing measures must be taken as some fraction of the flood damage to the structures not flood proofed to account for damage outside the buildings, plus the damage outside the area protected, plus all the damage inflicted by floods larger than the measure design flood. Quantitative data on the cost of flood proofing is scarce since so few programs have been undertaken.

The most significant use of flood proofing, hence the best data source, is probably that in Bristol, Tennessee-Virginia reported by Sheaffer (24).

Flood proofing applies only to structures and since it can be implemented on a "per building" basis is often applicable in areas where urbanization is too scattered to merit structural measure protection. Flood proofing promises to have widespread applicability to the flood problem in Appalachia where the valleys are too narrow for levee construction and are filled with homes, towns, highways, railroads, etc., thus making economical reservoir sites scarce, and where all the feasible building sites are in the flood plain, thus ruling out the second nonstructural measure, land use restriction.

Land use restriction measures are those that keep out of the flood plain property that is more subject to damage and that gains little benefit from its flood plain location. The idea of land use regulation is not new. In March, 1937, "Engineering News Record" asked, "Is it sound economics to let such property be damaged year after year, to rescue and take care of the occupants, to spend millions for their 'local protection', when a slight shift in location would assure safety?" (8, p. 385). But it was not until 1966 that the President issued Executive Order 11296, which now

requires all Federal planning agencies to include nonstructural measures in their economic analyses of possible flood control projects.

The annual cost of land use management depends on the relative value of the flood plain land if it were free from the threat of flood damage (13, pp. 122-124). The pertinent factors may be condensed into the equation:

$$C_1 = CRF_t^i (MV_0 - PWF_t^j MV_t) - IA - IP \quad (5)$$

where  $C_1$  is the annual cost of preventing urban development for a period of  $t$  years,  $MV_0$  is the market value of the land at the beginning and  $MV_t$  at the end of the  $t$  year period,  $i$  is the interest rate for project evaluation,  $j$  is the rate of return required by private investors in land,  $CRF$  is a capital recovery factor,  $PWF$  is a present worth factor,  $IA$  is the average value of agricultural income one would expect if the land were farmed, and  $IP$  is a monetary expression of the average annual satisfaction the community loses when urban land displaces aesthetically pleasing open spaces. The cost of enforcing land use restrictions should also be included in the analysis.

Damage residual to land use measures include the damage to developments that were in the flood plain before new construction was restricted, damage to the land in its restricted use (usually agriculture), and damage to development outside the restricted

area when the design flood is exceeded.

Land use measures are applicable when future urban development is expected to encroach on the flood plain, providing there are alternative sites available for this development. It is not applicable when no urbanization is foreseen or when the flood plain is already intensely urbanized.

### DYNAMIC ANALYSIS

In planning a flood damage mitigation program having a design life of 50 to 100 years, it is necessary to project future population and future urbanization patterns. However, projections of the future are uncertain at best. For this reason, it is desirable to keep development plans as dynamic and flexible as possible. One of the best ways to fulfill this need is to introduce into the analysis of alternative measures the concept of planning stages. The total planning period, usually taken as the design life of structural measures, may be divided into planning stages. Based on the current conditions and the expected trends through the first stage, the analysis should begin by determining the optimum flood control measures to be installed now. If desired, and as based on the current projections, the further measures that should be adopted at the start of each subsequent planning stage may also be determined. The current as well as projected future action

should also be checked to insure that it forms a logical sequence when viewed over the entire planning period. The advantage of dynamic analysis is that at any time during the planning period that the urbanization and land use patterns are seen to be varying significantly from the original projections, revised estimates can be used to bring the flood control plan up to date. Projection errors do not produce an unneeded, large fixed investment. Details of optimum timing in stage construction are described by Dorfman (5, pp. 152-158).

Another problem in dynamic flood plain analysis is determination of whether one should hold extra right-of-way for future project construction. Whenever the cost of land is increasing at a faster rate than the project discount rate, it is economically advantageous for the planning agency to obtain and hold right-of-way that it expects to be required for construction in subsequent stages. James (16, p. 252) found that in a typical growing urban fringe this option should be exercised whenever the surrounding land is between 2 per cent and 70 per cent urban and the eventual need for the land is reasonably certain. In areas that are less than 2 per cent urban, land is too inexpensive to make holding worthwhile; for percentages larger than 70, the land is too expensive to justify taking a chance on buying land ahead of the time it is needed.

## METHODOLOGY OF ANALYSIS

The first procedure for selecting the optimum combination and level of protection of both structural and nonstructural measures (excluding reservoir storage) while including in the analysis all the considerations described above was developed by James at Stanford University and was presented in 1964 as his doctoral dissertation, "A Time-Dependent Planning Process for Combining Structural Measures, Land Use, and Flood Proofing to Minimize the Economic Cost of Floods" (13). In his research, James performed all the optimization calculations by slide rule or desk calculator. Roughly six hours was required for the calculations for just one channel reach in one planning stage. Consequently, the first in this series of research projects, designed to develop a practical means of executing and extending the procedure, was a project to convert the computational techniques into a computer program. This work was done by Rachford and is described by him in Research Report No. 1 (22). His initial computer program was dubbed "The University of Kentucky Flood Control Planning Program I", abbreviated hereafter UKFCPPI. At this point, the calculations that had taken six hours long-hand could be completed by the IBM 7040, then at the U. K. Computing Center, in about six seconds. Installation of the new IBM 360/50 computer along with improvements in program efficiency



have made the analysis even faster.

Addition of new program features, generalizations to make the program applicable to additional situations and improvements in computational efficiency, all to be described in the next chapter, were the steps leading to UKFCPPII. Program II is capable of analyzing up to 25 flood plain reaches or subwatersheds in virtually any complex arrangement. For example, part of the subwatersheds may be on each of several tributary streams and others on the main stream.

Program III (UKFCPPIII) has now been developed to determine the optimum flood control plan for a series of subwatersheds in sequence downstream. The most significant difference in Programs II and III is the inclusion of reservoir detention storage into the Program III analysis. The details of Program III are given by Villines (38).

In both Programs II and III, the hydrology is a vitally important factor. In Program III the routing procedures used require that the program not only be supplied with the flood peak data required by Program II but also similar information on flood volumes and flood hydrograph timing (see Chapter 4). This need for more hydrologic data, coupled with the sensitivity of the program results to hydrology, has led to a detailed study of the hydrology

involved in implementing the Flood Control Planning Programs .

Details of this study are presented by Dempsey (4).

In their up-to-date form, both Flood Control Planning Programs II and III are in Fortran IV computer language suitable for execution on the IBM 360/50 system at the University of Kentucky Computing Center. Program II requires 83,300 computer storage bytes, exclusive of system core storage, while the more complex Program III takes 132,500 bytes.

## Chapter II

### COMPUTER PROGRAMS DEVELOPED FOR FLOOD MEASURE ANALYSIS

#### PROGRAM II

Those responsible for flood control planning have been given what would by traditional computational methods be a very time consuming task. A thorough economic analysis considering many levels of protection by many different measures, both structural and nonstructural, should be used to determine what flood control measures should be employed. The optimum measures vary in time and space, and the chosen plan should be sufficiently flexible so it can be adjusted to changing conditions.

These planning refinements are essential to proper project formulation but multiply the complexity of the analysis. Flood control planning agencies were worked to capacity in planning for structural flood control measures alone. A shift to a more thorough analysis would increase their work load many fold. The only solution to this problem is in expanding the use made of high speed digital computers. The computer makes possible more than an acceleration of conventional computations. It permits use of many numerical methods of analysis which once could not be used

because of the required computational time. Programming the basic procedure for economic analysis allows comparison of many more alternatives than could ever be done by hand while freeing the planner from tedious computations so more time can be devoted to data collection and analysis interpretation.

The University of Kentucky Flood Control Planning Program II determines the combination and level of channel improvement, flood proofing, land use measures, and residual flooding that minimize the economic cost of flooding. The Program requires input which is either currently being collected for evaluating structural measures or will necessarily have to be collected for evaluating nonstructural measures in compliance with Executive Order 11296.

Program II consists of a main or "central program" and 14 subroutines. Each subroutine has a specific function to perform and may be called by the main program or by other subroutines to perform computations based on conditions currently being considered. A complete listing of the Program is in Appendix A. A dictionary defining all the variables used is in Appendix B. The reader should refer to this appendix for definitions of program variables subsequently used in the text.

The approach of Program II is that developed by James (13) and programmed into Program I as described in detail by Rachford (22).

Modifications made to Program I to develop Program II include consideration of new planning alternatives, generalizations to make the Program applicable to additional situations, and improvements to increase computational efficiency. Since these changes, Program I has become obsolete and is no longer applied. These changes, exclusive of minor changes to improve computational efficiency, follow.

The average annual damage is the area under the damage-frequency curve. The Program determines average annual damages from damages caused by floods of a number of different frequencies. Each flood damage figure is then multiplied by a frequency range centered around that frequency for which the damage was calculated. The summation of these products approximates the area under the damage-frequency curve, hence, approximates the average annual damages. In Program I, the damage was based on floods of 100 different frequencies. Program II follows the same technique but uses only 16 flood frequencies. This change was found to save a great deal of computing time with negligible loss of accuracy.

The main program as presented by Rachford was quite long. To simplify program development, the original main program was divided into a much smaller central control program and four subroutines. The new subroutines and that part of the function of

the old main program assumed by each are:

- (1) CHDATA - reads all the input data .
- (2) CHHYDR - determines the relationship between flood peak and frequency, and the frequency at which flooding begins .
- (3) CHOPTM - selects the optimum combination of channel improvement and nonstructural measures for a given subwatershed stage .
- (4) STROUT - prints out a summary of selected channel improvements .

A new feature of Program II was the addition of a right-of-way holding option. If this option is used, the Program determines whether or not right-of-way should be purchased in the early stages of the analysis for channel construction anticipated in subsequent stages. If the holding of extra right-of-way is found to be economical, the Program also determines the amount that should be held, the annual cost of holding the right-of-way, and the duration for which the land should be held before resale if the anticipated future improvements do not materialize. Details of the theory behind this option are presented by James (16).

The input data include the length of channel in each subwatershed that was improved prior to the beginning of the planning

period. A new subroutine, CHFIX, was added in Program II to establish the dimensions these previously improved channels would have according to the design criteria used by the Program for new channels. These dimensions are selected to provide a channel large enough to contain the design discharge specified by the data. It is desirable that the dimensions of channels improved before and during the planning period be based on the same criteria so that the cost of enlarging channels initially improved before the planning period began will be consistent with the cost of enlarging those initially improved during the period of analysis. CHFIX is also used in Program III, hence its details are presented by Villines (38).

A second new subroutine incorporated into both Programs II and III is CALCLU. This subroutine calculates the location (land use restriction) cost per acre for each subwatershed. Intuitively, the location cost should increase with the growing scarcity of land as the subwatershed becomes more urbanized. CALCLU, therefore, is designed to check whether or not the cost increases monotonically with urbanization. If it does not, the high early land value is probably caused by country estates and land speculation. In such cases, the Program reduces the high early value to the lowest location cost calculated for any subsequent stage.

Villines (38) presents the details of subroutine CALCLU.

Program I only applied flood proofing measures to urban structures. Provision was made in Program II to consider flood proofing for protection of farm buildings as well. The evaluation of flood proofing farm structures follows the same procedure used for urban structures (13, pp. 110-115).

The data for Program I was not grouped by related variables and was read using standard Fortran formats. The data have since been regrouped into the order presented in Chapter IV so data having related significance will appear together. A special READ subroutine was also added to read the data in a free format. Data need only match the variable type and be punched on the data cards in the proper order. Comments may be placed on the data cards to the right of an asterisk. The advantage of this free format becomes readily apparent by reviewing the input data listings in Appendices C and D.

In Program I, crop damage was assumed to be independent of the depth of flooding. The crop damage per acre of each soil type flooded was weighted according to the fraction of the flood plain in the respective soil types, and the composite per acre damage was multiplied by the area flooded to get the total crop damage. In Program II there are two per acre damage factors for each soil



type. The first is the damage per acre flooded to a minimal depth (fixed); the second is the additional damage per acre for each incremental foot of flood depth (variable). The composite variable damage factor is multiplied by the depth of flooding, and their product is added to the fixed damage factor. The total crop damage is the product of this sum and the area of crops flooded.

The two flood parameters, K1 and K2, used to relate the area and depth of flooding to the discharge in excess of channel capacity are described in detail by James (13, pp. 80-85). In Program I, the values for K1 and K2 for each subwatershed were calculated manually and included in the data. Program II is designed to calculate K1 and K2 from input subwatershed values of the discharge, depth, and area (QK12, DK12, and AK12 respectively) flooded by some historical flood event and from the existing channel capacity.

It was shown by the Manning equation (eq. 3) that lining, as well as enlargement, increases channel capacity. The narrower lined channels are particularly economical in areas of high right-of-way cost. Once a channel was improved using an unlined section, Program I only considered enlarging to provide the additional capacity as needed in later stages. Program II also considers lining the previously improved section without further enlargement.

In Program I, eq. 1 ( $C_f = \text{COEFDM}$ ) was used without regard to the depth of flooding or the calculated damage. Consequently, a very deep flood would be estimated as doing more damage to a building than the building was worth. This fallacy is corrected in Program II by assuming the damage to increase at COEFDM dollars per foot of depth per dollar of structure value until 25 per cent of the structure's value is destroyed. Then the damage is assumed to increase at half this rate until the damage reaches 75 per cent of the structure's value. It is finally assumed that no increase in damage is caused by greater depths, or regardless of the flood severity, 25 per cent of the value of a structure can be salvaged.

Because channel improvement benefits the local subwatershed at the expense of increased damages in those subwatersheds downstream, the downstream effect must be considered before channel improvement can be justified. This damage increase was estimated as the cost of enlarging downstream channels to handle the increase in the design frequency flood peak in Program I. However, such an estimate was found excessive in some cases. A new subroutine, QCST, was made a part of Program II to estimate the net increase in downstream flood damages brought about by the increase in flood peaks induced by the upstream channel improvement.

Each time subroutine QCST is utilized, it calculates the net

average annual induced damage in one downstream subwatershed. The induced damage is calculated from the relationship between flood peak and damage and the set of 16 flood peaks as they would be with and without the upstream channelization. Since one downstream subwatershed is evaluated each time, subroutine QCST is called once for each subwatershed downstream from the subwatershed being analyzed. Each time, the increase in damage with upstream channelization over that without is evaluated and compared with the cost of improving the downstream channel to accommodate the flow increase as determined by subroutine COST. The smaller of these costs is deducted from the benefits that the channel improvement being considered provides in its flood plain.

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PROGRAM III

The main difference between Program II and Program III is that the latter considers reservoir storage as an alternative structural measure, while the former has as its only structural measure, channel improvement. Because reservoir storage only affects flow in channels directly downstream, Program III is limited to a single line of up to 15 subwatershed flood plains numbered in sequence downstream. Program II may be used to analyze up to 25 subwatersheds arranged in any "tree" or confluent pattern.

The theory of Program III as well as a listing of the Program are given by Villines (38). The dictionary in Appendix B of this report also applies to Program III.

The increase in downstream flood damage induced by upstream channel improvement is not figured in Program III as it is in Program II. There are two basic reasons for this. First, Program III incorporates reservoir storage, which far more than offsets any channel induced increase in flood peaks. Second, estimation of downstream effects of upstream main line channelization would require routing of entire hydrographs rather than mere estimation of a peak flow as done in Program II. The use of the extra computer time was not considered justified in Program III in view of the few times the decision to build was found reversed by downstream costs from experience with Program II. Furthermore, Program II could be applied to the flood plain where downstream costs were believed significant.

## Chapter III

### APPLICATION OF COMPUTER PROGRAMS TO SOLVING A FLOOD CONTROL PROBLEM

#### PROBLEM DEFINITION

Due to the presence of water and other locational advantages, man has in the past and will continue into the future to concentrate his centers of civilization on rivers. In addition, local runoff often inundates low lying land far from any major watercourse. Consequently, flooding is currently and will continue into the indefinite future to be a very widespread problem. It is obvious, however, that the flood problem cannot be solved by one giant project for all the world and for all time. Each flood control project must be aimed at reducing damages in a preselected area for a limited period of time.

The limits on space and time to which analysis of a particular flood problem is to be confined are usually rather arbitrarily picked and may vary widely. In terms of space, the question might be whether or not to zone a given 20-acre tract against urban encroachment, or it might be to determine the optimum flood damage abatement plan for a complex river system where every conceivable flood control measure is potentially applicable. In terms of time,

the planner might be trying to determine the best thing to do right now, or he might be engaged in long-run planning to determine the optimum measures and installation timing for the next 50 or 100 years. Senate Document 97 requires that planning agencies base their economic analyses on the smallest practical independent units of time and space and that the measures prescribed for each time and space unit be justified by the resulting benefits (31).

In applying the Flood Control Planning Programs, the problem is first bounded in time and space by determining the total area and the total period of time over which the analysis is to be extended. The preliminary analysis should also include examination of the tributary area for promising reservoir sites. The space units or subareas into which the total selected problem area is divided are called subwatersheds. The subwatershed divisions are made by inspecting a topographic map of the flood plain and subdividing it into areas, each one having a relatively homogeneous flood problem. If the analysis is to be confined to flooding by a single major watercourse or if reservoir storage is to be analyzed, the subwatersheds will be in a single line pattern. If, however, flood control measures are to be considered for tributary channels as well as the main channel, the subwatersheds will lie in a "tree" type arrangement.

To assure homogeneity of the flood problem within each subwatershed, a subwatershed boundary should be placed:

1. at the junction of major tributaries because a confluence causes a sudden change in the tributary drainage area and thus in the flood frequency relationship;
2. at dam sites to be studied (applies to Program III only);
3. at major breaks in flood plain geometry or channel capacity because these will change the local flood hazard;
4. at major breaks in flood plain development, such as at the upstream and downstream end of urbanized areas because these will change the amount of local damage;
5. at the ends of existing channel improvements;
6. whenever needed to prevent the subwatershed flood plain from becoming too big geographically to be reasonably considered as a small homogeneous unit.

If Program III is being used for the analysis, a maximum of 15 subwatersheds may be used, and they must be arranged in a single line and numbered consecutively downstream. Program II can analyze as many as 25 subwatersheds along channels of any complex arrangement.

The total planning period is next divided into shorter time

periods called planning stages. By examining immediate needs through relatively short planning stages, project justification is no longer dependent on economic and demographic projections applying to the distant future, and revised projections can be used to bring the flood control plan up to date before determining what measures to take at the beginning of each subsequent stage. If the economic and demographic projections show the economy and population to be static, a single stage analysis is all that is needed. Ten-year planning stages work well for growing communities.

#### ALTERNATIVE METHODS OF ANALYSIS

The traditional flood planning approach has been to determine the least cost combination of structural measures. However, since this approach ignores nonstructural measures, it does not meet the requirements of Executive Order 11296. Agency experience has shown planning structural measures to be a very time consuming process. Others have demonstrated the inadequacy of plans that ignore nonstructural measures. Inclusion of nonstructural measures into the economic optimization promises to make manual (slide rules or desk calculators) analysis hopelessly long and involved.

The tremendous speed with which digital computers perform repetitive computations appears to make their use a promising solution to this time problem. Furthermore, use of the computer for



routine work frees the engineers to devote more time to collecting more reliable data and to comparing a larger number of measure combinations.

The data required by the computer programs presented in this report are roughly those already gathered by planning agencies except for the additional data required to evaluate nonstructural measures and for stage construction analysis. It will, however, be necessary for agencies to begin collecting data to evaluate non-structural measures in order to comply with Executive Order 11296, whether the analysis is to be by computer or not. The time and effort spent in making the intermediate projections (USUBW, UTOTR, and VALUE) for stage by stage analysis will be recouped many fold due to the more economically efficient plans implemented. If the planning agency elects not to consider stage construction, the Program options can be used to prevent consideration of more than one planning stage, and the intermediate projections will not be necessary.

It is not necessary for everyone involved in input data development and output interpretation to be familiar with all the theory and programming involved in the analysis. Consequently, relatively short training programs will be sufficient for a large part of the planning staff.

However, individual planning agencies may find it desirable to revise some of the programming to conform to their own policy and design standards. This can be accomplished by making minor changes in the Planning Programs. Agencies desiring greater accuracy in the estimating procedure than is currently provided could refine or add new features to the Programs and the data collection process to attain the desired degree of accuracy.

The Flood Control Planning Programs are designed strictly for planning, not for final design of water resource projects. The Programs determine what measures should be installed, the degree of protection to be provided by each measure, and the optimum project timing. Final design of the selected flood control measures is still required. The data should be revised and the Program rerun where final cost estimates vary substantially from planning estimates.

#### PLANNING SITUATIONS

Every flood problem encountered by a planning agency is different. The method for collecting data and applying the two Programs must be varied accordingly. To guide potential users in how to deal with different flood situations efficiently, several cases are given here along with a suggested technique for determining the optimum planning policy using the University of Kentucky Flood Control Planning Programs.

#### CASE 1: SPOT ANALYSIS

The simplest planning application is probably one that applies to one small area. For example, a local channel capacity restriction might cause local flooding, or a city zoning board may need to know whether or not flood plain zoning should be made applicable to a newly annexed section of the city. In such cases as these, where reservoir storage is certainly not feasible, Program II should be used for one subwatershed (MW = 1) and probably for one planning stage (NSTEMX = 1). Data for the local area should be developed and supplied as described in Chapter IV.

#### CASE 2: MAIN STREAM ANALYSIS

Another situation might be one in which all the flood damage of any significance occurs in the flood plain along the main channel, the tributaries posing no particular damage threat. For such a main stream analysis the planner should utilize Program III. If there is a feasible reservoir site upstream from the flood area, the data for this site and for the flood plain subwatersheds through the downstream end of the flood problem area should be developed and used. If no feasible reservoir site is available, fictitious reservoir data might be supplied for a hypothetical site upstream from the problem area along with the other data required for all the subwatersheds within the flood problem area being analyzed. The fictitious

reservoir may be eliminated from consideration by the NODAM option described in Chapter IV.

It should probably be noted here that "main channel" as far as the analysis by Program III is concerned is not necessarily the largest channel, nor does "tributary" necessarily refer to a small stream flowing into a larger one. For example, no potential reservoir site may be available on a relatively large river, while a very good site might exist on a smaller creek. In such a case, the "main channel" analyzed by Program III would be the creek from the proposed dam site down to the confluence with the river and the river from this point downstream through the problem area. The "tributary" area would include that drained by the river upstream from the confluence.

### CASE 3: MAIN STREAM ANALYSIS WITH SEVERAL RESERVOIR SITES

If the flood problem is like the one just described in that it is confined to the main channel flood plain but differs in that more than one potential reservoir site exists on the main channel, Program III should be used, as described in the previous case, once for each feasible reservoir site. The results may then be compared to find the combination of reservoir and other measures having the smallest total cost.

#### CASE 4: TRIBUTARY FLOODING WITH NO RESERVOIR SITES

In cases where flooding is prevalent along a number of confluent streams rather than just along the main channel, and where no potential reservoir sites are available, a single application of Program II will suggest the optimum flood control plan.

#### CASE 5: TRIBUTARY FLOODING WITH ONE RESERVOIR SITE

The flood damage may occur along several confluent streams, but there may be only one potentially feasible dam and reservoir site. Since neither Program will solve this problem alone, both Programs must be applied in a coordinated manner. Program II should be applied first for the entire problem area. The measures found optimum by this analysis would apply to all the subwatersheds upstream from the reservoir site or tributary to the main channel downstream from the reservoir site. After incorporating any channel improvement found optimum by Program II into the total channelization data (CTOTR), Program III may then be used to determine whether the potential reservoir is justified and, if it is, the optimum measures to be implemented along the main line channel downstream from the dam site.

#### CASE 6: RESERVOIR SITES ON A NUMBER OF TRIBUTARIES

If the flood problem under study is not entirely along the main channel and if there are several potential reservoir sites available,

application of the Programs becomes more complex. Program II may still be initially used for an analysis of the entire problem area. Program III may then be applied to each potential reservoir site assuming no other site is utilized. Those sites not justified are dropped from the analysis, and the reservoirs that are found feasible are listed in order of decreasing net benefit (effected reduction in downstream cost net of incremental reservoir cost for flood control).

Any reservoir in this list would be justified if installed independently of the others, but it is unlikely that installation of all the listed reservoirs could be justified without double counting the benefits. The next step, then, is to determine the best combination of these independently justified sites. The first site to be selected should be that producing the highest benefit. Program III should then be successively applied to the other reservoir sites on the list, beginning with the reservoir having the second highest net benefit, and assuming the reservoirs higher on the list to be in place. For example, the first of these runs would be based on the second best reservoir site with the reservoir having the highest net benefit assumed in place. If this second reservoir proved economical, the second run with Program III would be based on the third best reservoir site with the two best reservoirs being assumed in place. This process would continue until the next reservoir on the

list could not be justified. Any previously untried combination of reservoirs that looks particularly promising should also be tried and should be selected if it reduces the total cost of the previously selected optimum combination. Once the optimum combination of reservoirs has been selected, the optimum downstream measures may be determined by the methodology of Case 8.

By efficient operation during floods, reservoir outflow can be reduced to very low values when runoff from subwatersheds downstream is at its peak. Consequently, for the purpose of applying the Programs, assuming a justified reservoir to be in place is accomplished by reducing the area contributing to the flooding in each subwatershed by the tributary area upstream from the "in place" reservoir. Where gating is not used to make flood storage so effective, the reduction in the tributary area should be an appropriate fraction as hydrologically determined.

#### CASE 7: A NEW RESERVOIR TO SUPPLEMENT AN EXISTING RESERVOIR

If the flooding is along a single stream having one or more existing reservoirs on its tributary streams, Program III should be used. Again, the existing reservoirs are accounted for by deducting all or part of the drainage area the reservoirs control from the area of the subwatershed in which they are located.

## CASE 8: FLOOD PLAIN ANALYSIS DOWNSTREAM FROM EXISTING RESERVOIRS

The final case is that of seeking the optimum combination of local measures to complement an existing group of upstream reservoirs. The best approach is probably to first apply Program II, deducting all or an appropriate part of the drainage area controlled by each existing dam and reservoir. The measures found economical in this analysis are applied to the tributaries not downstream from any storage reservoir. Then, for the main channel downstream from each reservoir, Program III should be used, the dam and reservoir data supplied being that for the existing facilities. Mainline analysis downstream from the smaller reservoirs should be discontinued at the point where a junction occurs with a stream more effectively controlled by another larger reservoir. The minimum reservoir design flood (MRDF) used in the Program III analysis should be the flood frequency requiring the design flood storage pool (FLDSTR) in the existing reservoir.

### VARYING CONTROLS

By making minor changes in the input data, users of the Flood Control Planning Programs can incorporate a great deal of variation into the analysis. For example, the program control parameters specify which alternative measures should be considered in the



analysis; and the value assigned to LINING determines what types of channel improvement will be considered.

It is suggested that for the first analysis the planner use the input data he feels best describe the existing situation and the measures most likely to prove economical. In subsequent runs, the data can be varied to test the sensitivity of the output to variations in the input so that the data having the most significant effect on the optimum plan can be reviewed and revised as needed. The planner should, of course, avoid wasting computer time on consideration of impractical measures. For example, if all the damage is to agricultural crops, flood proofing should certainly be omitted from the analysis.

The very low cost of repeating the computations with different input data makes the Planning Programs valuable tools for testing different design standards. For example, an agency should consider in its review of a policy on the maximum allowable tractive force used in channel design by soil type the effect of alternative choices on the cost and nature of the optimum combination of measures.

An agency that does not currently employ some of the available options might run the Programs, first without, then with, the particular option included in the analysis. Comparison of the

costs would aid agency evaluation of current planning practices. A prime example of this use of the Programs is the question of stage construction. It is suggested that the Program applicable to the particular situation being analyzed be run first for a single stage whose duration is that of the entire planning period ( $NSTEMX = 1$  and  $TIME = TIMST$ ). The same analysis should then be run with stage construction made available ( $NSTEMX$  planning stages, each of duration  $TIME = TIMST / NSTEMX$ ). Cost comparison of the two optimum plans devised will show whether or not stage construction should be employed.

#### LIMITATIONS

The University of Kentucky Flood Control Planning Programs are by no means capable of analyzing all potential measures in all possible flood damage situations. As does any newly developed procedure, this innovation has limitations and weaknesses, many of which will be overcome by future research.

Although the Programs may be applied to channels and flood problems of any magnitude, they provide the greatest savings in computational time for flood problems on smaller channels where the flood plain is not yet urban but is expected to develop rapidly during the planning period. Such a situation reaps the full benefits of the stage construction and dynamic analysis offered by the Programs.

The method proposed to account for existing reservoirs (deducting all or part of the area they control) and the failure to account for flood routing interaction among reservoirs make the analysis an approximate one for multi-reservoir systems. More sophisticated combined routing procedures need to be developed.

The construction of levees is not included in the analysis. Neither is detention storage other than that to be provided by earth dams with an open channel emergency spillway and conduit principal spillway. The handling of gate opening and closing in the Program is rather crude, the only information used being the number of hours that the reservoir release is held at a constant low value after the storm begins. The optimum operating policy would incorporate a more sophisticated procedure for opening and closing gates according to whether flood damages are minimized by increasing reservoir releases to provide more storage for an impending flood or reducing releases to reduce current damage. Such an operating policy optimization may ultimately be incorporated into the Planning Programs.

As more experience is gained in using the Programs, and as more physical and cost data become available, particularly for nonstructural measures, the optimizing equations and also the input data can be made more accurate. This increased accuracy in input and programming will naturally result in more refined

selection of the optimum damage abatement measures.

Benefits as well as adverse project consequences that are not related to flood control must be evaluated outside the computer program. Only flood control benefits are taken into account by Program III in its economic justification of a reservoir.

Finally, at this time, the right-of-way holding option is available only for right-of-way for channel improvements. Inclusion of a similar option for acquiring right-of-way for future reservoir sites is another potential improvement.

## Chapter IV

### DEVELOPMENT OF INPUT DATA

#### INTRODUCTION

The policy selected by any optimization procedure is a product of the input data. The more reliable the data, the greater confidence one can have in the results. The central purpose of this chapter is to describe the data collection procedures required to insure dependable results from both Programs.

As a practical matter, use of the Programs is going to depend on the ability of potential users to develop the required input information from readily available sources without spending an unreasonable amount of time and effort. Most of the required data is currently collected by Federal agencies analyzing alternative combinations of structural measures for flood control. Even with the extra data collected to comply with Executive Order 11296, the much faster computational process realized from computer analysis will speed total planning time many fold.

The data development process may be best described through an example. Other studies have described application of the programs to expanding urban areas (13, 4) and to farming areas (38). The different environment selected for this study was a narrow flood-prone

Appalachian Valley. A location whose flood problem had been studied by a Federal agency was thought to be advantageous because the derived flood control plan would provide an independent check for the results of this study. Finally, a site where reservoir storage provided reasonable promise of proving economical was needed to test Program III.

### THE STUDY AREA

One area which meets these criteria quite well is located along the upper reaches of the North Fork of the Kentucky River in Breathitt, Knott, Letcher, and Perry Counties near Hazard, Kentucky (Fig. 1). The study area was more precisely defined as the flood plain of the North Fork of the Kentucky River upstream from the mouth of Troublesome Creek in Breathitt County to the proposed Kingdom Come Dam Site in Letcher County plus the flood plain of Carr Fork upstream to the dam currently under construction by the U. S. Army Corps of Engineers in Knott County (Fig. 2). The problem comes under Case 6 of Chapter III as three reservoir sites on two streams were selected for analysis; however, no tributary flooding other than that on the two mainline streams was considered. The third dam site studied was at Cornettsville on the North Fork of the Kentucky River.

The total study area was divided into twelve subwatersheds (outlined on Fig. 2) following the criteria presented in Chapter III.

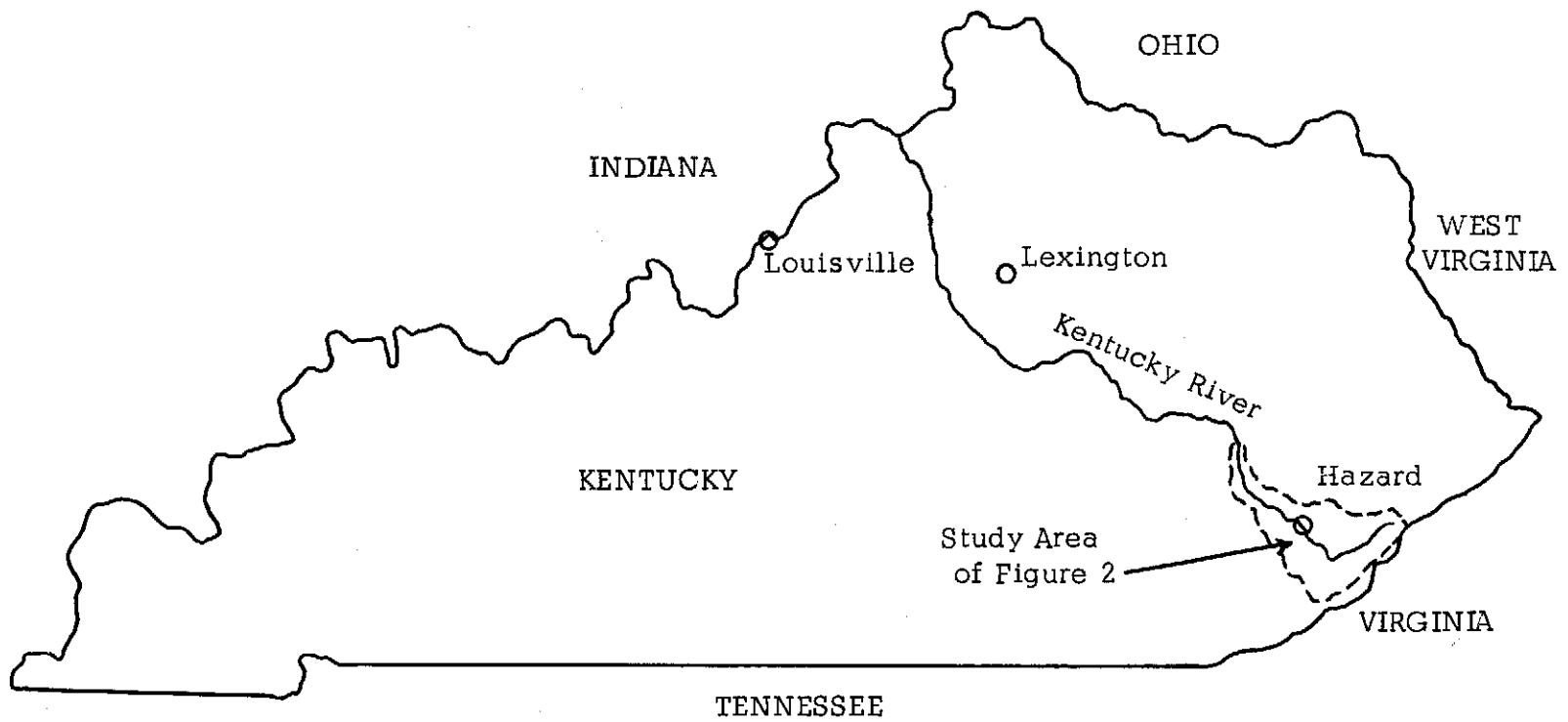


Figure 1. General Location Map

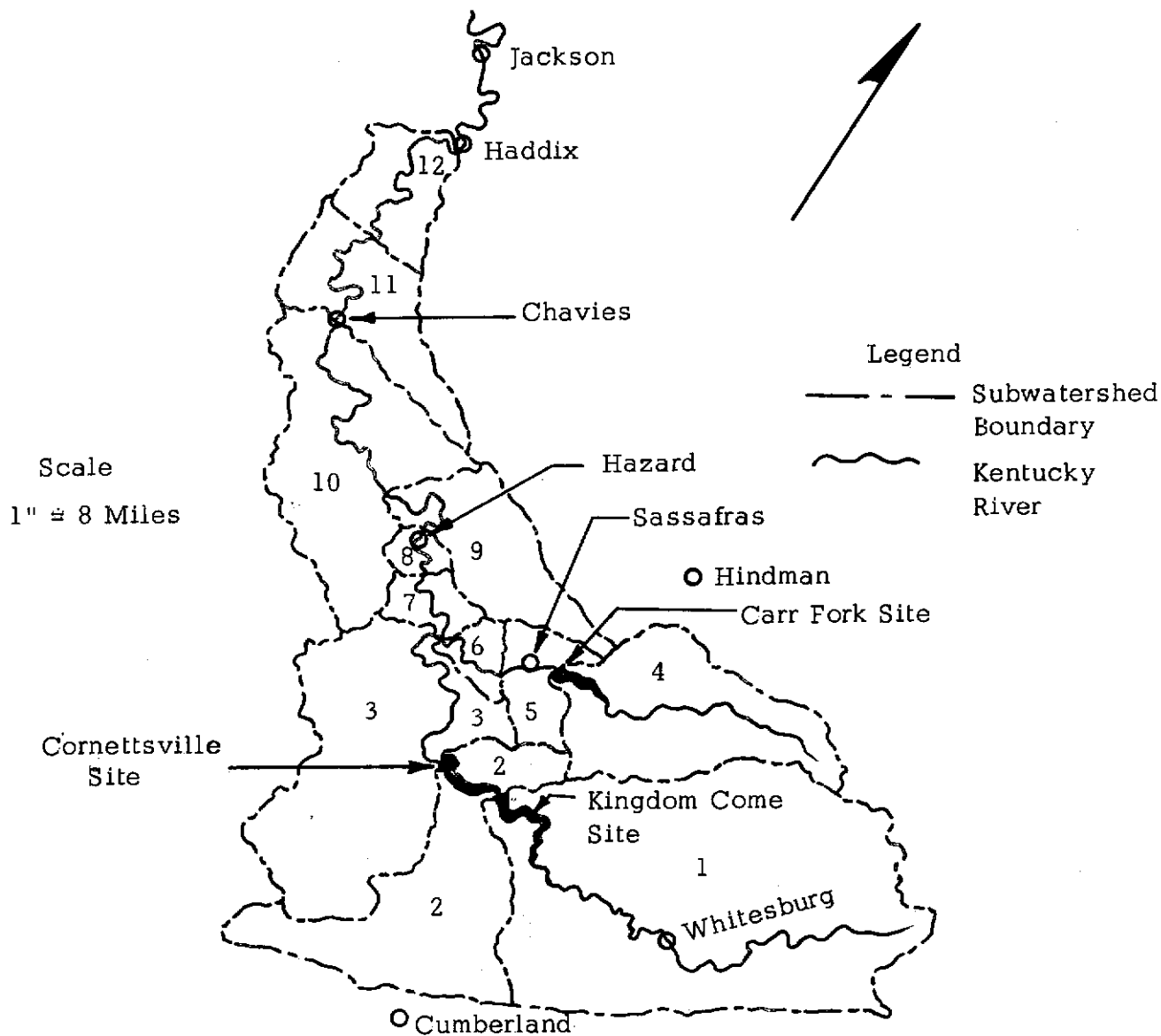


Figure 2. Specific Location Map



Of the total, nine (4, 5, 6, combined 1-3 and 7, 8, 9, 10, 11, and 12) applied to the Carr Fork Dam site, nine (1, 2, 3, combined 4-7, 8, 9, 10, 11, and 12) applied to the Kingdom Come Dam site, and eight (combined 1-2, 3, combined 4-7, 8, 9, 10, 11, and 12) applied to the Cornettsville Dam site.

A comprehensive study of flood plain development and flood losses along the Kentucky River was begun in 1955 by the Corps of Engineers. Extensive damage surveys were also taken in the area following the floods of 1957 and 1963 (27, pp. 72-73). The severity of the flood problem at Hazard is demonstrated by the storm of 1957, when the river rose almost 30 feet between midnight and 6:00 P.M. on January 29. The flood crest of 37.5 feet was nearly 20 feet above flood stage. Damage in the Hazard area alone was estimated at \$6,813,000 (21, p. 80).

The dam site is some 8.8 miles upstream from the confluence of Carr Fork with the North Fork of the Kentucky River. A flood control reservoir was economically justified at this site in the study by the Corps of Engineers. The majority of the flood damage reduction benefits are expected to accrue in Hazard. The drainage area tributary to the reservoir site is 58 square miles out of the 466 square miles upstream from Hazard. It is estimated that Carr Fork Reservoir would have reduced the 1957 flood peak at Hazard by three feet (29).

The tributary watershed is covered by U. S. Geological Survey 7.5 minute topographical maps which were very helpful in developing much of the data. The reservoir site and the downstream flood plain are also included in the "Reconnaissance Soil Survey; Fourteen Counties in Eastern Kentucky" (20). Agricultural data, population trends and other pertinent information were readily available.

The entire drainage area involved is in the mountains of eastern Kentucky, on the western margin of the Appalachian Plateau. The physiography is characteristically made up of sharp-crested ridges, separated by deep narrow valleys. The land use distribution is as follows: 5.5% cropland, 3.2% pasture, 81.0% forest, 0.3% Federal land, 1.7% urban and other built-up areas, and 8.3% idle land (20, p. 2).

The economy of the area has been centered around the mining of soft coal. Forest products, farming, and a small amount of light industry supplement the economic base. Due to mechanization of mining and agriculture, unemployment is rising. As a result, the population is decreasing. For example, in Perry County, where most of the study area is located, the population decreased from 47,828 in 1940 to 46,566 in 1950 and further to 34,961 in 1960 (12). The Corps of Engineers states that people are leaving their mountains and remote hollow homes and are moving into the flood plains along

the larger streams (27, pp. 78-79). However, even the population of Hazard, the chief urban center of the area, has dropped from 7,397 in 1940 to 6,985 in 1950 and further to 5,958 in 1960 (33).

Much of the population is scattered over the ridges, valleys, and hollows and into remote areas having very limited access. School facilities are inadequate, with many one- and two-room schools still in operation because of the difficulty in running busses over many rural mountain roads. Less than 36 percent of the children entering the first grade finish high school. In 1958, there was about one doctor for each 2,000 people (20, p. 3).

The steepness of the mountain ridges has forced nearly all intensive agricultural and urban development into the only level land, the flood plains adjacent to the rivers. Most of the existing commercial and industrial development is in the flood plain and is subject to severe and frequent flooding. While the local people have learned to adjust to this problem, the absence of level flood free land is a major deterrent to new economic development. As a result, potential flood benefits, both from reducing direct damages and from land enhancement, are very high. High unemployment rates and low income levels also provide a large potential for local secondary and income redistribution (23) benefits.

However, the concentration of population and transportation

arteries in the valleys also causes a very high cost for reservoir storage. Major railway and highway routes would have to be relocated. The large number of people living along the river would be forced to move at a high social cost (11). Many potential reservoir sites contain large underground coal reserves. Thus the cost of reservoir storage is also very high.

The size of the river and the high cost of right-of-way along its banks also make channel improvement very costly. Land use control is not effective in preventing existing damage to a community of decreasing population. Flood proofing, however, is already employed informally and could potentially effect substantially more flood damage reduction.

Agriculture within the flood plain has also adjusted to the flood threat. Farm houses are most often found on the outer edge of the flat area on higher ground in poorer soil. The higher valued crops are grown at lower elevations on better soil but high enough to be free of frequent flooding. Much of the best soil is in areas of highest flood hazard and is inundated too frequently to realize its full agricultural potential.

#### THE DATA COLLECTION PROCESS

A complete set of input data for both University of Kentucky Flood Control Planning Programs was developed for the North Fork of

the Kentucky River Flood Plain and the Carr Fork Reservoir site.

The data for Program II is listed in Appendix C and that for Program III is listed in Appendix D. Description of the data compilation will be handled by presenting each input variable in the order it is read. Discussion of each variable will include the physical significance of the variable, how numerical values may be obtained, and how the values read are used by the computer programs.

#### PROGRAM CONTROL PARAMETERS

Each flood hazard area has its own peculiar characteristics. For this reason, the Programs were made flexible so that a wide variety of situations could be handled without changing the programming (Chapter III). The program control parameters help provide this flexibility by specifying the inclusion or exclusion of any of the damage abatement measures. They also control the amount of output printed according to the needs of the planner.

L1, B<sup>1</sup>: If this variable is read as integer 1 the damage attributable to the uncertainty of flood occurrence is calculated by eq. 2 and

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<sup>1</sup>Notation: "2" indicates variable is used in Program II (Appendix C).  
"3" indicates variable is used in Program III (Appendix D).  
"B" indicates variable is used in both Program II and Program III (Both Appendices).

added to the average annual flood damage. If the input data for L1 is integer 0, uncertainty damages are ignored.

L2, B: If this variable is read as integer 1, the Programs evaluate flood proofing. If the value is read as integer 0, flood proofing is not considered.

L3, B: If this variable is read as integer 1, the Programs evaluate land use measures. An integer 0 value causes the Programs to omit land use measures from the analysis.

L4, B: If this variable is read as integer 1, the Programs consider channel improvement in the overall flood damage abatement plan. An integer 0 value eliminates channel improvement from consideration.

L5, B: The analysis of the optimum flood control program for each subwatershed-stage considers up to ten alternative levels of protection against floods by each individual structural and nonstructural measure and also examines various combinations of these measures. If the user assigns integer 1 to this variable, the Programs state which measures are being considered each time a new combination of channel improvement (S), flood proofing (P), and land use adjustment (L) is tried in the subwatershed-stage. The results provide some idea as to the value of each of the three measures because

measures that are almost justified will be tried at many alternative levels in the hope some level will be accepted while measures whose cost is way out of line will be dismissed after the first trial.

L6, B: The Programs analyze a subwatershed-stage by first estimating the annual flood damage if no measures at all are implemented and then trying various measure combinations in a search for the least expensive. This option causes the Programs to print each new combination of measures having a smaller total cost than any group of measures tried previously in the subwatershed-stage. An example of this output is shown in Chapter V. Reading an integer 0 will cause only the finally selected optimum consideration to be printed.

L7, B: If the user desires the Programs to consider purchasing right-of-way for channel construction in stages before it is actually required, he should assign an integer 1 to this variable. The Programs determine and write out whether or not the extra land should be obtained and if so, the optimum number of acres to be acquired and the number of years the land should be held if it is not subsequently used. An integer 0 value assigned to L7 eliminates consideration of holding extra right-of-way from the analysis.

L8, 3: The major difference between Planning Programs II and III is that Program III considers reservoir storage as one flood control

alternative. If L8 is read integer 1, the Program will print a number of additional structural details describing each dam analyzed.

Tables summarizing these details are shown in Chapter V. An integer 0 value instructs the Program not to write this information.

L9, 3: When Program III is determining reservoir feasibility, the procedure is to first route a series of flood hydrographs defined by frequency through the downstream subwatersheds. Then the floods are routed through the reservoir, and the less severe outflow hydrograph is then routed through the downstream subwatersheds. The difference between the cost of the optimum combination of downstream measures associated with the natural floods and that with the floods as reduced by the reservoir storage is the benefit attributable to the dam and reservoir. An integer 1 value assigned to L9 causes the Program to print hydrograph formulation parameters, reservoir routing details, and downstream flood hydrographs as shown in Chapter V. If an integer 0 is supplied, these details are not included in the output.

L10, 3: Inspection of the listings of Program III (38) will reveal that it is comprised of a "main" or central control program and several subroutines. Each subroutine has a specific function and may be called to perform that function many times. If the user feels that it would be helpful in reviewing the output to be able to



determine where each subroutine was called, he should assign an integer 1 to this variable. The Program will then print a statement each time execution passes from one subroutine to another telling which subroutine is involved and whether it is being entered or left. An example can be seen in Chapter V. If L10 is made integer 0, subroutine entry and exit is not included in the output.

L11, 3: Even though Program III is designed to consider construction of a dam and reservoir, the user may want a run where the downstream flood situation is evaluated without any upstream storage effects. Such output is obtained by assigning an integer 0 to L11. The Program will then determine the optimum combination of measures specified by Program control parameters L2, L3, and L4 for each subwatershed stage. If integer 1 is supplied for L11, a flood control reservoir will be considered in the analysis.

NSTEMX, B: To the variable NSTEMX, the user assigns the number of planning stages to be used. The Program determines the optimum mix of measures to be implemented at the present and at the beginning of each subsequent stage. The Program uses NSTEMX primarily as a loop index to determine how much input data should be read and how many times the Program should proceed through the stage analysis loop. The Program can handle as many as five planning stages.

MW, B: For MW, the user supplies the number of subwatersheds into which he has divided the flood plain. The Programs use the value to determine how many times to go through the subwatershed flood measure optimization computations. Each subwatershed must be assigned a higher number than any subwatershed upstream from it. Subwatershed 1 for Program III is the area tributary to the reservoir site.

#### PHYSICAL CHARACTERISTICS OF DRAINAGE AREA AND CHANNELS

Each drainage basin has its own unique physical configuration of subwatersheds of varying sizes, shapes, and arrangement. Particularly important, due to their effect on the flood hydrology, are the size and shape of the drainage areas and the length, arrangement, and state of improvement of the channels.

AW(MW)<sup>1</sup>, B: The analysis of flood hydrology requires subdividing the total flood plain into reasonably homogeneous segments. The drainage area in square miles contributing to the flood peak to be estimated from the subscripted subwatershed area is read into this array. In Program II, all tributary upstream area is included because each flood peak by frequency is developed without routing.

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<sup>1</sup> Value(s) in parentheses is(are) variable dimensions. Variable names not followed by parentheses are single-value variables.

In Program III, only the tributary area added between the upstream and the downstream end of the subwatershed is included because the added area is needed to develop the local inflow hydrograph to add to the main line hydrograph routed downstream through the subwatershed. Drainage areas are measured from watershed boundaries plotted on topographic maps. The areas are used in Program II for estimating flood peaks and in Program III for estimating flood peaks, flood volumes, and the time to flood peak; all intermediate steps in developing the flood hydrograph.

INDEX (2,MW), 2: Program II is designed to handle complex channel arrangements having flood plains on two or more confluent branches. The arrangement applying to a particular study area must be read by the program. This array acts as an "index" to the upcoming array ID. The first row of values in INDEX gives the first and the second row gives the last locations in array ID containing numbers of the subwatersheds that are located downstream from the subwatershed specified by the column. Array ID should first be developed from the subwatershed arrangement. INDEX values can then be determined by noting which values in ID apply to each subwatershed. Zeroes are used for the most downstream subwatershed to indicate that there are no subwatersheds further downstream.

NID, 2: This variable specifies the number of elements in array ID. The program uses NID to determine the number of ID values to read.

ID(NID), 2: Into this array is read the identifying numbers of all the subwatersheds downstream from each of the MW subwatersheds.

There is no data for the last subwatershed because no subwatersheds are further downstream. The program uses these values to determine which downstream subwatersheds are hydrologically affected by channel improvement in an upstream watershed as the first step in estimating the cost of contending with the resulting increase in flood peaks.

LC(MW), B: Each subwatershed contains watercourses through which the flood flows travel and which can be improved to reduce flood damages. In Program II, the length of channel within the subwatershed along which channel improvement is to be considered is read into this array. In Program III, no channel improvement is considered upstream from the reservoir site and only channel improvement on the mainline stream is considered downstream. Thus in Program III, the data read is the length of the mainline stream through the subwatershed. In both cases, the length should be measured along the route any channel improvement would be expected to follow, thus eliminating major meanders. Lengths in miles may be measured once

the channel alignments have been plotted on a project map. In both programs, this array is used to estimate the length of channel and thus indirectly the cost of channel improvement.

TCL(MW), B: Upstream channel improvement increases downstream flood peaks by creating a more rapid concentration of flows. The Programs estimate the magnitude of this effect from the fraction of the tributary channels which are improved. For any given subwatershed, the fraction equals the length of tributary improved channels divided by the length of all tributary channels. This array provides the stream length in miles for the denominator of the fraction for the subscripted subwatershed. In Program II, all upstream channels are included. In Program III, only channels within the area tributary to the mainline stream between the upstream and downstream end of the subscripted subwatershed are needed to develop the local inflow hydrograph.

All channels draining a tributary area greater than one square mile were counted in evaluating the fraction. A piece of paper having an area of one square mile to the scale of the topographic map was cut and used as a standard for estimating the point where channel tributary area reached this size. A map measurer was then used to determine downstream channel lengths.

The channelization fractions calculated using the data in this array are used in both programs for estimating the channel induced increase in flood peaks and in Program III for also estimating the increase in flood volumes and the reduction in time to peak.

SIC(MW), B: In some cases channel improvement will have been completed prior to the beginning of the period of analysis within the computer program. The data read into this array provide the length in miles of array LC(MW) which has already been improved. Normally the value will either be zero or equal to LC(MW) but may be some intermediate value if subwatershed boundaries were not placed at breaks between improved and natural channels. The existence and limits of channel improvement can be determined by field inspection, and detailed plans can usually be obtained from the constructing agency. The program increases the values in SIC(MW) as new channel improvement is found economical in one stage before proceeding to analyze a subsequent stage. Values of SIC(MW) are used in estimating the channelization fraction for hydrologic analysis as well as in determining whether right-of-way has already been purchased.

TIC(MW), 2: TIC represents the cumulative improved channel lengths, or the total length of improved channels tributary to the

downstream end of each subwatershed at the beginning of the first planning stage. The values are obtained by summing the improved channel lengths upstream from the successive subwatersheds. The program divides cumulative improved channel length by cumulative total channel length to arrive at a value for channelization of the total tributary area.

CTOTR(NW-1,NSTEMX), 3: The channelization fraction for Program III depends not only on mainstream channelization but also on channel improvement on the tributary streams. The program has already read the length of any initial mainline channel improvements (SIC). So that the program can know the overall degree of channelization for establishing local inflow hydrographs, it also needs the lengths of improvements by stage within the subscribed subwatershed but not on the main stream. The lengths of existing improved channels may be determined by field inspection of the watershed and read into the first column of the array. The lengths of expected future channel improvements should be determined by economic analysis of the flood hazard in the tributary area. Application of Program II to the area is recommended for this purpose.

#### HYDROLOGY

The magnitude of a flood peak of specified frequency expected

within a particular watershed depends on the precipitation patterns experienced, the interaction of the precipitation with the watershed surface, and the speed with which the runoff is able to flow downstream. Flood control measures have relatively little effect on precipitation, but urban development increases runoff and channel improvement accelerates flow concentration. A comprehensive flood planning program must incorporate changes in flood peak with time, caused by urbanization, into its dynamic analysis and consider the effects of upstream channel improvement on downstream flood damage.

The analysis begins with the flood peak, flood volume, and time to peak expected from a one square mile watershed containing no urban development or channel improvements and experiencing (1) a mean annual flood and (2) a 200-year flood. Use of this single set of five base values (time to peak is assumed independent of frequency) implies relatively homogeneous basin shape, soil cover, and soil conditions for basins of a given size within the study area. Where such conditions are known to vary drastically, the Programs should be individually applied to the separate hydrologic regimes. Correction arrays are provided to adjust the five basic values according to drainage area, urban development in the tributary area, and improvement of tributary channels.

The development of the hydrologic data has been based on use



of the Stanford Watershed Model (3) to study the hydrologic effects of urbanization and channelization in different locales (4). Although a lot of work goes into deriving the urbanization and channelization arrays, they can be used verbatim over a wide area having similar climatic patterns.

Flood Peaks: The maximum water surface elevation and thus the maximum depth of flooding and area inundated occurs at the flood peak. In Program II, flood peak is calculated directly as a function of frequency, drainage area, urbanization, and channelization, thus the balance of the data described in this section is not needed. In Program III, flood peaks are one item of data required to develop a local flood hydrograph for combining and routing downstream to determine the main line flood peak. The Programs assume the peaks follow a Gumbel extreme value distribution to interpolate peaks for flood frequencies for which values are not directly calculated. The mean annual and 200-year flood peaks are always directly calculated, and the flood peak for the reservoir design frequency is also calculated where it is not one of the above two values.

QB43, B: This variable provides the basic flood peak for the mean annual flood from a one-square-mile area containing no urbanization or channelization. It is corrected to the mean annual flood peak for

a watershed of known area, urbanization, and channelization by multiplying by the product of the drainage area, an urbanization and channelization factor interpolated from array Q43, and an area factor interpolated from array AFCTR.

The value of QB43 should be developed from a regional plot of mean annual flood peak against drainage area based on available streamflow records. The ordinate of the curve at 1.0 square mile is QB43. McCabe (19, p. 10, Fig. 1) has developed relationships between mean annual flood peak and drainage area for various regions of Kentucky. The study area falls in Region 2 (19, p. 21). Assuming that Curve 2 on Fig. 1 represents an area having zero channelization and urbanization, which is very nearly the case, a value for QB43 of 177 cfs is read at a drainage area of one square mile.

QB05, B: QB05 is the flood peak discharge from one square mile with no urbanization or channelization for the 200-year flood frequency. It may be read from a regional plot of 200-year flood peak versus drainage area or obtained by adjusting QB43 by an appropriate ratio (18, p. 264). McCabe does not plot discharge against drainage area for this frequency but does for the 25- and 50-year return periods (19, p. 29), Fig. 13). These two curves provided the 25- and 50-year flood peaks from one square mile. Since flood peaks are assumed within the Programs to follow a

Gumbel distribution, the 25- and 50-year peak discharges were plotted against frequency on Gumbel probability paper. The line was extended and a peak discharge for the 200-year return period (QB05) of 550 cfs was read.

Q43(11,11), B: The ratios of mean annual flood peaks from a given drainage area for various degrees of urbanization and channelization to the flood peaks from the same area with no urbanization or channelization are read into this array. One ratio is required for each combination of urbanization and channelization fractions ranging from 0.0 to 1.0 in increments of one tenth. The program uses double interpolation to establish the proper multiple of QB43 to correct for urbanization and channel improvement. Dempsey (4) developed the array used for analyzing the Hazard flood plain based on the relationship between urbanization and channelization and input parameters to the Stanford Watershed Model determined from historical runoff trends in an urbanizing area just south of Louisville.

Q05(11,11), B: Array Q05 is analogous to array Q43, but it applies to the 200-year instead of the mean annual flood. Generally speaking, multiples are smaller for larger floods where moisture losses are a relatively smaller fraction of total rainfall. Dempsey's analysis for Louisville also established these values.

AFCTR(3,11), B: The flood peaks are corrected for the variation of the actual drainage area from one square mile by multiplication by two quantities. The first is the drainage area in square miles; the second is AFCTR.

The peak discharge from a 100-square-mile drainage area is less than 100 times the discharge from a one-square-mile area. In other words, the larger the drainage area, the less the flow generated per square mile (measured in cubic feet per second per square mile, or csm). AFCTR values are the ratios of csm from a given drainage area to csm from one square mile. AFCTR is a three by eleven array. The first row contains eleven drainage areas, the second row contains the csm ratios for the mean annual flood for the drainage area in the corresponding column, and the third row contains the same ratio for the 200-year flood.

The data contained in the AFCTR array should essentially describe the curve of flood peak in csm versus drainage area characteristic of the drainage basin under analysis. A curve plotting as a straight line on semilog paper (logarithm scale on the area axis) can be adequately described by two points. A curved line can be represented by as many as eleven points taken at breaks or changes in direction of curvature.

McCabe's curves for the region containing the upper reaches

of the Kentucky River plot as a straight line on semilog paper and thus can be defined by two points. The second set of values is repeated nine times in Program III to fill the array dimension requirement. A third set of values to provide for larger drainage areas was used in Program II.

The first of the AFCTR sets selected is for a drainage area of one square mile, both the mean annual and the 200-year ratio being 1.0. The second point should represent an area larger than the largest subwatershed being analyzed so that the program can interpolate between the two points. For the 400 square miles selected for the Kentucky River study, the mean annual discharge is 15,800 cfs (19, p. 10, Fig. 1). From each square mile the flow is  $15,800/400 = 39.50$  csm. The mean annual flow from one square mile (QB43) is 177 cfs. Hence the mean annual AFCTR ratio is  $39.50/177 = 0.223$ . Since McCabe gives no information for the 200-year flood, the 50-year value was computed by the same procedure as was used for the mean annual ratio, the csm value being  $38,500 \text{ cfs}/400 \text{ square miles} = 96.25$ , and the AFCTR ratio being  $96.25/437 = 0.220$ . Since previous studies (13, p. 77) have shown the factor for the 50-year flood to nearly equal that for the 200-year flood, 0.220 was used for the 200-year AFCTR.

Flood Volumes: Because a complete hydrograph rather than a flood

peak alone is needed for "with and without" routing to determine the effectiveness of reservoir storage, Program III contains a subroutine which generates hydrographs from flood peaks, flood volumes, times to flood peak, and typical hydrograph shapes (38, Subroutine RSHYDR). The data used to estimate an appropriate flood volume for a particular drainage area are analogous in format and physical significance to the flood peak data. Program III uses the data to evaluate an appropriate flood volume for any desired combination of frequency, drainage area, urbanization, and channelization.

VB43, 3: The volume of the mean annual flood from one square mile is defined as the average flow during the peak TBW hours of the flood hydrograph, roughly for a simple hydrograph, the time from when the flow begins to rise until it drops to about 10 percent of the peak.

VB43 may be determined by reading the value for 1.0 square mile on a curve of flood volume plotted against drainage area. Dempsey describes how such a plot can be estimated from a long-term record of recorded or synthesized flood hydrographs (4). For the Kentucky River study, a more approximate value was developed from the ratio of VB43 to QB43 found by Dempsey (4) and Villines (38).

VB05, 3: The volume of the 200-year flood from one square mile is also defined as the average flow during the peak TBW hours of

the flood hydrograph. The method of evaluation parallels that for VB43.

V43(11,11), 3: This urbanization-channelization correction array for mean annual flood volumes was developed, and is described in detail, by Dempsey (4).

V05(11,11), 3: The 200-year flood volume correction array for urbanization and channelization was also developed and described by Dempsey (4).

AFCTRV(2,11), 3: The data in this array is used to correct average flood flows estimated for one-square-mile drainage areas to drainage areas of larger size in a manner analogous to that described for flood peaks in presenting AFCTR. The first row contains factors for the mean annual flood, and the second row contains factors for the 200-year flood. Both rows correspond to the drainage areas read into the first of the three rows of AFCTR.

The values in the array may be based on the curves of mean annual flood volume and 200-year flood volume versus drainage area used to determine VB43 and VB05 respectively.

Flood Peak Timing: Program III develops the flood hydrograph at the mouth of each mainline channel reach by combining the hydrograph

being routed down the channel with the local inflow hydrograph (the hydrograph of the flow contributed by the local subwatershed). The way the two combine depends on their relative timing. The program assumes runoff from a storm of given frequency to begin simultaneously over the entire watershed.

Calculation of a time to peak for a given watershed is based on the same basic procedure of applying correction factors to a time for a one square mile watershed containing neither urbanization nor channelization as used for flood volumes and flood peaks. Flood peak timing was found by Dempsey not to be appreciably affected by urbanization. It does, however, vary significantly with channelization and drainage area.

TPB, 3: The basic parameter of flood peak timing is the number of hours into the flood hydrograph from one square mile with no channelization at which the flood peak occurs. It is best determined from a plot of drainage area versus time to peak developed by analyzing regional hydrographs. The value used for the Hazard study has been developed and is presented by Dempsey (4). The program multiplies TPB by factors from the two arrays which follow to determine the time to peak of the hydrograph from a given drainage area having a given fraction of its channel lengths improved.



TP(11), 3: The increase in streamflow velocity caused by channelization causes the flood hydrograph to reach its peak earlier. The more channel improvement, the shorter will be the time to peak. This eleven-element array contains the ratios of time to peak with various degrees of channelization, ranging in tenths from 0.0 to 1.0, to the time to peak with no channel improvement. Again, the values were developed from studies based on the Stanford Watershed Model by Dempsey (4). The TP value corresponding to the existing channelization is interpolated from the array and multiplied by TPB.

AFCTRT(11), 3: This array is analogous to AFCTR (for peaks) and AFCTRV (for volumes) in that it corrects for the deviation of the drainage area from one square mile; but in this case, the Program estimates the time to peak by multiplying AFCTRT directly by TPB instead of including drainage area in the product. Each point is still based on the areas contained in the first row of AFCTR. Each point may be read from the curve of time to peak versus drainage area used to determine TPB. The curve should reflect the decrease in slope as one proceeds downstream through the drainage basin. The relationships developed by Dempsey and Villines were used in this study.

Hydrograph Shape: Program derived flood hydrographs may take on

many different shapes. A small, urbanized and channelized area would be expected to produce a sharp, short duration hydrograph. A large, rural watershed with poor channels would produce a very flat (low peak, long duration) hydrograph. Between these extremes are an infinite number of possible shapes.

HYDINT, 3: A hydrograph is a curve obtained by plotting streamflow against time. The curve is specified within the computer analysis by a series of flows separated by a time interval of HYDINT hours. For convenience in combining main channel and local inflow hydrographs, the horizontal spacing, or the time interval between points on the hydrograph, is held constant for all subwatersheds. The value of HYDINT (two hours was selected for the Carr Fork site) should be such that the fifty element hydrographs developed by Program III describe reasonably completely the rising and receding limbs.

HYDBAS(21,5), 3: The user of Planning Program III supplies five alternative simple hydrograph shapes, and the program selects and uses the shape appropriate for a particular combination of flood peak and flood volume. The five hydrograph shapes are given as flows at each five-percent of the total hydrograph base time, the discharge being expressed as a multiple of the peak

discharge. The twenty-first array element gives the ratio of average flow to peak flow for that particular shape. The Program calculates the ratio derived for the subwatershed at hand and interpolates hydrograph elements between the bounding pair of ratios in HYDBAS. The five shapes, called "sharper, sharp, average, flat, and flatter," were developed by Dempsey (4).

#### FLOOD DAMAGES

The Programs try various levels of design and various combinations of measures and calculate expected annual flood damages residual to each combination in seeking the minimum sum of measure cost and residual flood damages. The parameters in this section provide the data necessary for estimating the area inundated to various depths by a given flood peak and the amount of flood damage to be expected when each flood peak occurs.

Depth-Area-Discharge: The Programs estimate the area and depth of flooding caused by a given discharge by interpolation between two known sets of depth-area-discharge data. The first set is zero depth and area of flooding for a flood peak equalling the existing channel capacity. The second set is the data read into the three variables described in this section and obtained for some flood of record. Normally, the largest historical flood for which

reliable information on flood peak, depth of flooding, and area flooded can be obtained should be used so the interpolation range bounds as many flood peaks as possible. The Programs can extrapolate data for larger floods, but some accuracy is lost.

The interpolation is based on the assumption that the area and depth of flooding is determined by the flow in excess of channel capacity and that the flood plain can be represented by two uniform cross slopes toward the channel (13, pp. 80-85).

Q0(MW), 2; Q0(MW-1), 3: Flood damage is caused by flows in excess of the channel capacity. The planner must supply, through array Q0, values for the existing capacity of each subwatershed channel. Where the channel within a subwatershed varies substantially in capacity along its length, the minimum capacity or the flow at which water first leaves the channel should be used.

Channel capacities may be most accurately determined by taking periodic cross sections and running a backwater profile. As a more approximate method, profile sheets for the Kentucky River and Carr Fork channels, showing the stream bottom, low bank, and high water profiles for selected floods (including the 1957 flood) were obtained from the Corps of Engineers. However, the low bank line was modified due to the absence of damageable property in the extremely low-lying bottom land. From "Surface

Water Records of Kentucky" for 1964 and 1965 (35), stream discharges and the corresponding stages at the stream gage near the Carr Fork dam site were used to plot a stage-discharge curve. Taking the smallest vertical distance from the stream bottom to the revised low bank in each subwatershed as the stage corresponding to the channel capacity for that subwatershed,  $Q_0$  values for Carr Fork were read from the stage-discharge curve.

The largest flood recorded by the Hazard stream gage occurred in 1957 when the stage ( $Z_{57}$ ) was 37.54 feet and the corresponding discharge ( $Q_{57}$ ) was 47,800 cfs (35). Stage ( $Z$ ) and discharge ( $Q$ ) values for smaller floods (36, p. 339) were used to plot  $Z/Z_{57}$  against  $Q/Q_{57}$ . Taking  $Z$  for each subwatershed from the Kentucky River profiles as the minimum height of the revised low bank above the stream bottom, and taking  $Z_{57}$  as the 1957 high water stage at the same point, a  $Z/Z_{57}$  value was calculated for each subwatershed on the Kentucky River. The corresponding  $Q/Q_{57}$  value was read from the plot and multiplied by  $Q_{57}$  to yield the channel capacity ( $Q_0$ ) for each subwatershed channel.  $Q_{57}$  for each subwatershed was estimated from the relationship between flood peak and drainage area (see QK12).

The Program subtracts the  $Q_0$  value from each flood peak to determine flow excess responsible for flood damages. The Programs

internally increase Q0 to correspond to planned channel improvements.

QK12(MW), 2; QK12(MW-1), 3: The user, through this variable, relates to the Programs the peak discharge in each subwatershed for a known flood event. The 1957 flood was selected for our analysis as the largest historical flood for which a high-water profile was available for estimating depth and area of flooding. McCabe (19, p. 23) gives the peak 1957 discharge for three stream gaging stations (Whitesburg, Hazard, and Jackson) along the North Fork of the Kentucky River. The drainage area tributary to each of these gages was determined (35), and a plot was made of the 1957 flood peak as a function of contributing drainage area. A QK12 value for each subwatershed was then read from the plot corresponding to the area tributary to the downstream end of the subwatershed.

AK12(MW), 2; AK12(MW-1), 3: The AK12 values represent the area inundated by the selected flood event, in this case the 1957 flood. The high water profiles for the 1957 flood were used to plot the area flooded on topographic maps. AK12 values were obtained by measuring from the map the flooded area outside the stream banks outlined within each subwatershed. The Program uses AK12 along with QK12 to correlate flood discharges with the corresponding area flooded.

DK12(MW), 2; DK12(MW-1), 3: The third group of subwatershed values for the known historical flood contains the maximum depth of flooding in each subwatershed. The maximum overbank depth is desired, so the values are obtained by scaling, within each subwatershed, the largest vertical distance from the revised low bank up to the 1957 flood profile. The Program, using corresponding values of QK12 and DK12, can approximate subwatershed flood depth from the flood discharge.

Urban: The expected value of flood damages are separately estimated for urban and agricultural property. Damage to urban structures flooded to a given depth depends on the susceptibility of the property to damage as roughly indexed by its value and by the fraction of the total value that is destroyed as a function of the depth of flooding.

VLURST, B: This variable represents the average value of urban structures in the urban fraction of the flood plain expressed in dollars per acre. The Programs multiply it by the urban area inundated to estimate the total value of the urban structures flooded.

As an arbitrary rule, any structure located on a parcel smaller than two acres was considered urban. From a random sample of 39 properties supplied by the Knott, Letcher, Perry,

and Breathitt County tax assessors, structures having a total value of \$882,850 were found to occupy 23.86 acres. Division gave a value for VLURST of \$37,000 per acre.

COEFDM, B: Flood damage to urban structures increases with the value of the buildings and with the depth of flooding. The user supplies here the unit damage per foot of flood depth per dollar of building market value ( $C_f$  in Eq. 1). The value of 0.052 was derived by James (13, pp. 85-88) as the sum of direct and indirect damage for composite residential, commercial, and industrial urbanization. The damage used assumes no flood proofing as this alternative is one of the program decision variables. The coefficient used assumes moderate to low flow velocity, flood duration, and flow sediment content and should be raised for more adverse conditions.

The Program multiplies the total value of urban structures flooded by COEFDM and by the average depth of flooding to estimate the damage to urban structures inflicted by shallow floods. A curved depth-damage relationship is used in Subroutines CD1 and CD2 to estimate damages from deeper floods. The sensitivity of planning decisions to COEFDM has been studied and presented by James (14).

Agricultural: Flood damages to crops and farm structures are termed



agricultural damages. The crop damage depends on the types of crops grown within the flood plain as determined in part by the agricultural productivity of the soil. The Programs thus provide separate crop damage estimates for up to three soil classifications. Farm structure damage is calculated in the same manner used for urban structure damage except that the structural market value per acre of land would naturally be much lower than that found in urban areas.

D(MW,3), 2; D(MW-1,3), 3: Different soil types have different agricultural productivities and are suited for growing different crops. These arrays provide the fraction of each subwatershed flood plain that is in each of up to three soil types. The soil maps of Knott, Letcher, Perry, and Breathitt Counties (20) indicate the three major soil associations in the flood plains to be: (1) Pope-Stendal-Allegheny (most productive), (2) Jefferson-Muskingum-Holston-Dekalb (intermediate), and (3) Dekalb-Muskingum-Berkes (least productive). In each subwatershed, the length of main channel abutted by each soil association was measured and divided by the total subwatershed main channel length to arrive at the fraction of the subwatershed flood plain in each soil type.

The Program determines the crop damage per acre to each soil type when flooded, multiplies these values by the fraction of the subwatershed flood plain in each respective soil type, sums these

products and multiplies by the area in farmland to determine the subwatershed crop damage.

CDA, B: The fixed crop damage is caused by the fact of flooding. This damage is due to elimination of soil, air and sediment erosion and deposition. As the depth of flooding increases, so does the damage because more of the plant is submerged for a longer duration by greater velocity flows. This is the variable damage. CDA represents the fixed damage in dollars per acre that is inflicted on crops in the most productive soil by a flood of minimal depth. The variable CDAV represents the additional damage per foot of flood depth.

Crop damage has two aspects. A certain cropping pattern exists within the flood plain under flood hazard conditions prevailing without the project. CDA is the fixed damage, and CDAV is the variable damage to this cropping pattern. If the flood hazard is reduced, the cropping pattern may shift to higher valued crops. Where such a shift can be reasonably expected, the resulting increase in farm income (often called a land enhancement benefit) may be added to CDA.

Since the agricultural data needed to determine crop pattern by soil type is published by county, and the majority of the study

area flood plain lies in Perry County, this, as well as the next five crop damage values, were based on Perry County data as being most representative of flood-plain cropping patterns.

By summing AK12 values within Perry County, 2,296 acres were found in the flood plain under analysis. Because the steep mountain relief forces all significant commercial agriculture into the flat lands along the streams, the total available farm land in Perry County was estimated from the ratio of the total length of Perry County channels to the study area flood plain channel lengths to give 6,165 acres as the approximate area of the flood plain in the county. From urbanization data to be described later, it was found that 85.8 percent of these 6,615 acres, or 5,280 acres, were not in urban use. From the 1964 U. S. Census of Agriculture (32), the most important crops in Perry County, the number of acres dedicated to each crop, and the corresponding percentage of the total non-urban area are as shown on Table 1.

TABLE 1  
AGRICULTURAL LAND USE IN PERRY COUNTY

Crop	Acres	Percent of Total Agricultural Land
Corn	700	13.3
Hay	260	4.9
Fruit	280	5.3
Vegetables	100	1.0
Tobacco	40	0.8
Pasture	1000	18.9

The help of those familiar with local farming practice was used in estimating the suitability of each of the three soil types to growing each crop. This information was then combined with that on Table 1 to develop a composite crop acre by soil type. The Soil Conservation Service provided approximate crop yields and prices applicable to the Hazard area as well as a group of tables (Table 2 is an example) giving the fraction of the total crop value destroyed by flooding as determined by depth of flooding, crop yield, and the month during which flooding occurred. It was assumed that the damage for a depth range of "0' - 2'" applied at 1 foot and that the value given for "over 2'" applied at 3 feet. Information on the relative flood threat by month of the year was developed from benefit by month values developed by Dowell for Central Kentucky and expressed on a fractional basis in Table 3 (6, p. 58, Table 12). A crop damage value in dollars per acre for the given month, flood depth, crop, and soil type is evaluated as the product of the damage fraction (Table 2), flood threat probability (Table 3), crop yield per acre (county farm records), and crop price. For example, for corn in "A" soil, flooded to a depth of one foot in June, the values are:

$$\begin{aligned}
 \text{CDA1} &= 0.30 \times 0.052 \times 60 \text{ bushels/acre} \\
 \text{(corn, June)} & \\
 \times \$1.11/\text{bushel} &= \$1.03/\text{acre}.
 \end{aligned}
 \tag{6}$$

This is repeated for each month, the summation being  $\text{CDA1}_{(\text{corn})}$ .

TABLE 2

## PERCENT OF TOTAL CROP VALUE DESTROYED BY FLOODING

Crop and Depth of Flooding	Yield	April	May	June	July	Aug.	Sept.	Oct.	Nov.
<u>Corn</u>									
					<u>Percent</u>				
0-2'	50 bu.	2	10	30	20	8	2	2	
	75 bu.	1	7	29	21	8	3	2	
	100 bu.	1	6	28	21	8	3	2	
Over 2'	50 bu.	2	12	44	52	24	16	13	2
	75 bu.	1	9	42	54	25	17	14	3
	100 bu.	1	8	41	56	26	18	14	3

TABLE 3

## RELATIVE FLOOD THREAT BY MONTH

Month	Relative Flood Threat	Month	Relative Flood Threat
January	0.1302	July	0.0136
February	0.1696	August	0.0109
March	0.1574	September	0.0461
April	0.1492	October	0.0002
May	0.1194	November	0.0488
June	0.0515	December	0.1031

Repeating the calculations for depths "greater than two feet" (hence three feet),  $CDA3_{(corn)}$  is developed. Values for  $CDA_{(corn)}$  and  $CDAV_{(corn)}$  are derived as shown in Fig. 3. Finally, the CDA value for each crop was multiplied by the fraction of the most productive soil devoted to that crop, and the products were summed to give the composite crop acre value for CDA. An analogous approach was used to obtain the composite crop acre value of CDAV.

The Program multiplies CDAV by the average flood depth, adds the product to CDA, and multiplies the sum by the product of the area flooded, the fraction of the subwatershed in type "A" soil, and the fraction of the available land farmed to arrive at the total crop

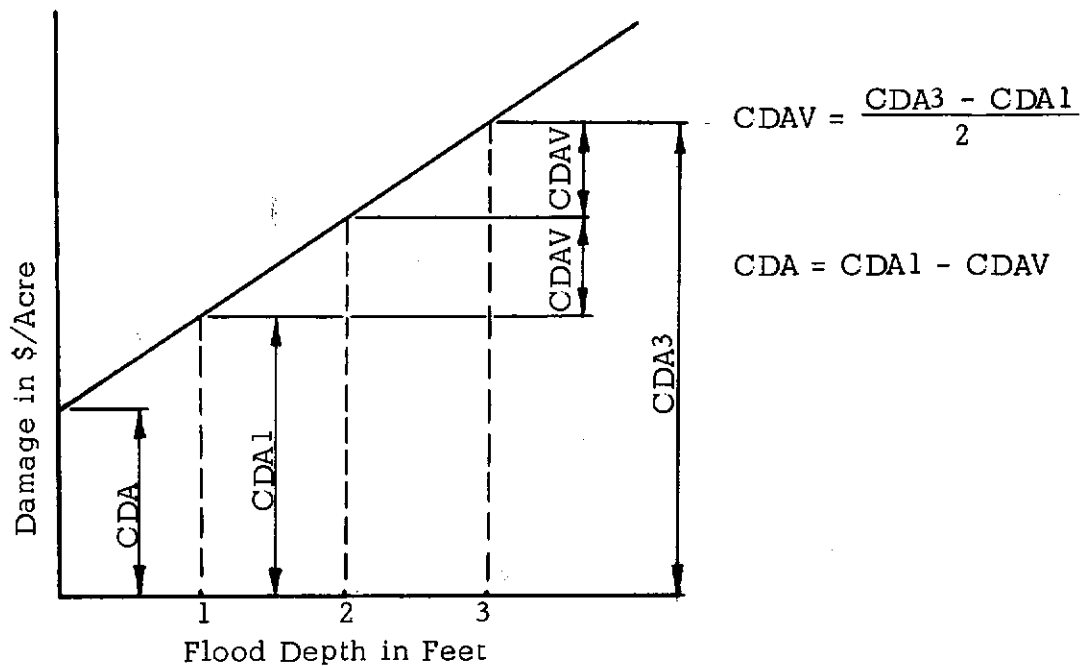


Figure 3. Variation of Crop Damage with Depth of Flooding

damage in the most productive soil type. For flood depths greater than about five feet, crop damage is assumed to have reached a near maximum value, and the variable damage is not increased further (38, CD1).

CDB, B: The significance, development, and Program use of this value are the same as those for CDA except that CDB refers to the intermediate, or "B" type, soil rather than the most productive soil.

Crop yields must be reduced in going to soils of lesser productivity. For the productivity variation between the two soil groups as defined for this study, the crop yields for "B" soil were taken as 80 percent of the "A" soil values. This yield change, in addition to its direct effect on the monthly crop damage values (Eq. 6), also changed the fraction of the crop value destroyed by flooding (Table 2).

CDC, B: The discussion of CDA can also be applied to CDC, keeping in mind that the "fixed" crop damage is for the least productive instead of the most productive soil. The crop yield was taken as 50 percent of that for the best soil for this study.

CDAV, B: The physical significance, numerical evaluation, and Program use of the incremental increase in crop damage per foot

of additional depth of flooding have already been discussed under CDA.

CDBV, B: The discussion of CDAV also applies to CDBV with the single modification of being associated with the intermediate rather than the most productive soil.

CDCV, B: This variable, too, is analogous to CDAV, the only difference being that it refers to the least productive soil.

FRU(11), B: As urban development expands into an agricultural area, an increasingly large percentage of the remaining open land is no longer farmed. James (13, pp. 207-208) developed the data used in this study to express, for each 10 percent urbanization interval from 0 to 100 percent, the ratio of the fraction of the available open land which is farmed to the fraction which would exist if there were no urbanization. The initial study was based on a detailed study of farm land use on the fringes of Sacramento, California. The data was not revised for this study because urbanization in the Hazard area is too minor to warrant a detailed study. The Program interpolates from this array an FRU value appropriate for the degree of urbanization and uses the resulting fraction as a multiplier for crop income and damages.



VLAGST, B: When farms are flooded, structures as well as crops are damaged. Damage to agricultural structures is calculated by the Program by using the same unit damage factor (COEFDM) and the same methodology (38, CD1) as for urban structural damage. The only difference is that a new average value of agricultural structures, in dollars per acre, is needed and is supplied through VLAGST.

The evaluation of VLAGST may be similar to that of VLURST. That is, the total value of structures in the flood plain on plots of land having an area in excess of two acres (from data supplied by county tax assessors) may be divided by the total area on which they are located to give the value desired. In developing the Carr Fork data a different approach was taken to avoid the necessity of distinguishing between urban and agricultural structures when urbanization was evaluated for USUBW. The total value of structures outside the Hazard subwatershed (\$393,850) was divided by the 78 such structures in the sample to get an average value of \$5,050 per structure. This value was then divided into VLURST (\$37,000/urban acre) to determine that 7.33 rural houses could be considered equivalent to one urban acre. In determining the degree of urbanization for subwatersheds outside Hazard, the total number of houses in the flood plain was divided by 7.33

to give the number of urban acres. Thus, since agricultural structures were included in determining urbanization, their damage is included with urban structure damage; and VLAGST was made zero.

Uncertainty: Because of financial, social, and psychological problems involved in suffering large, infrequent damages, most people would be willing to pay a fixed annual sum in excess of the expected mean annual damage they actually suffer. This excess is called uncertainty damage and is evaluated by the Program by use of the Thomas Uncertainty Fund.

VA, B: In calculating uncertainty by the Thomas Uncertainty Fund, a decision is made as to the chance (probability) one is willing to take that the hypothetical fund will be exhausted by several large floods. VA is the normal deviate having this probability of being exceeded. The normal deviate for various probabilities can be found from any normal distribution table. A positive value would usually be taken, but a negative value could be used for reflecting the point of view of the gambler willing to use the flood plain on the chance a flood will not occur while he is there. The value used in the Carr Fork data corresponds to a probability of 0.50 percent and is 2.575.

## GENERAL DESIGN VARIABLES

Most of the remaining input data is used to design and determine the cost of the alternative flood control measures. The variables presented in this section are used in evaluation of a number of the alternatives and thus cannot be assigned to any of the more specific headings to follow.

R, B: Anyone would prefer a dollar today to a dollar one year from now because of a time preference pattern that favors the present over the future. For this reason, determining the present worth of future benefits and costs requires discounting. R is the normative discount rate for use in project analysis. The literature abounds in discussion of selection of an appropriate discount rate, but a federal agency is required to use the rate currently paid on outstanding long-term U. S. government bonds, a rate of 0.03125 in 1967. One of the major advantages of being able to use the Programs is that alternative values of such controversial parameters can be used readily to determine the resulting policy effects. The Program uses the discount rate in all conversions among present, future, and average values involved in the planning process.

TIMST, B: The design life of structural measures represented by this variable name is used by the Program in distributing the initial

cost of structural measures over the design life to determine the annual cost. Fifty years is a commonly used value for structural design life.

TIME, B: The flood control Planning Programs determine the economically optimum dynamic plan based on separate evaluation by planning stage. The duration of one planning stage is represented by TIME. The duration selected should divide into TIMST an even number of times not greater than five. In the Kentucky River study, no significant change in flood plain conditions was predicted; therefore, one fifty-year stage was used to avoid repetition of identical calculations in each stage. If, for any other reason, multi-stage analysis is not desired TIME can be set equal to the total planning period, or TIMST. TIME is used by the Program in converting from present worth to average annual costs within a planning stage and is divided into TIMST to determine the number of stages to be analyzed.

MRDF, 3: The design frequencies considered by the Program are read into array DF beginning with the most frequent and ending with the rarest event to be considered in selecting the design yielding the maximum net benefit. The planner may not consider it acceptable to design a flood storage reservoir that can contain only a frequently occurring event such as the mean annual flood because of the extra

economic consequences associated with underdevelopment of a reservoir site and a false sense of security which may be given to those living downstream. Use of a rarer design storm might also make the difference between whether or not it is necessary to line the emergency spillway because of its more infrequent use. On the other hand, design of channel improvement and nonstructural measures against a lesser design flood may be acceptable, so low design frequencies are read into array DF. The user supplies for MRDF the location in the frequency array of the smallest flood for which reservoir storage is to be considered. In analyzing the possibility of reservoir detention for flood control, those frequencies to the left of that in location MRDF are ignored. MRDF was made 1 in the Carr Fork data; thus flood storage analysis began with the most frequent flood.

NDF, B: The number of flood frequencies to be considered in design of damage abatement measures is represented by NDF. Any desired value from one to ten may be used. The Program uses the value to know how many data values are to be read into the flood frequency array.

DF(NDF), B: In seeking the optimum flood control policy, the Programs consider different levels of protection by each measure.

The levels of protection to be considered are specified by the planner by supplying to this array the desired design frequencies. Any set of NDF frequencies of monotonically increasing rarity may be specified for Program II, but Program III requires that the most frequent flood used be the mean annual and that the rarest be the 200-year.

#### DESIGN DATA FOR SUBWATERSHED MEASURES

Flood damage reduction measures may be employed either upstream, as in the case of reservoir detention storage, or within the individual subwatersheds. Among the possible subwatershed measures are channel improvement, flood proofing, and land use measures. The data supplied in this section pertains to these measures.

Channel Improvement - Physical Factors: Since flood damage is caused by the flow in excess of channel capacity, channel improvement to increase capacity is an effective flood damage abatement measure. Channel improvement may involve enlarging the cross section, installing drop structures for grade stabilization, or lining. The Programs select the least expensive method by estimating the cost of alternative designs. The data contained in this section are used to develop design quantities and cost estimates for alternative channel improvement schemes.

A0(MW), 2; A0(MW-1), 3: In estimating the quantity of

excavation involved in channel enlargement within a subwatershed, the average initial channel cross sectional area for the subwatershed (represented by  $A_0$ ) is subtracted from the cross sectional area of the enlarged channel. The difference is multiplied by the length of the proposed enlargement to yield the excavation volume. The area needed is the average existing channel cross section area along the alignment selected for improvement. It will normally be zero where a new alignment is proposed and can be determined from channel cross sections at other locations.

The initial area for each subwatershed in our study was evaluated by measuring the channel top widths (the measurements being made across bridges), selecting a representative depth from the stream bottom to the low bank from the stream profiles, and by observing that the channel banks had approximately a 1:1 slope. The area was calculated as that of a trapezoid, whose long base, height and side slopes were known.

LINING(MW), 2; LINING(MW-1), 3: The Programs consider four alternative methods of channel improvement: a prismatic unlined section, a prismatic unlined section with drop structures to increase stability, a pneumatically placed concrete lining on a trapezoidal section, and a structurally reinforced concrete lining on a rectangular section. Unless instructed otherwise, the Program will

automatically select the least expensive of the four methods. The prismatic unlined section will be selected unless more expensive initial construction is justified to maintain channel stability or conserve expensive right-of-way.

However, in order to avoid the possibility of the Program selecting a method of channel improvement varying from one subwatershed to another, to signify a previously constructed type of channel improvement, or for other policy reasons, the planner may wish to specify the types of improvements he wants considered by the Program in each subwatershed. The numbers that may be used are as follows:

- "0" - All four types of improvement are considered, the type having the largest net benefit being implemented.
- "1" - This causes the Programs to consider only unlined prismatic channels, but drop structures may be required if they are needed as indicated by the channel design tractive force.
- "2" - This number causes the Programs to go directly to consideration of drop structures without first considering unlined prismatic sections where drop structures are known to be required or are already existing.



"3" - Construction of trapezoidal lined channels only is considered.

"4" - This considers only construction of rectangular lined channels.

FQ(MW), 2: As the stream flows through each subwatershed, local inflow causes the discharge to increase. Hence, the subwatershed outflow is greater than the flow at any other point in the reach.

The user can account for this effect by supplying, for each subwatershed, an FQ value expressing the average design flow for the channel reach as a fraction of the design flow at the downstream end of the reach. When Program II was tested downstream from Carr Fork, a conservative value of 1.0 was used for each subwatershed, thus designing the subwatershed measures for the outflow discharge. The Program develops the flood peak for the downstream end of each subwatershed, then multiplies by the appropriate FQ value to determine the average design flow for the subwatershed.

MANNU, B: The dimensions of the channel section required by a given design flow are determined by successive trial enlargement of cross section dimensions until sufficient capacity is available as estimated by Eq. 3 in which MANNU is the value of the roughness coefficient for unlined prismatic channels. Values for

various channel conditions can be found in most hydraulics text books or handbooks.

MANNT, B: This variable is the roughness coefficient that applies to trapezoidal lined channels and is smaller than MANNU since lined channels are smoother than unlined ones. A look at the Manning equation shows that lining increases channel capacity.

MANNR, B: MANNR is the roughness coefficient for rectangular lined channels and is normally still smaller than MANNT.

ZU, B: The cross section of improved, unlined channels is trapezoidal in shape. ZU represents the side slope expressed as the ratio of the horizontal to the vertical dimensions. The design value depends on the soil stability (17, pp. 205-208), 1.5 being the value for this study. The program uses the ZU value in determining the cross sectional area of a channel of given flow depth and bottom width.

ZT, B: Due to the increased stability of lined channel sides, the side slopes can be made steeper than unlined slopes. This effect combines with the lower hydraulic roughness to reduce the channel top width and hence the amount of right-of-way required. For ZT the planner supplies the channel side slope to be used in design of

trapezoidal lined channels. The value should be determined from soil slope stability and the practicality of placing lining on steep slopes.

S(MW), 2; S(MW-1), 3: In using the Manning equation, the slope of the hydraulic grade line through each subwatershed channel reach is required. This slope is very closely approximated by the average channel bed slope through the reach and is supplied for each flood plain subwatershed through this array. Values were obtained from the channel profiles by dividing the loss of channel bed elevation through the reach by the length of the subwatershed channel over which the drop took place.

TF(MW), 2; TF(MW-1), 3: As flood water rushes over the channel bed, a drag force known as the tractive force tends to scour away the bed material. For each trial unlined prismatic channel design, the Program compares the tractive force developed by the flow with the maximum tractive force the bed material can withstand without scour; this second value is supplied to the Program through this TF array. If the force is greater than the channel bed can withstand, it must be reduced by making the hydraulic grade line flatter than the natural channel slope by installing drop structures to concentrate elevation loss in local protected areas. These drop structures

are overflow weirs with concrete energy dissipators downstream to prevent the falling water from eating away the channel. The maximum allowable tractive force depends on soil properties with grain size being the determining factor for noncohesive soils and plastic index being the most widely used index for cohesive soils (2, 17:9).

The tractive force limitation is not a factor in the Hazard area because most channel beds are in solid rock. For this reason, an arbitrary very large TF value of 2.5 pounds per square foot was used for each subwatershed.

**BDMAX, B:** BDMAX represents the maximum ratio of bottom width to depth allowed in design of improved channels. Very wide shallow channels are undesirable because low flows will meander around the bottom. A maximum bottom width to depth ratio of 10.0 is commonly used in channel design. The program initially tries a minimum ratio (BDMIN) and calculates, based on the Manning equation, the depth of flow required to carry the design discharge. If this depth exceeds HMAX, a larger ratio is tried, and the process is repeated until the depth is acceptable. This repetition is constrained by the fact that the Program will not allow the ratio to exceed BDMAX even if the prescribed HMAX must be exceeded. However, none of the three factors were critical in the Kentucky River example because channel improvement was at no time found economical.

BDMIN, B: The minimum allowable ratio for bottom width to depth in channel design is represented by BDMIN. It is difficult for most construction equipment to excavate a channel of too narrow bottom width. It is the ratio at which the channel sizing calculations begin as described under BDMAX. A value commonly used in channel design is 4.0.

HMAX, B: This is the variable name for the maximum design channel depth allowed. The value was determined by inspection of the stream profiles. The design depth is limited to approximately the natural channel depth to avoid expensive excavation into the channel bed over the entire bottom width and to prevent adverse stream bed gradients at the downstream end of improved reaches. HMAX is used by the Program as explained under BDMAX above.

NIN, B: Drainage inlets must be provided to get local storm water into the improved channels. The number of these inlets required per mile of channel is represented by NIN. The value is determined by looking at a topographic map or the existing storm drainage system in urban areas and approximating the number of small streams or natural drainage ditches that must enter the channel, per mile. The Program multiplies NIN by the cost of one drainage inlet structure and by the improved channel length to estimate the

inlet cost in determining the total cost of channel improvement.

CAP(MW,8), 2; CAP(MW-1,8), 3: It is necessary to eliminate any existing channel constrictions that cannot accommodate the design channel flow. The most common constrictions are at bridge openings. In the CAP array, the planner provides the Programs with the capacities, in cfs, of all bridges in each flood-plain subwatershed. The Programs can handle up to six highway bridges and two railroad bridges per subwatershed. The first six values read pertain to highway and the last two to railway bridges. The values within each subwatershed and bridge category must be listed in descending order. If there are fewer than six highway or two railroad bridges in a subwatershed, values of -1. are used to fill the array. In case of fords or proposed new road or railroad stream crossings, a CAP value of 0. will cause the Programs to include the cost of building a new bridge whenever any subwatershed channel improvement can be justified. The capacities of existing bridges were calculated by the approximate formula:

$$Q = 4.5bd^{1.5}, \quad (7)$$

used by James (13, p. 65) to indicate the maximum flow which can pass through an opening without excessive backwater. In eq. 7, b is the clear bridge span measured perpendicular to the flow, in

feet, and d is the vertical distance from the stream bed to one foot below the underside of the bridge deck. The Programs, as they evaluate channel improvement possibilities in each subwatershed, compare the design flow with each bridge capacity. Each time a bridge is found that does not have ample capacity, the cost of replacing the bridge is included in the channel improvement cost.

**BW, B:** BW represents the design width in feet of the new highway bridges proposed to replace old ones of insufficient capacity. The value is determined by noting the width of existing bridges on the general type of roads that will cross the channel. Since the roads in the study area are all two-lane, a 30-foot width was specified based on 12-foot lanes with 3-foot shoulders. A four-lane highway could be handled by specifying two bridges.

The Program multiplies BW by the new bridge length, measured as the water surface width of the design channel, and by the unit cost of highway bridges to arrive at the cost of building a new bridge.

Channel Improvement - Cost Factors: The cost of channel improvement is estimated by multiplying estimated construction quantities by unit costs and the sum of the products by some factor to account for incidental or minor items, contingencies, engineering, etc.

Unit costs and cost multipliers are supplied to the Program by the data in this section.

CX, B: When the channel is enlarged, excavation is required. The unit cost of channel excavation in dollars per cubic yard is represented by CX. The value is determined from contract bid prices on similar excavation in the same general area. The Programs multiply the number of cubic yards of excavation by CX to determine the basic cost of channel enlargement.

FM, B: Unlined channel construction usually requires riprap at points of expected erosion on curves, transitions, and junctions and seeding the banks to establish a protective grass cover. The multiplier applied to the channel excavation cost to account for these and any other similar items is supplied through FM. The value is obtained from contract bid prices for similar channels by dividing the total contract cost of the earth channel by the cost of excavation alone.

CIN, B: CIN represents the cost of installing each drainage inlet. If lump sum bid prices are available on inlets of a suitable type, a representative price can be directly selected for CIN. If none are available, a value for CIN may be developed from the unit costs and approximate quantities of materials and labor



required for each inlet. The Program multiplies CIN by the number of inlets to arrive at their total cost. This cost is then included in the total cost of channel improvement.

CLSF, B: Since the sides of trapezoidal channels lie at some slope, the lining of these channels is a type of paving operation. The unit cost of placing the lining material plus wire mesh reinforcement if desired is expressed in dollars per square foot by CLSF. Contract bid prices on similar work are again the source of data. The program multiplies the wetted perimeter plus freeboard allowance times the lined channel length to obtain the area to be lined. This area is then multiplied by CLSF to evaluate the total cost of lining trapezoidal channels.

CCY, B: Installation of rectangular channels, with their vertical walls, requires structural concrete. The unit cost of placing this concrete including reinforcement and structural excavation and backfill, represented by CCY, is given in dollars per cubic yard. The cost may be estimated from contract bids on similar structural concrete work. The Program multiplies twice the wall height to the top of the freeboard plus the bottom width by a one foot slab thickness and multiplies the sum of the products by the improvement length to determine the concrete quantity. This volume is

then multiplied by CCY to yield the cost of rectangular lining.

CBR, B: The value supplied for this variable is the total cost of highway bridge construction in dollars per square foot of bridge deck. A value can be derived from contract bid prices or other available construction cost information. In determining the value, the total cost of bridge construction should be divided by the area of the corresponding bridge deck. If culvert rather than bridge construction is planned, the Programs can still be used by evaluating CBR as culvert cost per square foot of theoretical bridge deck. The Program multiplies CBR by the area of the new bridge deck (the product of BW and the design water surface width) to determine the cost of highway bridge construction.

CRR, B: The cost of railroad bridges varies with the length of the bridge and the number of pairs of track on the railway. The unit cost, represented by CRR, is expressed in dollars per linear foot of the bridge. The unit cost, like CBR, may be estimated by dividing the total contract construction cost associated with similar railroad bridge construction by the bridge length. The Programs can handle a mixture of single line and double line bridges by providing CRR for single line bridges and reading two bridges of identical capacity into array CAP. The Programs

multiply the CRR value by the length of any required new railroad bridges to get this component of channel improvement cost.

AQR, B: From land values and quantities of right-of-way to be purchased, the Programs estimate the amount which will have to be paid to purchase land and improvements for right-of-way. AQR is the ratio of the total economic cost of acquired right-of-way to the price of land and improvements. The value may be approximated by first determining the total financial cost of right-of-way (including damages, value of mineral rights, severance damages, resettlement costs, and agency cost in transacting the purchase) and dividing by the cost of land and improvements. For the Kentucky River study, an additional component of AQR, developed by Higgins (11), was included to account for the personal value of the property to the owner above the fair market price. Higgins found social and psychological attachments to real property to comprise a real economic value to the unwilling seller, and the value he found, expressed as a fraction of the sale price, for Dewey Reservoir in another Appalachian valley was also used for this study. The value for AQR of 3.584 used for this study was obtained by adding the personal value factor (0.861) to the ratio of the total financial cost associated with right-of-way acquisition to the cost of land and improvements (2.723) as determined from the Corps of

Engineers project report on the Carr Fork project. The numerator of the ratio includes, in addition to the cost of land and improvements, isolation and severance damages, mineral rights, resettlement, and acquisition costs. The Program multiplies the cost of land and improvements by AQR to approximate the total cost of right-of-way.

SAFC, B: As a safety factor to overcome difficulty in forecasting future requirements for channel right-of-way, it may be wise to purchase more right-of-way than current estimates indicate to actually be required for holding for future channel construction. Provision for this is made by the variable SAFC, which is the ratio of the right-of-way width to be held to that width expected to be required. The Program forecasts the area of right-of-way needed for channel construction in future stages and multiplies by SAFC to determine the area of right-of-way to be purchased now.

RWF, 2: Cost estimates during planning are always subject to error. The planner may wonder what the effects would be on the optimum flood control policy if his best estimate were in fact in error. RWF is an arbitrary multiple of right-of-way cost that may be used for this purpose. Program II multiplies RWF by all computed right-of-way costs before selecting the optimum policy. The value used in this study of 1.0 should normally be

used in the first run for any study area. If the planner later wishes to analyze the effects on his analysis of varying right-of-way costs, he may then run the Program again after changing the value of RWF.

CSM, B: Most agencies include a contingency allowance in their cost estimates by adding a fixed percentage to the estimated installation cost. CSM is a multiplier (1.0 plus the contingency percentage) for channel construction cost. The purpose of this factor is to protect against having the preliminary cost estimates be too low as a result of unforeseen difficulties and costly delays in construction. The 1.15 value used by the Corps of Engineers in planning Carr Fork reservoir was used for this study.

ESM, B: ESM is another multiplier for channel construction cost, in this case accounting for the cost of design, administration, and supervision of construction. The factor is best evaluated by dividing channel improvement costs, including these items, from previous project records by the cost of construction alone on the projects. The value of 1.45 used in this study was obtained by assuming that the value calculated for ESMD from the Corps of Engineers project report on Carr Fork for the dam also applied to ESM for channel construction. The Programs multiply the sum of all other construction costs, including contingencies, by ESM.

MIN, B: Once flood control measures are employed, they must be maintained if they are to continue to perform their design function. Maintenance cost varies widely with measure type, but for measures of a given type the greater the initial cost, the greater the annual maintenance cost. For this reason, the annual maintenance cost may, for planning estimates, be expressed as a fraction of the first cost. MIN is this fraction for concrete structures. The value is approximated from records on annual maintenance costs and initial installation cost for existing structures. An alternative approach is to develop and estimate the cost of a suitable maintenance program. The Programs estimate the annual maintenance cost by multiplying MIN by the first cost of the concrete structure. This cost is then added to the other annual costs of channel improvements distributed over the structure life by the Program.

MCH, B: MCH accounts for the annual maintenance cost of earth channels. MCH can be expected to be considerably larger than MIN since earth channels are much less durable than concrete structures. For a channel improvement including concrete drop structures and drainage inlets in an otherwise unlined channel, total maintenance cost is estimated by adding the product of MCH and the initial excavation cost to the product of MIN and the initial concrete structure cost. Bridge maintenance is not included

in the flood control cost as it may be fairly allocated to the total cost of the transportation facility, particularly since flood control should reduce bridge maintenance by reducing bridge flood damage.

MTLCH, B: MTLCH accounts for annual maintenance cost of trapezoidal lined channels. MTLCH values will probably be intermediate between MIN and MCH.

SF, 2: SF is a cost sensitivity study factor analogous to RWF except that it applies to channel installation rather than right-of-way cost.

Flood Proofing - Cost Factors: Flood proofing comprises various flood damage reduction measures taken by individual property owners as described in Chapter 1. Research into flood proofing alternatives, as well as the concentrated use of proofing to abate flood damages, has been very limited; and consequently cost data is very scarce. While additional research is needed to obtain firmer cost estimates, the flood proofing cost estimates made for Bristol, Tennessee-Virginia, provide the values used in this study (15, 24).

FP, B: FP represents the cost of flood proofing per foot of design flood depth per dollar of building market value. In units and

application, it is analogous to COEFDM. Both should be interpreted as a statistical average for a large number of buildings rather than a reliable estimate for any individual structure. Detailed analysis of flood proofing on a building by building basis is not warranted during preliminary planning, but some preliminary field observations to determine the practicality of flood proofing under local conditions should precede setting a value on FP. The value derived from the Bristol studies (13, pp. 110-113) of 0.035 was used in the Kentucky River study. In determining the cost of flood proofing, the Program multiplies FP by the area to be flood proofed, the value of buildings per unit area, and by the average depth of flooding.

VF, B: In some parts of the country, particularly in flat or arid regions, floods of the same magnitude may not inundate the same area each time they occur. This is due to sediment scour and deposition, changing channel vegetation patterns, and changing bank conditions. As a result, it may be necessary, in protecting against floods of a given frequency, to flood proof an area larger than that inundated by any one flood of this frequency. VF is the ratio of the area requiring flood proofing to the area inundated by the design flood. The value is obtained by inspecting maps or records showing the area flooded by different floods of similar



magnitude. The Program multiplies the area flooded by the design flow by VF to determine the area requiring flood proofing.

DD, B: DD is the multiplier for flood proofing installation cost to account for design and contingencies. A value is probably best determined by dividing the cost including these items by the basic construction cost for projects similar in nature and scope to flood proofing installation. Data will become more reliable and easy to obtain as more flood proofing measures are installed.

MFP, B: MFP is the factor for estimating annual maintenance cost for flood proofing measures as a fraction of initial cost. Where no data is available on maintenance of flood proofing measures as such, data from other improvements of similar durability should be used.

PF, 2: PF is another cost sensitivity study factor. It is analogous to RWF except that it applies to flood proofing cost.

Location Adjustment Cost Factors: While a great deal of publicity has recently been given to reducing flood damages by keeping people out of the flood plain, a community cannot sacrifice the development of its flood plain without cost. Some of the cost accrues in establishing and enforcing the land use restriction.

The bulk of the cost comes from depriving the economy of beneficial use of land which may have a number of desirable characteristics. As a general rule, flood plain land should not be developed if the expected flood damage exceeds its value in use. The land should be developed if its value in use exceeds the expected flood damage. The Programs develop a statistical average cost. More refined studies would show some kinds of development economical within a given flood plain while others are not. The information required to estimate the cost of keeping urban development out of a particular flood plain is provided the Programs by the data described in this section.

CLEN, B: Legal restrictions on flood plain land use cannot effectively control flood damage unless they are implemented in a prescribed manner and strictly enforced. For this variable the planner supplies the annual cost of implementing and enforcing land use restrictions, expressed in dollars per acre. No agency is known to have collected the data necessary to evaluate this variable, but theoretically a value could be approximated by estimating the legal fees, costs of maintaining an inspection team, and a proportional share of other costs of operating a planning and zoning board. A value of one dollar per acre per year was used for this study; however, the land use restriction measure did not

apply because no urban growth was forecast in the flood plain. The Program adds CLEN to the other land use management cost specified by Eq. 5,

RPI, B: The method used by the Programs for estimating the cost to the community of restricting development from the flood plain is based on Eq. 5. RPI is represented by  $j$  in Eq. 5. It is the rate of return expected by private investors in real property. A rate of 0.08 was used in this study (13, p. 122). The rate prevailing in a given farm area may be estimated as that discount rate which equates the present worth of expected future farm income to the prevailing market prices of farm land per acre.

FIA, B: When land use measures are implemented to abate flood damages, urban development is excluded from the area. This leaves the land open for agricultural use, which is allowed under use restrictions. The agricultural income derived from this land must be subtracted from the expected urban income which would otherwise occur to obtain the net cost of land use restriction measures (Eq. 5).

FIA is the variable name for the farm income expected annually per acre of the most productive soil type, provided no flooding occurs. Under variable CDA, it was described how a

composite crop acre by soil type was developed along with expected crop yields. Gross income (in dollars per acre) is estimated by multiplying yields by price. Those familiar with local farming practice can help provide farm budgets for determining the approximate net incomes from each crop, based on the gross incomes already calculated. For each crop, the fraction of the most productive soil used in growing this crop is multiplied by the corresponding net income per acre. This is the farm income per acre for this crop. Repeating the process for each crop, multiplying each value by the fraction of the soil type in the crop, and taking the sum gives the FIA value. The Program multiplies FIA by the fraction of the flood plain in "A" soil and combines this product with analogous values for "B" and "C" soils to evaluate IA in Eq. 5.

FIB, B: FIB is analogous to FIA except that it applies to the soil of intermediate productivity.

FIC, B: FIC is also analogous to FIA except that it applies to the least productive soil.

IPP, B: Areas from which urban development has been prohibited as a means of flood damage reduction have a value as green belts, historical sites, or parks. People in the surrounding

community enjoy these "nature spots" more than they would enjoy the urban developments displaced. The value they attach on this enjoyment (13, pp. 46-49) is a favorable effect of land use restriction measures, which increases as the surrounding areas become more urbanized. IPP (IP in Eq. 5) represents this annual value in dollars per acre expressed as a multiple of the fraction of surrounding land that is urban. Attaching a dollar value to IPP is a value judgment for which the planner has little guidance other than referring to pertinent literature (9, 10). A value of 0.0 was used for our study site because green areas are so abundant around Hazard. The Program multiplies IPP by the urban fraction of the subwatershed and by the area whose land use is to be controlled to determine the value for IP applying to the subwatershed.

LF, 2: LF is the multiple for use in sensitivity studies to evaluate the effect of varying land use restriction cost on the optimum project selected. It works in the way presented for variable RWF for right-of-way cost.

#### URBANIZATION AND LAND VALUE PROJECTIONS

The dynamic aspect of flood control planning is introduced by analysis of the effects of changing flood plain conditions on the optimum combination of damage reduction measures. The

analysis requires data on the magnitude of these changing conditions. Information on changing flood damage potential through changing flood plain urban development is supplied through array USUBW. Information on changing flood hazard through the hydrologic effects of changing urbanization in the tributary watershed is supplied through array UTOTR. Information on the changing cost of right-of-way and its resultant effect on the cost of land use restriction (Eq. 5) is supplied through array VALUE. Where a single stage rather than dynamic analysis is used, values for each variable at the beginning and ending of the project life are required, and analysis is based on discounted average annual values assuming a uniformly varying gradient.

USUBW(MW,NSTEMX+1), B: In the USUBW array, the planner supplies the fraction of each subwatershed flood plain in urban land use at the beginning and end of each planning stage. For the first subwatershed in Program III, that upstream from the reservoir site, the probable area required for right-of-way rather than the flood plain should be used.

The area inundated by the 1957 flood was used for calculating the urban fractions for this study. It was determined (see VLAGST) that 7.33 houses could be considered equivalent to one urban acre. The number of houses in each subwatershed flood plain shown

on the topographic map was counted and divided by 7.33 to determine the number of urban acres in that flood plain. Where individual buildings were not shown, the entire acreage shown in red on the topographic maps was counted as urban. The urban acreage was divided by the total subwatershed flood plain area to get USUBW. Since past population trends and future projections indicate no future urbanization increase in the study area, USUBW values for the end of each stage are the same as the current value. Dempsey (4) and James (13, pp. 218-232) describe projection procedures that can be used in areas of increasing population.

The Program uses USUBW values to estimate expected flood damage and to multiply by IPP in determining open space amenities from land use restriction. Urban damages and the value of open space increase with urbanization while crop damages decrease.

UTOTR(MW,NSTEMX+1), B: Dempsey (4) presents the effect of urbanization on the hydrology of a drainage area. This effect on mean annual and 200-year flood volumes, is quantified in arrays Q43, Q05, V43 and V05 respectively. UTOTR is the fraction of the drainage area contributing to the flow being calculated that is in urban development. Therefore, in Program II, UTOTR is the degree of urbanization of all the area tributary to the downstream end of the subscripted subwatershed while in Program III, the

value is the urban fraction within the area used to develop the local inflow hydrograph.

Individual isolated houses do not have much effect on runoff; it is rather larger groups of urban buildings draining directly into a water course. Thus, a different approach than that used to calculate USUBW was required. Closely spaced structures are characteristic of an urban area. From urban lot size data obtained for the Hazard area from the Perry County tax assessor, an average lot depth was taken to be about fifty feet. This depth implies one urban acre for every row of closely spaced houses 800 feet long shown on the topographic map. Smaller concentrations of houses or other buildings were ignored. The total number of urban acres in each subwatershed was determined, including the Hazard urban area measured directly, and divided by the subwatershed area to get UTOTR for Program III. For Program II, urban area as well as total area was cumulatively summed through the subscribed subwatershed, UTOTR being the ratio of urban to total area in each case. Projections again indicated no change in UTOTR values during project life, but the projection methodology presented by Dempsey (4) and James (13, pp. 218-232) should be used where applicable.

The program uses UTOTR values for interpolating to find the effect of urbanization on flood peaks in both Programs and on flood volumes in Program III.



VALUE(MW,NSTEMX+1), B: The unit value per acre of land (excluding buildings and improvements) in the subwatershed flood plains is supplied the Program through array VALUE. For subwatersheds 7, 8, and 9, those near Hazard, urban development plays an important role in determining land value. For these three flood plains, land value was obtained by dividing the total assessed value by the acreage of the land represented in the random sample of 41 properties obtained from the tax assessor offices. In the more rural subwatersheds, the land value depends more on agricultural potential. For the current land values in each of these subwatersheds, the expected annual farm income from each soil type is multiplied by the fraction of the flood plain in the corresponding soil type. The summation of these values, representing the expected overall annual farm income, is divided by RPI. Thus the land value is taken as the present worth of all future net farm income. Projection methods for use in areas having a growing economy are presented by Dempsey (4) and James (13, pp. 218-232). Current and future flood plain land values are used by the Program in determining costs of right-of-way and values of  $MV_0$  and  $MV_t$  in Eq. 5 for evaluating land use regulation measures.

#### DESIGN DATA FOR DAM AND RESERVOIR

The main difference between Planning Program II and III is the

fact that Program III considers construction of a flood control reservoir in addition to the subwatershed measures studied by Program II. Following are data required by Program III for its analysis of flood detention storage.

Reservoir Hydrology: In determining whether or not flood control storage is economically feasible, the Program determines the effect that a proposed reservoir would have on downstream floods. The analysis requires routing of the design flood downstream through the reservoir and through the main line channel, first without, then with, the reservoir in place. The data presented in this section is used in routing as well as in determining the amount of conservation and flood control storage to be made available.

HYDMLT, 3: In order to ensure dam safety, it is necessary to route through the reservoir a very rare flood to make sure it will not be overtopped. HYDMLT is the variable name given to the ratio of the emergency spillway design flood peak to the 200-year flood peak. The value depends on the policy of the planning agency in emergency spillway design and the consequences of dam failure. The value used in this study was picked so the Program would provide the design emergency spillway capacity planned for Carr Fork by the Corps of Engineers. Program III might be used to

analyze the cost of increasing the emergency spillway design flood to increase dam safety by varying HYDMLT.

AWG, 3: AWG represents the drainage area in square miles used to develop the cumulative runoff curve, CUMVOL, described below. CUMVOL is developed from streamflow records so AWG is the drainage area tributary to the location of the selected stream gage. The value is generally given along with the streamflow data for the gaging station (35). The cumulative runoff needed by the Program is that tributary to the reservoir site. There will probably not be sufficient streamflow records at the reservoir site to develop the curve directly, and a record from a tributary area as close as possible to that desired should be selected. The Program assumes cumulative runoff is directly proportional to drainage area in adjusting the figures in CUMVOL from AWG to AW(1).

IMPTY, 3: A major problem in operating a flood control reservoir centers around the question of whether flood inflow should be held in the reservoir to reduce the current peak or released to provide for the possibility of a second even larger flood closely following the first. The longer water can be held in the reservoir, the greater is the effected reduction in the current peak but also the greater is the risk of a new flood occurring on top of partially

filled flood storage.

IMPTY is the integer number of days that the design flood is detained in the flood control reservoir. The value depends on the design policy of the planning agency and should ideally be based on analysis of the probability of back to back floods in the local hydrologic area. Twenty days was used for this study. The Program uses IMPTY in sizing the principal spillway so flood storage can be emptied by the required time.

CUMVOL(26), 3: In any flow sequence, the longer the flow duration considered the smaller will be the average flow. For example, the instantaneous peak flow is larger than the average flow over the maximum day, and both are larger than the average flow over a five-day period. CUMVOL contains, for the mean annual flood, the average flow in cfs for various durations in days.

The stream gage at Sassafrass, Kentucky, very near the Carr Fork reservoir site, has been there a relatively short time. Since at least ten years of record are needed to insure with any degree of confidence that the average value over the years will approximate the mean annual values, streamflow records on the North Fork of the Kentucky River at Hazard were used in developing CUMVOL (35). For each year from 1957 through 1966 the instantaneous peak flow was recorded (0 days duration) as well

as the largest average flow over each duration from one to twenty days. For example, the largest total flow in any ten consecutive day period during the year was divided by ten to get the ten-day CUMVOL value in each year. The average CUMVOL value over the ten year record for each duration is used as the mean annual CUMVOL at Hazard. Similarly, a CUMVOL value was determined for each duration from 0 (instantaneous) to 20 days for the Sassafrass stream gage, using only the 1965 Sassafrass record. The ratio of 1965 Sassafrass CUMVOL to 1965 Hazard CUMVOL for each duration was multiplied by the mean annual Hazard CUMVOL for that duration to obtain the mean annual Sassafrass CUMVOL value desired. The first few CUMVOL values were plotted against duration, and CUMVOL values for 0.25, 0.50, 0.75, 1.25, 1.50, and 1.75 days were read from the graph.

The CUMVOL array is used by the Program to determine the total inflow to the reservoir that can be expected over the prescribed drawdown period of IMPTY days. CUMVOL (corrected for frequency) for IMPTY days is used to size the principal spillway. The first estimate of the required volume of flood storage is based on the maximum amount of water that would accumulate in the reservoir as the flow, expressed by CUMVOL for durations shorter than IMPTY, entered while discharge occurred

through the principal spillway. Routing the design frequency flood later refines this initial estimate. CUMVOL, again adjusted for frequency, is also used to estimate inflow into the reservoir at the time the storm begins as the average flow during the IMPTYth largest flow day of the year.

IB, 3: Program III provides for conservation storage (water saved in the reservoir for any type of beneficial use) in its analysis of reservoir cost. Flood control storage is justified if the resulting benefit exceeds the incremental cost of enlarging the reservoir to provide it. In the event conservation storage is being considered but the Program cannot justify flood storage, two possibilities exist. If the reservoir is to be built for conservation storage anyway, IB is read as 1. The Program then goes on to complete the reservoir design on this basis and determine the effect of surcharge storage on flood peaks before evaluating the optimum combination of measures for each downstream subwatershed. If no reservoir is to be built unless flood storage can be justified, IB is read as 0.

The value to use for IB should be determined from a benefit-cost analysis for project purposes other than flood control. The value of 1 was used in the Kentucky River studies, but additional runs were also made to evaluate flooding with no conservation storage (NODAM=1).

GDELAY, 3: The flood damage reduction benefit from reservoir storage can usually be increased by operating the reservoir using a gated principal spillway so that the peak reservoir release does not coincide with downstream inflow peaks. Full advantage of such gates is only realized by a complex set of operating rules based on flood forecasting and reservoir system response. It was not feasible to program a complex operating procedure, but GDELAY provides for holding back reservoir releases until downstream runoff has subsided. Reading a positive value of GDELAY will cause the Program to hold reservoir flood releases constant at the base flow value for GDELAY hours after the storm begins, hour zero in the hydrograph time to peak calculations.

Use of the variable is most advantageous where the reservoir is located on one leg of a Y and the release can be delayed until flow subsides on the other leg. Delaying the release is less beneficial where no major tributary enters the main stream between the dam site and the area of primary benefit or where one of the tributaries is so large that holding the mainline flows back would make them more likely to coincide with tributary peaks. The best policy is to read 0.0 for GDELAY for the initial run and then try larger values in later runs to see if any significant advantage is gained. GDELAY did not help in justification of flood control storage at

the two dam sites on the Kentucky River.

CHKN(MW-1), 3: Program III determines the flood hydrograph in any subwatershed by routing the main channel flow hydrograph through the channel reach and combining it with the local inflow hydrograph. The channel routing is accomplished by the Muskingum method (18, pp. 228-229). In order to have flood peaks with and without a potential channel improvement for estimating resulting flood control benefits, it is necessary to route the flows through both natural and improved channels. CHKN is the Muskingum storage constant for natural channel reaches and is approximated by the time of travel of the flood through the reach.

The Corps of Engineers provided estimates of travel time between the Carr Fork site and various points downstream based on analysis of recorded hydrographs at various points along the river. The river length between these points was divided by the corresponding travel time to get the average flow velocity. The length of each subwatershed channel reach was divided by this velocity to determine the travel time through the natural channel reach, or CHKN.

CHKY(MW-1), 3: CHKY is the Muskingum storage constant used by the Program in routing flood flows through improved channel



reaches. Since both  $n$  (Eq. 3) and travel time are inversely proportional to streamflow velocity, travel time must be directly proportional to Manning's  $n$  value. It was estimated that Manning's  $n$  for improved channels was approximately 25 percent lower than that for natural channels like those in the study area. Thus the CHKY value for each subwatershed was taken as  $0.75 \times \text{CHKN}$  for that subwatershed.

CHXN(MW-1), 3: CHXN is the value, for natural channels, of the Muskingum constant that expresses the relative importance of channel reach inflow and outflow in routing. Values may be determined graphically from historical hydrographs (18, p. 228). The values used for Carr Fork were developed for natural channels in Central Kentucky by the Soil Conservation Service. The Program uses CHXN in routing floods through the natural channels by the Muskingum method.

CHXY(MW-1), 3: The inflow-outflow constant for improved channel reaches is represented by CHXY. The derivation is similar to that for CHXN, the values used again being supplied by the Soil Conservation Service.

Dam Site Properties: To select the optimum reservoir and dam dimensions, the Program must be supplied the topographic and

geometric properties of the proposed dam site. The arrays that follow provide the Program pertinent physical dimensions of the dam, reservoir, and emergency spillway as well as relocation costs, all as functions of elevation.

IMAX, 3: IMAX represents the total number of elevations and corresponding dam site properties supplied. The channel bed at the Carr Fork dam site is at an elevation of 948 feet; hence this was the first elevation used. Elevations used were then increased in ten-foot increments from 950 to 1,080 and in forty-foot increments from 1,080 to 1,200 to make a total of 18 elevations. The Program can handle a maximum of 25. The Program uses IMAX to determine how many sets of elevations and corresponding dam site properties to read and to use in later computations.

NHILSD, 3: For many potential reservoir sites, the emergency spillway site suitable for a dam of one height will not be suitable for a dam of another height. Because the planner cannot know ahead of time which reservoir size will prove optimum, he may desire to read data pertaining to NHILSD alternative spillway locations. The number can be determined by examining topographic maps for possible saddle sites for an emergency spillway at increasing elevations. The Program can handle up to three

different locations. If more than one location is to be considered, the dam top elevations at which the Program would shift from one site to another should also be read. The Program reads NHILSD-1 break point elevations and NHILSD site cross sections.

HBRLM, 3: HBRLM represents the break-point dam top elevation between the lowest and intermediate emergency spillway locations. The value is determined by inspection of the topographic map of the dam site. At dam top elevations below HBRLM, the Program uses the emergency spillway cross section data from array HLSIDL. When the top elevation reaches HBRLM, the cross section used is taken from the HLSIDM array. HBRLM is not read unless NHILSD equals two or three.

HBRMH, 3: HBRMH refers to the break-point elevation between the intermediate and highest emergency spillway sites. Consequently, the Program, upon reaching a dam top elevation of HBRMH, shifts the emergency spillway cross section it uses from HLSIDM to HLSIDH. HBRMH is not read unless NHILSD equals 3.

ELEVA(IMAX), 3: ELEVA is the array of IMAX elevations for which the dam site properties are supplied. The first value should be the stream bed elevation at the dam site. The second should be a higher contour plotted on a topographic map of the site, and

successive higher contours should follow until an elevation higher than the expected catch point of the hillside cut above the emergency spillway is reached. The contours used need not be evenly spaced, but should be close enough together to portray site characteristics. ELEVA functions solely to provide the Program the elevations to which the data in the eight following arrays apply.

RESACR(IMAX), 3: RESACR provides for each water surface elevation in ELEVA the corresponding reservoir surface area in acres. RESACR values can be obtained by measuring the area bounded by the appropriate contour line on the topographic map. For the Carr Fork site, a curve relating surface area and elevation was supplied by the Corps of Engineers. The Program uses RESACR in determining the reservoir storage volume versus water surface elevation, the acres of right-of-way required by the reservoir, and the number of acres to be cleared.

LGDAM(IMAX), 3: For this array the planner supplies the crest length required for a dam, at the proposed site, having a top elevation equal to the corresponding ELEVA value. Values are obtained by scaling the shortest distance, at the reservoir site, between contours on opposite sides of the stream. Lengths of saddle dams where required should also be added to the total.

The Program uses LGDAM in calculating the dam embankment volume and the area on the upstream face of the dam to be riprapped.

LGEMSP(IMAX), 3: For LGEMSP the user supplies the emergency spillway lengths required for dams having as their top elevations the corresponding ELEVA values. In evaluating LGEMSP, the user approximates on the topographic map, for each ELEVA, the location of the emergency spillway. The spillway length is measured from the map as the distance from the spillway crest or high point on the ridge through which the spillway is cut, to the point downstream from the dam site where flow over the spillway will re-enter the channel. Normally, LGEMSP should be measured in a straight line. The Program uses LGEMSP to determine the excavation and concrete quantities required by spillway construction.

LGAPCH(IMAX), 3: LGAPCH represents, for a dam having the corresponding ELEVA as its top elevation, the length of the emergency spillway approach channel. The spillway having been located for each ELEVA in determining LGEMSP, LGAPCH is measured from the map as the horizontal distance from the point at which cutting into the hillside upstream from the emergency spillway begins to the spillway crest. LGAPCH may be measured

along either a straight or a curved line depending on which requires the less excavation. LGAPCH is used by the Program in calculating approach channel excavation quantities.

CRELOC (IMAX), 3: CRELOC represents the cost of relocations made necessary by construction of a dam whose top elevation is the corresponding ELEVA value. It should be determined by a survey of the types and length of facilities requiring relocation and associated cost estimates. Highways and railroads usually comprise the bulk of the cost, but powerlines, cemeteries, telephone lines, etc. may also be involved.

At Carr Fork, the Corps of Engineers plans to relocate all highways previously located more than approximately twenty feet below the dam top. The total cost of relocations was \$8,308,000, the majority of which was for relocating 19.91 miles of highways. The number of miles of required highway relocations up to various contours was measured and multiplied by  $\$8,308,000/19.91$  miles to estimate the total cost of relocations up to these contour elevations. The method assumes total relocation cost to be proportional to the length of highways relocated. The relocation cost was then plotted against relocation elevation. By adding twenty feet to each value on the elevation axis, the plot became CRELOC as a function of ELEVA. Intermediate values of CRELOC were read from

the curve. The cost of relocations made necessary by the design dam height is included in the total cost.

HLSIDL(IMAX), 3: HLSIDL contains a cross section of the lowest of the alternative emergency spillway sites (the only site if just one is used). If the site is on the side of a hill monotonically rising above the stream, the array should contain the horizontal distance from the center of the stream to the point on the hillside having the elevation specified in ELEVA. If the site is on a side saddle, a value of 0.0 should be used for all elevations below the bottom of the saddle, and the appropriate saddle width should be used for higher elevations.

Values are obtained by scaling on the topographic map. The Program uses HLSIDL in locating the emergency spillway cut catch points, figuring the crest excavation cross section, and determining the excavation quantities.

HLSIDM(IMAX), 3: The discussion of HLSIDL applies here also except that HLSIDM refers to the second lowest alternative emergency spillway site. No data is read into the array unless NHILSD equals 2 or 3.

HLSIDH(IMAX), 3: HLSIDH is also analogous to HLSIDL, referring to the highest alternative emergency spillway site. No data is

read unless NHILSD equals 3.

NWH, 3: Retaining walls are required for the sides of vertically walled emergency spillways and stilling basins built in earth. Rather than executing a wall design for each wall height required, the Program is provided data describing the quantity of wall concrete as a function of required wall height. The data should be based on a retaining wall design appropriate for the soil conditions at hand.

Villines (38) determined for various wall heights (HWAL) the volume of concrete (CONWAL) per foot of length of the wall. The Program, having calculated the wall height, uses this height to interpolate or extrapolate CONWAL values to determine the concrete volume per foot of wall length. NWH represents the number of wall heights and corresponding unit volumes that are supplied, and hence the number of each to be read.

HWAL(NWH), 3: For HWAL the user supplies the wall heights for which the corresponding unit concrete quantities are provided in CONWAL. HWAL values should cover the entire range of wall heights expected to be encountered in design.

CONWAL(NWH), 3: CONWAL represents the unit volume of concrete, in cubic yards per foot of length, of a retaining wall



having a height equal to the corresponding value of HWAL. Values may be determined for various wall heights by standard foundation design procedures (26). Since the Carr Fork emergency spillway is in solid rock, no retaining walls are needed. Thus a value of 0.0 is used for CONWAL for each wall height. The Program multiplies the value interpolated from CONWAL by the wall length and by the unit cost of structural concrete to determine the cost of retaining walls.

Physical Factors: A number of physical characteristics of the proposed dam site and design dimensions for the dam and reservoir must be supplied the Program. These are used by the Program in arriving at the dimensions and cost of the optimum flood control reservoir.

BYVERT, 3: For BYVERT the Program user supplies the vertical distance in feet above the dam top to the right-of-way purchase line. If the line is lower than the dam top, BYVERT is negative. The value depends on the right-of-way purchasing policy of the planning agency. The Program adds BYVERT to the dam top elevation to get the right-of-way purchase elevation. This elevation is taken into RESACR to interpolate the number of acres of right-of-way to be purchased.

CONBOT, 3: CONBOT represents the thickness in feet of the concrete in the emergency spillway chute bottom. The value is determined by structural design or more approximately from standards used by the planning agency. The emergency spillway at Carr Fork is in solid rock so no concrete bottom is needed. The Program uses CONBOT in determining the volume and hence the cost of emergency spillway concrete.

CTBW, 3: When dams are built on pervious material, a cutoff trench is dug and backfilled with impervious material to prevent seepage water from undermining the dam. CTBW represents the bottom width of this cutoff trench. A value may be selected by analysis of seepage flow nets. CTBW is used by the Program in calculating the trench volume. The cost of excavating and backfilling the cutoff trench with impervious material is calculated by multiplying the trench volume by the combined unit cost of excavation and backfilling.

CWEIR, 3: The emergency spillway discharge associated with a given reservoir water surface elevation is based on the equation:

$$Q = KLH^{3/2}, \quad (8)$$

where Q is the discharge in cfs, L is the weir length (in this case the spillway width) in feet, H is the head on the weir in

feet and K (CWEIR) is the weir coefficient. A value may be obtained from tables in hydraulic texts or handbooks (34, pp. 270-282), model studies, or analysis of flow over weirs of known profile at existing dams. The Program applies Eq. 8 to get the emergency spillway discharge.

DMTPW, 3: The top width of the dam in feet is read as DMTPW. Criteria for determining the top width (34, pp. 201-203) depend on dam height and whether a public or only a maintenance road is built across its top. The Program uses DMTPW in its calculation of the volume of dam embankment.

DPRCKH, 3: DPRCKH represents the mean depth in feet to bedrock at the site of the emergency spillway. This depth is determined by subsurface exploration of the spillway site. The DPRCKH value is used by the Program in determining how much of the spillway excavation will be in earth and how much will be in rock. The Program always sets the spillway crest control section in rock.

DPRCKV, 3: DPRCKV represents the mean depth in feet to bedrock under the dam as determined by subsurface exploration of the stream bed and adjacent alluvium. DPRCKV determines the cutoff trench depth and thus is used by the Program in determining the volume of earth excavation and backfill that will be required to

provide the dam with an adequate impervious foundation.

DPRP, 3: Large rocks, called riprap, or some other surface protection is usually placed on the upstream face of earth dams to prevent washing and sloughing of the embankment material. DPRP represents its depth in feet measured perpendicular to the upstream face of the dam. The depth used should depend on the severity of the erosive forces, the quality of the protective surface, and the erodability of the dam embankment material. DPRP is multiplied by the area covered and by the unit cost of riprap to get the total cost.

FPIPE, 3: The Darcy friction factor, represented by this variable name, is used in determining the size of principal spillway pipe required to accommodate a given flow. The basic equation is:

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad (9)$$

where  $h_f$  is the head drop through the pipe,  $L$  is the length and  $D$  the diameter of the pipe, and  $V^2/2g$  is the velocity head, all in feet, and  $f$  (FPIPE) is the friction factor. A value for FPIPE may be obtained from curves found in hydraulics texts or handbooks based on probable pipe size and concrete pipe. Taking the difference in the reservoir surface and tailwater elevations as  $h_f$ , and knowing  $f$ ,  $L$ , and  $g$ , the Program calculates the principal spillway flow velocity and discharge for a trial  $D$  to see whether

it is adequate.

QRATIO, 3: QRATIO is the ratio of the peak to the average principal spillway discharge during the IMPTY day drawdown period. An approximate value is obtained from the ratio of discharge through the principal spillway when the flood storage is full to discharge when half full. QRATIO is used in sizing the principal spillway to estimate average flow during the design storm (see CUMVOL).

SEDIN, 3: Soil particles displaced by rainfall and runoff are carried along in turbulent streams and deposited in quiescent reservoirs. In reservoir design, extra storage must be allocated for this sediment deposit. Otherwise, the capacity of the reservoir would gradually be reduced with time until it would no longer function properly. SEDIN is the annual sediment inflow to the reservoir in acre-feet per square mile of tributary drainage area. The value depends primarily on ground slope, soil erodability, rainfall intensity, and vegetative cover (2, pp. 17:2-17:33). SEDIN is multiplied by the drainage area tributary to the reservoir site and by the design life of the reservoir to get the storage reserved for sediment.

STLBOT, 3: At the point where the emergency spillway flow re-enters the stream channel, a stilling basin may be required to dissipate the energy and prevent excessive channel erosion.

STLBOT represents the thickness in feet of the bottom of the stilling basin, and is determined by the structural design standards of the planning agency. Greater hydraulic forces usually require STLBOT to exceed CONBOT. Because of an infrequently used emergency spillway with a rock bottom, a value of 0.0 was supplied for STLBOT in our study. The Program uses STLBOT in calculating the quantities and hence the cost of providing the stilling basin.

TRV, 3: A trashrack or bar screen is provided at the principal spillway inlet to keep debris from entering and clogging the pipe or damaging the gates. TRV is the design velocity in feet per second of flow through the trashrack. The need for and the design of trashracks is based primarily on the size of the conduit and the nature of the trash burden (34, pp. 360-361). The Program divides the peak principal spillway flow by TRV to determine the inlet opening area required through the trashrack, which is in turn used to estimate the cost of the required inlet structure to the principal spillway.

TWELEV, 3: For TWELEV the Program user supplies the design tailwater elevation for use in design of the emergency spillway stilling basin and sizing the principal spillway. The design elevation can be taken from stream flood profiles or backwater computations as the stream water surface elevation predicted during the

spillway design flood.

WDEMSP, 3: The Program assumes a constant emergency spillway width from the crest downstream through the stilling basin. It determines the economically optimum emergency spillway width by balancing increased spillway cost against a smaller dam and right-of-way requirement. For WDEMSP the user supplies the initial width to be tried by the Program. The Program calculates the cost involved in using an emergency spillway of width WDEMSP, then tries smaller or larger spillways until the least costly width is determined. After the first run, computer time is saved by adjusting WDEMSP to the determined optimum value.

XTRSTR, 3: If the planning agency wishes to incorporate, within the reservoir, storage for purposes other than flood control such as recreation or water supply, the required capacity in acre-feet is supplied for XTRSTR. If such storage is not required, XTRSTR is assigned a value of 0.0. The Program uses XTRSTR in its determination of the size and cost of a conservation storage dam and reservoir. Flood storage is then justified if it produces benefits in excess of the cost of adding the additional required storage to the conservation storage reservoir. No provision is made for seasonal variation in flood storage requirement in multipurpose reservoirs.

ZCT, 3: ZCT represents the side slope (ratio of horizontal to vertical) of the cutoff trench described under CTBW. The value depends on the stability of the soil at the dam site. ZCT is used by the Program in calculating the excavation and backfill quantities involved in installing the cutoff trench.

ZDN, 3: The slope (ratio of horizontal to vertical) of the downstream face of the earth dam is represented by this variable name. The value is selected by a slope stability analysis of the dam face based on known soil properties and expected seepage rates (17, pp. 205-208). The program does not directly provide for benching the dam face, but an equivalent flatter slope can be substituted. The Program uses ZDN in its calculation of the dam embankment quantities.

ZES, 3: For this variable name, the user supplies the cut slope (again, the horizontal to vertical ratio) in the hillside above the emergency spillway. The slope depends on the stability of the in place soil. In solid rock hillsides, the slope may be nearly vertical (0.25 at Carr Fork). An equivalent average slope may be used where strata of varying stability are exposed or where benching is desirable. The Program uses ZES to calculate the quantities of emergency spillway excavation.



ZUP, 3: The statements made about ZDN also apply here except that ZUP represents the upstream rather than the downstream slope of the dam embankment. The slope stability study is generally based on forces on the dam face during rapid reservoir drawdown.

Unit Cost Factors: In determining the optimum level of flood protection, the Program maximizes the net benefits realized from flood storage. Net benefits are determined by subtracting the cost of providing flood control storage from the net reduction achieved in downstream cost. The cost of reservoir storage is calculated by multiplying quantities by unit costs. The user supplies these unit costs for the variables described below.

UCDAM, 3: UCDAM represents the unit cost of the dam embankment material in dollars per cubic yard. The value should also include the cost of items not otherwise accounted for in the subsequent unit costs. Such items might include sand filters, base and surface materials for appurtenant roads, guardrails, etc. The value of UCDAM is determined by referring to cost reports or contract bid prices for similar work in the vicinity. The total cost of items to be included under UCDAM is divided by the volume of the corresponding dam. The Program multiplies UCDAM by the calculated embankment volume to estimate the cost of the in place

dam embankment.

UCCT, 3: UCCT is the variable name for the unit cost of cutoff trench excavation and backfill, given in dollars per cubic yard. The value is derived from bid prices on similar work in the same area. The Program multiplies UCCT by the calculated cutoff trench volume to get the total cost of providing the trench.

UCRP, 3: For UCRP the Program user supplies the unit cost of riprap or other protective material for use on the upstream face of the dam expressed in dollars per cubic yard, again evaluated from local bid prices on previous work. The Program calculates the cost of providing riprap for the upstream dam face by multiplying the area to be protected by the riprap depth (DPRP) and by the unit cost (UCRP).

UCSPEX, 3: The cost in dollars per cubic yard of earth excavation for the emergency spillway is supplied for UCSPEX. The value, obtained from bid prices on similar excavation work, is multiplied by the volume of earth (as contrasted with rock) to be removed in forming the emergency spillway channel to determine the earth excavation cost to be included in the total emergency spillway cost.

UCRKEX, 3: UCRKEX is the unit cost of rock excavation required in emergency spillway construction.

UCSPCN, 3: UCSPCN represents the unit cost in dollars per cubic yard of in place structural concrete including reinforcing and structural backfill used in construction of the emergency spillway. The value, obtained from bid prices on similar work, is multiplied by the volume of concrete in the emergency spillway walls and slabs to get the total cost of concrete construction.

UCPRCN, 3: This variable supplies the unit cost of principal spillway conduit construction in dollars per cubic yard of the spillway pipe. The value is determined by inspecting bid prices on similar work or from cost reports of completed projects. The total cost involved in installing the principal spillway conduit, including such items as excavating, installing seepage collars, the cost of the pipe, and backfilling around the pipe, is divided by the volume of the conduit itself in cubic yards to obtain UCPRCN. The Program determines for the proposed dam and corresponding principal spillway flow, the length, diameter and wall thickness of the conduit. From these values, the pipe volume is calculated and multiplied by UCPRCN to get the total conduit cost.

UCCNID, 3: UCCNID is similar to UCPRCN except that UCCNID alludes to those items that pertain to the principal spillway outlet works or energy dissipator. The bid items that should be included

here include the concrete and reinforcement in the outlet works as well as appurtenant items such as riprap and guardrails. The Program multiplies the concrete volume in the design outlet works by UCCNID to get the cost.

UCTRK, 3: UCTRK represents the unit cost of the entire principal spillway inlet structure in dollars per square foot of the opening. From contract bid prices or cost reports on completed projects, the total cost of items pertaining to the principal spillway inlet is divided by the approximate area of the inlet opening to estimate UCTRK. Items comprising the cost may include the operating tower structure, antivortex device, service bridge, and inlet gates including the electrical mechanisms for opening and closing. The opening area is approximated by dividing the design discharge by the design trashrack velocity. The Program calculates the trashrack area required for each design flow and multiplies the area by UCTRK to obtain the total cost of the principal spillway inlet structure and trashrack.

UCCLR, 3: Again, from contract bid prices, the Program user determines the unit cost of clearing the reservoir site in dollars per acre to provide this value. The Program multiplies UCCLR by the area between an elevation five feet below the top of the conservation

storage pool and the emergency spillway crest elevation. A weighted average cost must thus be used where only spot clearing is required.

CSMD, 3: CSMD is a contingency factor used for reservoir installation cost analogous to CSM used for channel improvement. The Program multiplies the cost of constructing the dam and reservoir by CSMD to account for contingencies in dam construction.

ESMD, 3: ESMD is the multiplier for the dam and reservoir construction cost to account for the cost of project engineering, administration, and inspection analogous to ESM for channel construction. The Program multiplies the construction cost including contingencies by ESMD to get the total cost including engineering.

MDAM, 3: This variable supplies the annual maintenance cost for the dam and reservoir as a fraction of the construction cost. A value can be obtained from records of maintenance cost on completed facilities. The value used at Carr Fork was that derived by Rosenbaum (23) for Dewey Reservoir where annual maintenance cost divided by the construction cost gave an MDAM value of 0.008. The Program multiplies the reservoir construction cost by MDAM and includes this annual maintenance cost in the total annual cost of flood damage reduction.

Downstream Benefits: Program III calculates the project flood control benefits derived in up to 14 subwatershed flood plains downstream from the reservoir site. Actually, some beneficial effect may extend all the way downstream to the ocean. Data describing benefits realized downstream from the study area are read in this section. The benefits accruing downstream from the study area will increase with future flood plain development.

DMBN(2,10), 3: Array DMBN supplies estimates of the annual benefits (the second row) accruing downstream from the area analyzed directly by the Program as a function of flood control storage (the first row). The Corps of Engineers has made studies relating benefit to storage for major river systems (30). Values for intermediate reaches between the study area and a major river may be estimated by routing the flood flows for various reservoir sizes through the downstream reaches and using the change in flood peak to approximate the benefits in the flood plains. The Program, using the design flood storage, interpolates the corresponding DMBN value from the array. These benefits are added to the annual benefits realized in the study area as calculated by the Program.

DMBNF(NSTEMX), 3: To account for changes in the average annual downstream benefits with time, the planner supplies a DMBNF

value for each planning stage. This value represents the ratio of the average annual downstream benefits in the stage to the average annual downstream benefits over the entire planning period. Values for the array may be determined from population projections over the project life. The assumption that flood benefits are roughly proportional to population could be used to plot benefits versus time. Discounting computations provide average annual values during each stage and an average annual value for the whole project life. The Program multiplies the average annual downstream benefits over the entire planning period (interpolated by storage from DMBN) by the DMBNF value for the stage being analyzed to get the average annual downstream benefits during that stage.

## Chapter V

### INTERPRETATION OF OUTPUT

The findings of the University of Kentucky Flood Control Planning Programs are expressed in the output printed by the computer. The findings, once properly interpreted by the planner, form the basis for beginning the more intensive final project analysis leading to formation of formal construction plans and specifications. In order to guide the Program user in this interpretation, this chapter is divided into two main parts. First, each output provided by the Programs is presented and explained on illustrative tables. Second, the results of the study on the Upper Kentucky River are provided in order to illustrate the kinds of decisions which can be based on Program results in the context of a specific flood problem.

#### PROGRAM II

Since the output varies between the two Programs, each will be presented individually. Program II does not include consideration of a flood control dam and reservoir and thus has less output. Even so, the complete text of the computer output could not feasibly be presented here because of its great length. The output that is presented must thus take the form of tables illustrating each



output type. The order in which the output is printed varies substantially with Program findings, but the reader can get a good idea of output sequence by following the order in which WRITE statements appear in the listing of Program II in Appendix A.

While table headings and comments within the output are largely self explanatory, each type of output will be presented by an illustrative table copying exactly the format of typical computer output along with additional explanatory comments as needed. Since the Kentucky River studies did not find a number of potential flood measures to be economically justified, many of the numbers on the following tables were obtained from other studies. Furthermore, all are out of context with respect to the balance of the output. Thus, the reader should not attempt to attach any particular significance to the actual numbers on the following tables. They are unimportant for the purpose at hand.

#### UNIT COST OF LAND USE MANAGEMENT

Unit cost of restricting all urban development from the flood plain as estimated from Eq. 5 is developed and printed by subroutine CALCLU. Table 4 presents, for each subwatershed in each planning stage, the annual cost in dollars per acre. This output is printed only when L6 is read as 1.

TABLE 4

## ANNUAL COST OF LAND USE MANAGEMENT

## LOCATION ADJUSTMENT COST IN \$/ACRE BY SUBWATERSHED-STAGE

NW	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5
1	27.84	27.84	33.54	47.83	106.91
2	23.34	338.88	701.13	742.64	765.21

## TRACE OUTPUT

The TRACE output is obtained by reading L5 as an integer 1 value. The TRACE output shows the combination of channel improvement (S), flood proofing (P), and land use adjustment (L) being tried currently in CHOPTM, whether the measures are found economical or not. Each combination tried is represented in the output by the number of the subwatershed and a mnemonic for each measure. Repeated appearance of a letter in the output indicates a measure that is almost economically justified if it is not selected. The same mnemonic may be repeated several times for increasingly higher levels of protection. An example of TRACE output is shown on Table 5.

## CHECK OUTPUT

CHOPTM systematically compares alternative combinations of the three flood plain measures. If the planner is interested in knowing each new combination tried that has a lower total cost

TABLE 5

FLOOD PLAIN MEASURES CONSIDERED

- 2 S
- 2 S+P
- 2 S+P
- 2 S+P
- 2 S+P
- 2 S+L
- 2 S+L+P
- 2 S+L+P
- 2 S+L+P

than any other combination tried thus far, he reads L6 as integer 1 and receives CHECK output. This output (Table 6) shows the number of the subwatershed, a mnemonic for the combination of measures being tried, the frequency at which flooding begins in the subwatershed, and the design flood frequency, corresponding design discharge, and annual cost of channel improvement (S), land use (L), and flood proofing (P) measures respectively. The final three values are the cost of residual flooding, the cost of uncertainty, and the total cost associated with the measure combination. Since each combination costs less than that before as one goes down the page, the total cost in the last column will monotonically decrease. A mnemonic of LN indicates consideration of lining a previously improved channel, while BG indicates no new channel improvement and no nonstructural measures are being considered. In cases where the

TABLE 6

ALTERNATIVE FLOOD PLAIN MEASURE COMBINATIONS

FOLLOWING OPTIMIZATION THROUGH INNER LOOPS

BEG	CHANNELS			LOCATION			PROOFING			COST OF FLOODING	COST OF UNCERTAINTY	TOTAL COST
	S	QS	CS	L	QL	CL	P	QP	CP			
1BG	90.897	0.0	50.	0.	0.0	0.	0.0	0.	0.	768239.	89322.	857561.
1 P	90.897	0.0	50.	0.	0.0	0.	43.0	419.	14711.	472531.	133209.	620451.
1 P	90.897	0.0	50.	0.	0.0	0.	20.0	654.	21291.	300807.	118926.	441025.
1LP	90.897	0.0	50.	0.	43.0	419.	10776.	43.0	419.	1878.	79763.	121758.
1LP	90.897	0.0	50.	0.	43.0	419.	10776.	20.0	654.	4368.	60781.	105583.
1 S	90.897	0.050	2257.	36384.	.0	0.	0.	0.0	0.	0.	0.	36384.

- 160 -

TABLE 7

STAGE ANALYSIS SUMMARY

SUMMARY FOR STAGE 3

SUMMARY OF MEASURES AND COSTS

UNIT	BEG	CHANNELS			LOCATION			PROOFING			COST OF FLOODING	COST OF UNCERTAINTY	TOTAL COST
		S	QS	CS	L	QL	CL	P	QP	CP			
1	90.90	0.050	2257.	36384.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36384.
2	0.05	0.050	2733.	100010.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100010.
TOTAL COSTS				136394.			0.0			0.0		0.0	136394.

economically optimum measures cannot be implemented because of intangible considerations, the output in Table 6 is valuable in evaluating alternative potential combinations which might be substituted.

#### SUMMARY BY STAGE

This output (Table 7) summarizes the optimum combination of measures found in all subwatersheds at the end of each stage. Consequently, it is identical to the last line of CHECK output except that no mnemonic is printed. At the bottom of the table are also printed sums of the cost columns. Where right-of-way holding is being exercised, its cost is included in the total for channel construction and in the grand total but not in the individual subwatershed totals.

#### SUMMARY OF CHANNEL IMPROVEMENTS

The channel improvements incorporated by the program in the optimum combination of measures are presented for all the subwatersheds evaluated in the planning stage on a single summary table (Table 8). No output is printed on the table for subwatersheds where no channel improvement proves economical. No output at all is printed under the table heading if channel improvement is not economical in any subwatershed.

The summary of channel improvements relates to the planner pertinent data on the optimum channel found for the subwatershed-

TABLE 8

## SUMMARY OF CHANNEL IMPROVEMENTS

UNIT	TYPE OF CHANNEL	STAGE ACTION	CAPACITY CFS.	X-SECTION AREA SQ. FT.	TOP WIDTH FT.	ROW WIDTH FT.
1	TRAPEZOIDAL LINED	BUILT	2257.	180.6	36.1	63.5
2	RECTANGULAR LINED	ENLARGED	2733.	234.1	30.2	50.2

stage. This data includes the unit (subwatershed number), the type of channel (such as unlined with drop structures), the stage action (whether the improved channel described was initially built, enlarged, or unchanged during the current stage), the capacity in cfs, cross sectional area in square feet, and top width in feet of the channel, the width in feet of right-of-way to be purchased, the channel design depth in feet, the number and height in feet of drop structures in the reach, and the number of highway and railroad bridges that remain the same, are built, or are extended during the subwatershed-stage.

## TRACTIVE FORCE OUTPUT

When construction of an unlined prismatic channel is being considered, the actual tractive force developed by the design flow (TFF) is determined and compared with the maximum allowable tractive force in the subwatershed (TF). If the actual tractive force is found excessive, its value in pounds per square foot is printed (for example: "TFF = 1.37"), and a drop structure is added to reduce

TABLE 8 (Continued)

SUMMARY OF CHANNEL IMPROVEMENTS

DEPTH FT.	DROP STRUCTURES		HIGHWAY BRIDGES			RAILROAD BRIDGES		
	NUMBER	HEIGHT FT.	SAME	BUILT	EXTEND	SAME	BUILT	EXTEND
6.0	0	0.0	0	2	0	0	1	0
7.8	0	0.0	8	0	0	0	0	0

tractive force. The new tractive force is then calculated and checked against the allowable value. If it is still excessive, a larger drop structure is installed, and the second TFF value is printed. This process is repeated until the tractive force developed is less than the maximum allowed.

SUMMARY OF FLOOD PROOFING

This output (Table 9) is developed and printed by Program II as a stage summary whenever flood proofing is incorporated into the optimum flood control policy in any subwatershed-stage. The information given is the number of the subwatershed and the number of acres within the subwatershed flood plain within which all buildings

TABLE 9

SUMMARY OF FLOOD PROOFING MEASURES

UNIT	AREA PROTECTED
1	499. ACRES
2	307. ACRES

should be flood proofed. This area is that inundated by the flood proofing design flood shown on Table 6. If no flood proofing is selected in any subwatershed, the statement "NO FLOOD PROOFING CAN BE JUSTIFIED ECONOMICALLY IN THIS STAGE" is substituted for Table 9.

#### SUMMARY OF LOCATION ADJUSTMENT

This stage summary (Table 10) is similar to that for flood proofing. The output consists of the subwatershed number and the number of acres within the subwatershed flood plain from which urban development should be restricted. The statement "NO LAND USE ADJUSTMENT CAN BE JUSTIFIED ECONOMICALLY IN THIS STAGE" is substituted for Table 10 if no land use management practices are selected in any subwatershed.

#### SUMMARY OF RIGHT-OF-WAY HOLDING

If the Program finds it economical to purchase right-of-way in earlier stages for future channel construction, a stage summary of the holding (Table 11) is included in the Program output. The

TABLE 10

#### SUMMARY OF LOCATION MEASURES

UNIT	AREA OF RESTRICTED LAND USE
1	318. ACRES
2	197. ACRES



TABLE 11

## SUMMARY OF RIGHT-OF-WAY PRESERVED FOR FUTURE CHANNEL CONSTRUCTION IN STAGE 2

UNIT	HOLDING WIDTH FEET	CHANNEL WIDTH FEET	AREA HELD ACRES	UNIT HOLDING COST DOLLARS PER ACRE	TOTAL HOLDING COST DOLLARS
1	84.	0.0	25.44	47.	1203.
2	107.	0.0	27.13	59.	1601.
TOTAL ANNUAL HOLDING COST					2804.

- 165 -

TABLE 13

## FLOOD HYDROGRAPH

COMBINED HYDROGRAPH, MEAN ANNUAL FLOOD, NATURAL CHANNELS, INTERVAL = 2.00 HOURS

## COMBINED ROUTED AND LOCAL INFLOW HYDROGRAPHS AT SUBWATERSHED 1

.03	.07	.11	.15	.18	7.41	16.21	25.27	35.20	48.71
45.12	39.51	33.97	29.53	25.09	21.36	18.47	15.57	13.49	11.53
9.77	8.51	7.25	6.28	5.43	4.62	4.07	3.53	3.08	2.72
2.36	2.11	1.86	1.64	1.47	1.31	1.19	1.10	1.01	.93
.86	.77	.68	.58	.51	.43	.37	.33	.30	.26

summary contains for each subwatershed its number, the total width in feet of the right-of-way to be held, the width of any existing improved channel (right-of-way may be held for potential future channel enlargement), the number of acres of right-of-way held, the economic cost of holding in dollars per acre, and the total holding cost in dollars. The stage total for all subwatersheds is printed at the bottom and added into the grand total on Table 7.

#### AVERAGE ANNUAL COST OVER ALL STAGES

The final summary presented by the Program II output contains the discounted average annual cost totaled for all subwatersheds over the entire planning period for the measures found optimum in the analysis (Table 12). The summary consists of a list of the measures implemented (potentially channel improvement, land use, and flood proofing) and the average annual cost involved in implementing the optimum level of each. Also shown are the average

TABLE 12

#### AVERAGE ANNUAL COST OVER ALL STAGES

	DOLLARS/YEAR
COST OF CHANNEL IMPROVEMENT	82777.
COST OF LAND USE	2186.
COST OF FLOOD PROOFING	3226.
COST OF RESIDUAL FLOODING	6526.
COST OF UNCERTAINTY	938.
TOTAL COST	95654.

annual costs of residual flooding, uncertainty, and the average annual total cost associated with the flood control plan.

### PROGRAM III

All the output discussed for Program II except the "Summary by Stage" of Table 7 and the "Average Annual Cost Over All Stages" of Table 12 is also produced by Program III. The format and presentation of Tables 4, 5, and 6 are identical between the two Programs. Tables 8, 9, 10, and 11 are found in Program III printed out one line at a time for each subwatershed-stage rather than as single stage summary tables. In the event the line does not apply to a specific subwatershed-stage, no line is printed.

Program III also prints out many other output tables related to flood hydrograph development and routing as well as estimating quantities and costs for the dam and reservoir. Some of this output is optional upon request by the user through variables L8, L9, and L10, and some is automatically printed.

### HYDROGRAPH PRINTOUT

Program III determines the flood peak by routing hydrographs of various frequencies through the reservoir, if there is one, and thence through the downstream channel reaches, adding in each subwatershed the hydrograph of the flow generated within its

tributary area. If the user so specifies through variable L9, included in the output will be the reservoir outflow and each sub-watershed mouth hydrograph developed by the Program. Each hydrograph is headed in the output by an explanation of the channel conditions and frequency used in its development. All the hydrographs are given as 50 values of discharge separated by time interval HYDINT. An example of this output is on Table 13.

#### HYDROGRAPH PARAMETERS

In developing a hydrograph, the Program determines the mean annual and the 200-year flood peak and flood volume based on the frequency, the drainage area, and the degree of urbanization and channelization. Where the reservoir design flood frequency is neither of the above two values, its peak and volume is also determined. Based on the peak-volume relationship and the time to peak, a hydrograph shape is interpolated from HYDBAS. The HYDBAS values are expressed as a fraction of the peak flow so the actual hydrograph is developed by multiplying the HYDBAS values by the design flood peak. Included in the hydrologic details supplied by the Program are the parameters used in developing each hydrograph. These parameters (Table 14) are: the mean annual, 200-year, and design flood peaks and flood volumes in cfs (QF43, QF05, QFDS, VF43, VF05, and VFDS respectively); the time to peak (TPW); the

TABLE 14

## HYDROGRAPH PARAMETERS

## FLOOD PEAKS

QF43 = 7364.7

QF05 = 17014.4

QFDS = 8287.5

## AVERAGE FLOOD FLOWS

VF43 = 1131.2

VF05 = 3744.1

VFDS = 1381.2

TPW = 9.4 HOURS

## BASIC HYDROGRAPH PARAMETERS

AW = 23.53 U = 0.00 C = 0.50

MEAN ANNUAL FLOOD AFQ = 0.59 QT = 3.00 AFV = 0.65 VT = 1.59

200-YEAR FLOOD AFQ = 0.59 QT = 2.23 AFV = 0.66 VT = 1.83

subwatershed tributary area in square miles (AW); the fraction of subwatershed urbanization and channelization (U and C respectively); and for both the mean annual and the 200-year flood, the area correction factor for the flood peak (AFQ - interpolated from AFCTR), the urbanization-channelization correction factor for the peak (QT - interpolated from Q43 and Q05), the area correction factor for the flood volume (AFV - interpolated from AFCTRV), and the urbanization-channelization correction factor for the flood volume (VT - interpolated from V43 and V05).

## BASE FLOW

This output relates the flow expected to be passing through the reservoir at the beginning of each flood to be routed. It also provides a corresponding water surface elevation. These two items provide the initial reservoir flood routing conditions. A base flow

and water surface elevation are given for the mean annual, the design flood, and the 200-year frequencies (Table 15). The base flow is printed before the reservoir routing output. The water surface elevation at the beginning of a routing is printed just before the routing to which it pertains. Baseflow and water surface elevations increase for rarer floods because low as well as high flows can be expected to be larger on a frequency basis.

#### ROUTING SUMMARY

For each reservoir design, the floods are routed in the order: the reservoir design frequency hydrograph to size the flood storage, the emergency spillway design flood to size the dam and appurtenances, and the 200-year, mean annual, and design flood frequency hydrographs to develop three outflow hydrographs for routing downstream to define the flood frequency relationship at downstream points. After routing a flood through a potential reservoir, the Program prints a summary of the most important characteristics of the reservoir outflow hydrograph. This summary (Table 16) consists of the peak

TABLE 15

#### FLOW AND WATER SURFACE ELEVATION AT FLOOD BEGINNING

BSFL43 = 677.0 CFS    BSFLDS = 801.3 CFS    BSFL05 = 1973.7 CFS  
ELFDBG = 998.30  
ELFDBG = 998.64  
ELFDBG = 1001.08

TABLE 16

RESERVOIR OUTFLOW

PEAK DISCHARGE = 37416.  
 ELEVATION OF PEAK = 1037.79  
 TIME TO PEAK = 20.  
 TIME INCREMENT = 2.00

discharge in cfs, the water surface elevation at the peak outflow, the time to peak (in hours from the beginning of the flood hydrograph), and the time increment used in developing the 50-element reservoir outflow hydrograph.

ROUTING DATA

The procedure used by Program III to route floods through a reservoir is presented by Linsley, Kohler, and Paulhus (18, pp. 224-225). In this technique, reservoir outflow as well as the quantity  $(S/T + O/2)$  used in the routing are dependent on the reservoir surface elevation. In the expression above, S is reservoir storage, T is time interval, and O is reservoir outflow. If printing hydrograph details is specified by reading 1 for L9, the Program prints, for each reservoir routing, a table of values for  $(S/T + O/2)$  and outflow, along with the corresponding reservoir water surface elevations (Table 17). The Program interpolates, from this reservoir routing data, the values used in developing the routing table described

TABLE 17

## RESERVOIR DATA USED IN ROUTING PROCEDURE

ELEVATION	S/T + O/2	OUTFLOW
1016.45	97945.44	0.0
1016.50	98116.37	0.88
1017.00	99851.75	32.67
1018.00	103351.81	154.69
1019.00	106876.75	326.46
1020.00	110348.37	391.64
1021.00	114516.13	394.65
1022.00	118683.87	397.63
1023.00	122851.56	400.60
1024.00	127019.31	403.54
1025.00	131187.00	406.46
1027.00	139522.37	412.25
1029.00	147857.75	417.95
1034.00	171701.75	431.87
1039.00	196296.94	445.37
1044.00	224334.00	458.46
1049.00	253231.44	471.19
1059.00	320433.94	495.67
1069.00	399480.06	519.00
1079.00	491179.06	541.32
1099.00	738260.19	583.41
1119.00	988557.81	622.66
1139.00	1336722.00	659.58
1179.00	2141221.00	727.82
1219.00	3053889.00	790.19

subsequently. If GDELAY exceeds 1, the table is repeated for conditions with the gate closed.

## ROUTING TABLE

Each time a design hydrograph is routed through a reservoir, the Program, upon request by the user through variable L9, prints a detailed table of the routing. This output consists of inflow and



outflow hydrographs along with the corresponding (S/T + O/2) values, as shown on Table 18.

#### DAM QUANTITIES

If the user specifies through variable L8 that dam details be included in the output, the volumes of the dam embankment, the cutoff trench, and the riprap will be included in the output each time a dam design is tried (Table 19). The description of the dam appurtenances found in Tables 20-23 is also printed for each trial design.

TABLE 18

#### RESERVOIR ROUTING TABLE

S/T + O/2	INFLOW	OUTFLOW
103001.44	5.30	142.47
102627.31	21.19	129.43
104455.25	2283.98	208.46
116614.44	6861.15	396.15
133158.25	4785.14	407.83
143518.56	3009.53	414.98
149519.25	1900.90	418.92
152813.25	1199.87	420.84
154549.81	765.91	421.79
155030.44	497.31	422.14
154996.81	333.34	422.12
154574.12	232.26	421.87
153902.19	168.58	421.48
153086.13	131.89	421.00
152167.94	95.97	420.47
151140.37	61.45	419.87
150033.56	42.28	419.22

TABLE 19

DAM QUANTITIES

VOLUME OF DAM =	323864. CUBIC YARDS
CUTOFF TRENCH VOLUME =	7496. CUBIC YARDS
RIPRAP VOLUME =	4854. CUBIC YARDS

DEPTH OF FLOW IN EMERGENCY SPILLWAY

In solving for the depth of flow in the emergency spillway, Program III uses an energy equation, which turns out to be cubic and is solved by trial and error (38). By successively closer approximations, the Program determines the design flow depth at selected points in the emergency spillway. The depths tried by the Program in this trial and error solution are a part of the output (Table 20). If the spillway slope turns out to be too flat to support critical flow, the statement SUPERCRITICAL FLOW OVER EMERGENCY SPILLWAY is printed, and the planner may wish to modify the input data. If for any reason the Program cannot solve the cubic equation, the statement NO CHANGE OF SIGN UP TO  $D1 = 0.65$  (FALL).  $D1$  WILL BE SET =  $0.1$  (FALL) SO THAT COMPUTATIONS MAY PROCEED, will be printed. The planner should again reevaluate his input data to make sure they are realistic.

STILLING BASIN QUANTITIES

A stilling basin is provided at the downstream end of the emergency spillway to force a hydraulic jump and thus dissipate much of

TABLE 20

TRIAL FLOW DEPTHS

DEPTH = 1.982  
DEPTH = 1.803  
DEPTH = 1.796

the energy acquired by the water in its flow down the chute. Energy dissipation is necessary to prevent excessive scour in the downstream channel. If L8 is read as 1, descriptive output data (Table 21) include the flow depths just upstream and downstream from the jump, the elevation of the stilling basin bottom, and the volume of excavation and structural concrete involved in stilling basin construction.

EMERGENCY SPILLWAYS QUANTITIES

For each dam and reservoir design tried, the pertinent details of the accompanying emergency spillway are also obtained by reading L8 as 1. This information includes the following items: total excavation, its division between rock and earth excavation, volume

TABLE 21

STILLING BASIN QUANTITIES

FLOW JUMPS FROM DEPTH OF 0.74 FEET TO A DEPTH OF 15.47 FEET  
STILLING BASIN BOTTOM ELEVATION = 939.98 FEET  
STILLING BASIN QUANTITIES

CONCRETE = 0.0 CY  
EXCAVATION = 14835.75 CY

of concrete in the spillway, horizontal distance from the spillway crest to the stilling basin, area of the approach channel excavation cross section at the spillway crest, length of the approach channel, area of the spillway excavation cross section at the spillway crest, longitudinal slope of the spillway (vertical to horizontal), average height of the spillway walls, and finally the reference horizontal dimensions and elevations of the spillway excavation catch points (Table 22).

#### PRINCIPAL SPILLWAY QUANTITIES

The dam details, which can be requested by reading L8 as 1, describing the principal spillway are the head on the spillway during

TABLE 22

#### EMERGENCY SPILLWAY QUANTITIES

##### EMERGENCY SPILLWAY QUANTITIES

TOTAL SPILLWAY EXCAVATION =	192694.19 CU. YD.
SPILLWAY ROCK EXCAVATION =	181430.94 CU. YD.
SPILLWAY EARTH EXCAVATION =	11263.24 CU. YD.
SPILLWAY CONCRETE VOLUME =	1127.78 CU. YD.
DISTANCE FROM CREST TO BASIN =	218.30 FEET
AREA APP. CHANNEL AT CREST =	26199.57 SQ. FT.
APPROACH CHANNEL LENGTH =	201.58 FEET
SPILLWAY CREST AREA =	21925.69 SQ. FT.
SPILLWAY SLOPE =	0.30
MEAN WALL HEIGHT =	1.42 FEET

##### CATCH POINTS OF HILLSIDE CUT

	DISTANCE	ELEVATION
INNER	423.11	1040.31
OUTER	1188.79	1076.40

the design flood (water surface at the emergency spillway crest), the corresponding flowrate through the spillway, the pipe diameter, the volume of concrete in the spillway pipe and in the impact dissipator, and the area of the inlet trashrack (Table 23).

#### COST SUMMARY

An example of a dam and reservoir cost summary as requested by L8 is shown on Table 24. The first subtotal is the installation cost summing the cost of constructing the dam and reservoir and the engineering and contingency costs involved. The construction cost is further subdivided into the dam embankment cost, the emergency spillway cost, the stilling basin cost, the principal spillway cost, and the cost of clearing the reservoir site. The second subtotal includes the financial cost, along with the number of acres, of right-of-way purchased (the actual price of land and improvements), the "acquisition" costs (see AQR, Chapter IV), and the relocation costs (see CRELOC, Chapter IV). The total cost of project installation is then multiplied by the capital recovery factor for the project

TABLE 23

#### PRINCIPAL SPILLWAY QUANTITIES

FOR THE DESIGN PRINCIPAL SPILLWAY

HEAD = 77. FEET	FLOWRATE = 483. CFS	PIPE DIAMETER = 4.00 FEET
PIPE CONCRETE	= 395.84	CUBIC YARDS
IMPACT DISSIPATOR CONCRETE	= 67.50	CUBIC YARDS
TRASHRACK AREA	= 231.36	SQUARE FEET

TABLE 24

## DAM AND RESERVOIR COST SUMMARY

DAM EMBANKMENT COSTS	\$ 574735.69	
EMER. SPILLWAY COSTS	\$ 339191.75	
STILLING BASIN COSTS	\$ 6919.27	
PRIN. SPILLWAY COSTS	\$ 237069.31	
RESR. CLEARING COSTS	\$ 74665.56	
CONSTRUCTION COSTS		\$ 1232581.00
ENGR + CONTINGENCIES		\$ 822746.06
SUBTOTAL		\$ 2055327.00
RIGHT OF WAY COSTS	\$ 1419276.00	
1036.35 ACRES PURCHASED		
ACQUISITION COSTS	\$ 5881478.00	
RELOCATION COSTS	\$ 4238033.00	
SUBTOTAL		\$11538787.00
TOTAL INSTALLATION COST		\$ 13594114.00
ANNUAL CAPITAL RECOVERY COST =	\$ 540950.06	
ANNUAL RESERVOIR MAINTENANCE =	\$ 16442.61	
RESERVOIR STORAGE CONTAINING THE		
7.00 PERCENT FLOOD HAS AN ANNUAL COST OF	\$ 557392.62	

design life and planning discount rate the annual cost of initial installation is then given along with the annual maintenance cost, the total of these two being the overall cost of the project as given on the last line together with the frequency of the reservoir design flood.

## DAM DESIGN DETAILS

The printed physical characteristics of each dam considered include: principal and emergency spillway design flows; sediment, conservation, and flood storage; and the elevations of the principal

spillway inlet, emergency spillway crest, safety flood crest, and the top of the dam (Table 25).

FLOOD PEAKS

Flood peaks at the mouth of each subwatershed specified by frequency are printed if L9 is read as 1 (Table 26). The first six

TABLE 25

DAM DESIGN DETAILS

PRINCIPAL SPILLWAY DESIGN FLOW	=	416. CFS
EMERGENCY SPILLWAY DESIGN FLOW	=	35730. CFS
SEDIMENT STORAGE	=	873. ACRE-FEET
CONSERVATION STORAGE	=	15290. ACRE-FEET
FLOOD STORAGE	=	9306. ACRE-FEET

ELEVATIONS

PRINCIPAL SPILLWAY	=	1016.5 FEET
EMERGENCY SPILLWAY CREST	=	1030.5 FEET
SAFETY FLOOD CREST	=	1037.8 FEET
TOP OF DAM	=	1040.8 FEET

TABLE 26

SUBWATERSHED FLOOD PEAKS

FLOOD PEAKS AT SUBWATERSHED 4

Q43N	=	17.63 CFS
Q43Y	=	17.90 CFS
Q05N	=	54.37 CFS
Q05Y	=	54.72 CFS
QDSN	=	27.00 CFS
QDSY	=	27.26 CFS

DESIGN FLOOD PEAKS IN CFS

17.60 21.05 24.60 27.00 30.41 33.35 37.87 43.40 48.90 54.37

DESIGN FLOOD PEAKS IN CFS

17.88 21.32 24.86 27.26 30.68 33.62 38.16 43.71 49.23 54.72

values given are the mean annual flood peak for unimproved (Q43N) and improved (Q43Y) channels in the subwatershed and corresponding 200-year and design frequency peaks (Q05N, Q05Y, QDSN, and QDSY respectively). The next group of values are the flood peaks in the subwatershed for the NDF flood frequencies specified in array DF for unimproved subwatershed channels. The final NDF values are for the same frequencies but for improved channels.

#### ON LINE COST SUMMING

For each trial reservoir design, floods of various frequencies are routed through the reservoir and then downstream. The Program determines for each flood-plain subwatershed the economically optimum combination of measures and level of protection provided by each to complement the reservoir storage in the overall damage reduction program. When the best policy for a subwatershed has been selected, details of this policy are printed out in the format of Table 6. Also, a running total is kept and printed that shows, in addition to the annual cost incurred in the current subwatershed, the total annual cost incurred in the stage for all subwatersheds downstream through the one currently being analyzed (Table 27).

#### TABLE 27

##### ON LINE COST SUMMARY

TOTAL COST OF MEASURES WITHIN SUBWATERSHED = \$ 13684.91  
TOTAL COST OF MEASURES ON LINE TO THIS POINT = \$ 17276.44



## SUMMARY FOR RESERVOIR TRIAL

After the optimum channel improvement and nonstructural measures have been determined for all the subwatersheds downstream from a proposed reservoir, a cost summary is printed for the reservoir trial (Table 28). It includes the annual costs of measures installed and of residual flooding in the flood plain, the annual cost of the reservoir, the annual benefits attributable to the flood storage that accrues downstream from the area of primary analysis, and the total annual cost (benefits count as a negative cost) associated with this reservoir trial.

## JUSTIFIED RESERVOIR

The first flood control reservoir considered by the Program is designed to protect against a flood of the frequency in location MRDF of array DF. If the total cost of this reservoir trial (Table 28) is lower than the total cost of the optimum flood-plain measure mix with no reservoir, this first reservoir is justified; and a cost summary of the justified reservoir is printed (Table 29). Subsequent trials

TABLE 28

### SUMMARY FOR RESERVOIR TRIAL

FLOOD PLAIN COST	=	\$ 1170444.00
RESERVOIR COST	=	\$ 531706.44
DOWNSTREAM BENEFIT	=	\$ 28187.61
TOTAL COST	=	\$ 1673962.00

TABLE 29

COST OF JUSTIFIED RESERVOIR

CONSTRUCTION OF A RESERVOIR IN STAGE 1  
 TO CONTAIN A FLOOD HAVING A RETURN PERIOD OF 6.67 YEARS

COST OF DAM	=	\$ 531706.
DOWNSTREAM COST	=	\$ 1170444.
DOWNSTREAM BENEFIT	=	\$ 28188.
TOTAL COST	=	\$ 1673962.

are for reservoirs providing greater degrees of protection. Each reservoir trial yielding a lower total cost than any trial thus far is justified, and its cost is also summarized on a like table. The analysis stops when a trial yields a higher cost than the previous trial, and this output is not printed for the last, unjustified reservoir. It will never be printed if none of the reservoirs tried are justified.

SUBROUTINE ENTRY AND EXIT

This output is described under variable L10 in Chapter IV. The output enables the planner to know when subroutines are entered and left during program execution. Examples of the output are SUBROUTINE RETWAL ENTERED or SUBROUTINE RETWAL LEFT.

UCFIX OUTPUT

Subroutine UCFIX determines and prints out if L9 is read as 1, the discounted average urbanization fraction over the first

TIMST years following reservoir construction (PUT) and also the discounted average length of improved channels in miles over the same period (PCT). Both factors apply to the tributary drainage area for which the hydrograph described in the immediately following output (Table 13) is derived. Examples of this output might be:

PUT = 0.37      PCT = 4.09

#### EMERGENCY SPILLWAY SIZING

For dam safety, emergency spillway design is based on the maximum probable flood. The larger the emergency spillway provided to accommodate this flood, the smaller may be the dam and reservoir. Subroutine SPLSIZ determines the optimum emergency spillway width by first determining the cost of the dam that would be required to accompany a spillway of read width WDEMSP, then trying larger and smaller spillway widths, and selecting the width that yields the lowest total cost of the dam, reservoir, and emergency spillway. Each time a new spillway width is tried, output similar to the following is printed.

FOR TRIAL OF WDEMSP = 840. FEET  
TOP OF DAM AT 1026.5      QEMSP = 40643.0 CFS  
SPILLWAY SITE SELECTED IS 1

The economically optimum spillway width when selected is printed as:

FOR NSTAGE = 1      WDEMSP = 700.0 FEET

If the greater flood storage required by design for a larger flood event changes the specified spillway site to a higher saddle location, the Program prints REOPTIMIZE SPILLWAY WIDTH FOR A NEW SITE and proceeds to do so.

### KENTUCKY RIVER ANALYSIS

The application of the University of Kentucky Flood Control Planning Programs to the flood plain along the upper reaches of the North Fork of the Kentucky River followed the basic methodology of Chapter III or more specifically Case 6 (pp. 41-43). The total area was divided into subwatersheds (Fig. 2), and the necessary input data of Appendix C for Program II and Appendix D for Program III were developed. The analysis was based on conditions existing before construction began at Carr Fork.

### COMPUTER RUNS

Program II was initially applied to the problem area downstream from the Carr Fork reservoir site and indicated the optimum solution to be a flood proofing program similar to that presented later from Program III on Table 35. However, with only main line flooding, the hydrology is better handled by Program III where flood routing better incorporates the effect of basin shape.

Program III was applied individually to each of the three

reservoir sites as suggested in Chapter III (p. 42). Only flood storage at the Carr Fork site plus a flood proofing program along the Kentucky River were economically justified. The reduction in the sum of downstream flood damages and flood proofing cost was insufficient at the other sites to justify the cost of reservoir construction. However, a number of runs (Table 30) were made at all three sites in an attempt to better evaluate the overall situation.

The data used for evaluating the Carr Fork site by Program III were as listed in Appendix D except for the variation of three variables as shown on Table 30. The first run was for the purpose of evaluating downstream flooding if no reservoir were built. The second run added uncertainty damages to this evaluation. The third selected the optimum dam size were no flood proofing employed downstream. The fourth selected the optimum dam size supplementary to downstream flood proofing. The fifth selected the optimum dam size supplementary to downstream flood proofing if uncertainty damages were also considered. The same reservoir size was selected in two of the last three cases (Table 31), but a larger one was selected in Case 5.

The runs made for Cornettsville were based on data like that in Appendix D except as modified for the differences in downstream subwatersheds. The options used are indicated on Table 30. The NODAM run to evaluate downstream flooding with no reservoir was

TABLE 30

## DESCRIPTION OF COMPUTER RUNS

OPTION VARIABLE	RUN NO.	CARR FORK AW ( )	FLOOD PROOFING L2	NODAM L11	BYVERT BYVERT	UNC L1
CARR FORK SITE						
	1	-	Yes	Yes	+5	No
	2	-	Yes	Yes	+5	Yes
	3	-	No	No	+5	No
	4	-	Yes	No	+5	No
	5	-	Yes	No	+5	Yes
CORNETTSVILLE SITE						
	1	No	No	No	-11	No
	2	No	Yes	No	-11	No
	3	Yes	No	No	+5	No
	4	Yes	Yes	No	-11	No
	5	Yes	Yes	No	-11	Yes
KINGDOM COME SITE						
	1	No	Yes	Yes	+5	No
	2	No	Yes	No	-11	No
	3	Yes	Yes	Yes	+5	No
	4	Yes	Yes	No	-11	No

not required because the results would be identical to that for the NODAM run for the Kingdom Come Reservoir further upstream. The Cornettsville Reservoir could not be justified, but the size shown on Table 31 had the minimum negative net benefits. The cost data is based on reducing BYVERT from +5 to -11 in an attempt to minimize the costly right-of-way requirement. Runs reducing XTRSTR from 35,000 to 10,000 and increasing GDELAY from 0 to 36 were also tried, but net benefits were not increased. Runs without Carr Fork were based on eliminating from the input the entire area tributary to that dam.

The runs for Kingdom Come were based on data like that for Cornettsville but modified to add the one additional downstream subwatershed. Program options varied are also listed on Table 30. The Kingdom Come Reservoir had an even more negative net benefit than did that at Cornettsville, but the size having the minimum negative value is shown on Table 31.

#### COST DATA ON RESERVOIRS STUDIED

The cost data presented on Table 31 is that determined by Program III for the dam and reservoir at each site having the largest positive or the smallest negative benefit. The results may be compared with those found by the Corps of Engineers (Table 32).

TABLE 31

## DAM AND RESERVOIR DATA (PROGRAM III)

Reservoir:	Carr Fork	Kingdom Come	Cornettsville
TRIBUTARY AREA:	58.18 MI <sup>2</sup>	194.56 MI <sup>2</sup>	271.73 MI <sup>2</sup>
STORAGE:			
Sediment	873 AF	2,918 AF	4,076 AF
Conservation	15,290 AF	32,760 AF	35,000 AF
Flood	10,406 AF	18,460 AF	21,900 AF
ELEVATIONS:			
Conservation Pool	1,016.5	1,051.4	1,011.3
Flood Pool	1,031.9	1,065.5	1,027.6
Top of Dam	1,042.2	1,082.1	1,044.5
TOTAL COST DATA:			
Dam	\$ 2,003,000	\$ 5,455,000	\$ 6,513,000
Right-of-Way	6,957,000	14,170,000	8,471,000
Relocations	3,999,000	20,525,000	18,152,000
Total	\$ 12,959,000	\$ 40,150,000	\$ 33,136,000
ANNUAL COST DATA:			
Total	532,000	1,641,000	1,371,000
Incremental to Flood Control	135,000	365,000	403,000



TABLE 32

## DAM AND RESERVOIR DATA (Corps of Engineers)

	Carr Fork (under Construction)	Kingdom Come (Preliminary Findings)
STORAGE:		
Minimum Pool	11,830	32,610
Flood Control	31,660	95,790
ELEVATIONS:		
Minimum Pool	1,009	1,048
Flood Pool	1,055	1,100
Top of Dam	1,081	1,130
TOTAL COST DATA		
Dam	\$ 6,167,000	\$ 12,960,000
Right-of-Way	5,300,000	10,000,000
Relocations	8,308,000	32,540,000
Total	\$ 19,775,000	\$ 55,500,000

The main difference between the two studies is caused by use by the Corps of Engineers of much more flood storage than the economic optimum suggested by Program III. However, the Program could have been forced to select more flood storage by increasing uncertainty damages (VA). The cost figures agree well considering the difference in dam size except for a much lower estimate of the economic value of right-of-way as made by the Corps of Engineers.

The value of right-of-way for the Cornettsville site would be significantly higher than that shown on Table 31 if the permanent pool were to prevent mining significant coal reserves inundated by the proposed reservoir. However, since flood control storage is normally empty, much of the coal could still be extracted by proper coordination of mining with reservoir operation. The value of mineral rights may be adjusted in the Program by varying AQR.

#### RESERVOIR EFFECT ON HAZARD 200-YEAR FLOOD PEAK

Table 33 summarizes the effects of various combinations of the three proposed reservoirs on the 200-year flood peak flow and stage at Hazard. Based on 24 years of the Hazard streamflow record, the 100-year flood peak was estimated by assuming a Gumbel extreme value distribution to be 58,500 cfs. Program III estimated the 100-year peak at the downstream end of the Hazard subwatershed to be

TABLE 33

#### RESERVOIR EFFECT ON 200-YEAR FLOOD PEAK AT HAZARD

	Flow	Stage
No Reservoir Storage	70,480	50.3
Carr Fork Only	59,190	44.1
Kingdom Come Only	54,350	41.4
Cornettsville Only	42,430	34.7
Carr Fork and Kingdom Come	43,450	35.3
Carr Fork and Cornettsville	35,870	30.5

63,450 cfs assuming no upstream reservoir storage. At least part of the discrepancy may be attributed to local inflow between the Hazard gage and the downstream end of the subwatershed.

Furthermore, the Corps of Engineers (29) estimates that the reservoir currently under construction at Carr Fork and the reservoir proposed for construction at Kingdom Come, each acting alone, would have reduced the peak 1957 flood stage (frequency about 6%) by 3 and 8 feet respectively. Table 33 reveals that the reservoirs proposed for installation at these two sites by Program III would reduce the stage of the much rarer 200-year flood by approximately 6 and 9 feet respectively. Flood stages were estimated from the flood peaks developed by the Program through the stage discharge relationship published with the 1957 stream gage record (36) as extrapolated by assuming the relationship (18, pp. 68-69):

$$Q = KG^n \quad (10)$$

where Q is the flow in cfs, G is the gage stage in feet, and K and n are constants derived for the published curve to be 392 and 1.325 respectively.

#### BENEFIT EVALUATION

Analysis of the relative economic merit of the three reservoir sites (Table 34) was based on direct and indirect primary flood

TABLE 34

## BENEFIT COST ANALYSIS OF RESERVOIR ALTERNATIVES

	Benefits		Costs	B/C
	Surcharge Storage	Flood Storage		
Carr Fork	14,000	215,000	135,000	1.59
Kingdom Come				
Without Carr Fork	130,000	163,000	365,000	0.45
With Carr Fork	132,000	254,000	365,000	0.70
Cornettsville				
Without Carr Fork	228,000	228,000	403,000	0.57
With Carr Fork	211,000	303,000	403,000	0.75

control benefits. The surcharge storage benefits are based on downstream flood effects of a reservoir containing the conservation storage of Table 31. The flood storage benefits are additional benefits which accrue by adding the flood storage specified on Table 31. The benefit-cost ratio is thus based on incremental effects of adding the flood storage.

All reservoir benefits were based on flood damage reduction residual to the optimum flood proofing program (channel improvement and land use control were analyzed but never justified) and also, in some cases of the Kingdom Come and Cornettsville analysis, residual to reservoir flood storage at Carr Fork.

Greater benefits were realized from the Kingdom Come and Cornettsville reservoirs with than without Carr Fork because

flood storage controlling one major upstream tributary still leaves Hazard exposed to major flooding from the other. Furthermore, combinations of reservoirs operated together are more effective in reducing flood peaks, thus flood damages, than when operated separately.

## SECONDARY BENEFITS

Secondary benefits based on developing the economic potential of the local area or raising the income level of the local people may be used for project justification if they can be shown to stem directly from the project and not be offset by detrimental consequences elsewhere in the nation. Two types of secondary benefits were evaluated for the flood control features of the Cornettsville site with Carr Fork:

1. Income redistribution benefits, based on factors developed by Rosenbaum (20) for Dewey Reservoir in another Appalachian Valley, were estimated to be \$36,100/year.

2. Uncertainty benefits, for a one percent exhaustion probability (VA), as effected by Cornettsville flood storage were found to be \$157,900/year.

## EVALUATION OF UPSTREAM SITES

The analysis showed the Cornettsville to be the superior

of the two Kentucky River sites (Table 34). As the two sites are mutually exclusive (they back water over much the same area), the Cornettsville site should be selected over the Kingdom Come site subject to re-evaluation after obtaining more detailed topographic and geologic information and better cost estimates on mineral rights and highway and railway relocations. One of the major values realized from use of Program III is that the whole analysis can be repeated at a cost of 10 to 20 dollars to assess the effects of more recently gathered information on project justification.

For flood control at the Cornettsville site, annual costs amount to \$403,000/year, primary annual benefits amount to \$303,000/year, and secondary annual benefits amount to \$194,000/year. The total benefit is \$497,000/year to give a benefit cost ratio of 1.23.

However, the total annual cost of the reservoir was found to be \$1,371,000/year. The sum of primary flood control, secondary flood control, and surcharge flood control benefits was found to be \$709,000/year. Thus even though adding flood control storage to a 35,000 AF reservoir can be economically justified, the reservoir as a whole cannot be economically justified without \$663,000/year in demonstrated benefits from such other project purposes as recreation and low flow augmentation. These benefits were not evaluated

as part of this analysis.

### EVALUATION OF FLOOD PROOFING

The optimum flood proofing program found by Program III for the subwatersheds along the Kentucky River with Carr Fork Reservoir assumed in place is summarized on Table 35. Flood proofing was thus found to be potentially capable of substantially reducing gross flood damage in nearly every subwatershed. The finding should be followed by a more detailed investigation of existing buildings in the flood plain to design applicable flood proofing measures.

TABLE 35

#### OPTIMUM FLOOD PROOFING PROGRAM (Supplemental to Carr Fork Reservoir)

Flood Proofing Program Subwatershed	None	Optimal			
	Annual Damage	Design Flow	Annual Cost	Annual Damage	Annual Total
2	123,100	36,900	39,900	21,800	61,700
3	101,200	45,700	31,200	18,700	49,900
7	74,300	49,200	29,000	15,100	44,100
8	631,700	49,500	264,100	125,200	389,300
9	222,800	40,300	80,700	81,900	162,600
10	77,400	41,200	29,700	29,100	58,700
11	48,200	53,800	21,300	10,700	32,000
12	78,100	53,200	31,800	16,000	47,800

Flood proofing generally becomes less effective with more infrequent flooding (15). The measure thus could not be justified along Carr Fork downstream from an in-place reservoir because of its high degree of flood control. It was likewise not justified with both Carr Fork and Cornettsville reservoirs in place except in the extreme downstream subwatersheds where relatively less of the drainage area is controlled.

#### CONCLUSIONS

1. Construction of Carr Fork Reservoir is economically justified.
2. Construction of reservoir storage on the Kentucky River appears to be more economical at the Cornettsville than at the Kingdom Come site.
3. The Cornettsville Reservoir cannot be economically justified without \$663,000/year demonstrated benefits from recreation, low flow augmentation, and other non-flood-control purposes.
4. A flood proofing program would substantially reduce flood damage in Hazard. A detailed flood proofing study is especially recommended for downtown Hazard in light of the high flood damages currently suffered and the good chance reservoir storage upstream on the Kentucky River cannot be justified.
5. Channel improvement and land use management are not effective flood damage reduction measures in the study area.



## Chapter VI

### SUMMARY OF FINDINGS

#### SIGNIFICANCE OF FINDINGS

The design and economic evaluation of alternative measures for flood control is an extremely complicated and very time consuming task. Many of the most time consuming computational procedures lend themselves to digital computer analysis. Planning agencies systematically use computer programs to evaluate individual design components, but a great deal of time is still required to piece the components into an overall economic evaluation of the total flood problem. The two Programs described in this report comprise the first comprehensive attempt to combine the entire flood control planning process into a single computer operation.

While the Programs can provide a comprehensive project formulation, the results still need to be refined as the formulated project proceeds into the final design and construction stages. A major advantage of the computer analysis is that if the additional studies indicate a need for revising the design the economic consequences can be readily evaluated by a single computer run with modified input data.

The savings in planning cost made possible by use of the Programs is brought about through the virtual elimination of the burden of arithmetic computation. Planning time can be concentrated on gathering data, interpreting output, and revising planning options to test alternative approaches. The many more alternatives that can be evaluated provide the planner with much greater insight into the nature of the total problem. The computational savings can be illustrated by the fact that the 14 computer runs described on Table 30 used to evaluate alternative flood control measures along the Upper Kentucky River took a total of 44 minutes of 360/50 computer time.

#### NATURE OF APPLICATION

The Fortran IV listings of the Programs are found in Appendix A of this report for Program II and in Appendix A of Villines' report (38) for Program III. They can be adapted to any compiler that reads Fortran IV and any computer system capable of handling 132,500 bytes of program storage. Those interested in applying the Programs may obtain punched card decks, or listings on submitted tapes from the University of Kentucky Water Resources Institute, Lexington, Kentucky.

With the Program available, its use then hinges on ability to develop the required input data and to interpret the results.

Chapter IV guides the first step as Chapter V does the second. Help is available here, also, from the Institute for those who may experience difficulty.

#### POTENTIAL FOR EXPANSION

The limitations of the Planning Programs as previously presented (pp. 46-48) comprise the major directions for future Program changes. The changes may move toward even more comprehensive analysis by incorporating other project alternatives and other project purposes as computers with larger storage capacity become available. They may move toward more exhaustive project design where only very approximate methods are now used.

In any case, the current Programs should be regarded as no more than a base on which to build. Each application to a new problem will suggest refinements to increase the accuracy or the comprehensiveness of the analysis. Any help or suggestions you as the reader may have to improve the approach will be sincerely appreciated.

APPENDIX A

FORTRAN IV LISTING

OF

THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II

```
C CENTRAL CONTROL DECK
C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL K1,K2,MANNU,MANNR,MANNT,IA,IPP,LA,LC
LOGICAL CHANEL,PP,LL,SS,LG,PTF,LTF,STF,TRACE,CHECK,LINED,HOLDNG
C READS INPUT DATA
CALL CHDATA
C INITIALIZES LOOP CONTROL FOR FLOOD DAMAGE ANALYSIS
ITOP=16
FTOP=9.210
C INITIALIZE TOTAL COST OF PLANNING PROGRAM
ACP=0.
ACS=0.
ACU=0.
ACD=0.
ACF=0.
ACL=0.
C DETERMINES WHICH TYPES OF MEASURES TO BE CONSIDERED
PP=PTF
```

```

LL=LTF
SS=STF
DO 20 I=1,MW
C INITIALIZE FACTORS IN GUMBEL EQUATION FOR EACH SUBWATERSHED
XF4(I)=0.
XF3(I)=0.
XF2(I)=0.
XF1(I)=0.
A4(I)=0.
A3(I)=0.
A2(I)=0.
A1(I)=0.
C INITIALIZE OTHER CONDITIONS FOR EACH SUBWATERSHED
CH(I) = 0.0
LOC(I)=-1
ADDCS(I)=0.
IHOLD(I)=0
W0(I)=0.0
T0(I)=0.0
NDT(I)=0
FDA(I)=0.0
DO 10 K=1,13
10 OUTPUT(I,K)=0.0
DO 20 J=9,11
20 CAP(I,J)=0.
C CALCULATE EACH SUBWATERSHED AREA FACTOR FIRST FOR 43 AND THEN FOR 0.5
C PERCENT FLOOD
DO 50 K=1,MW
DO 30 I=1,10
IF(AFCTR(1,I) .LE. AW(K) .AND. AFCTR(1,I+1) .GT. AW(K)) GO TO 40
30 CONTINUE
40 AFW(1,K)=AFCTR(2,I)+(ALOG(AW(K))-ALOG(AFCTR(1,I)))/(ALOG(AFCTR(1,I+1))-ALOG(AFCTR(1,I)))*(AFCTR(2,I+1)-AFCTR(2,I))
AFW(2,K)=AFCTR(3,I)+(ALOG(AW(K))-ALOG(AFCTR(1,I)))/(ALOG(AFCTR(1,I+1))-ALOG(AFCTR(1,I)))*(AFCTR(3,I+1)-AFCTR(3,I))
50 CONTINUE
C PROBABILITY OF OCCURANCE OF 16 FLOODS SPECIFIED FOR USE IN
C COMPUTING ANNUAL DAMAGES.
DQCK(1)=0.0005
DQCK(2)=0.003
DQCK(3)=0.0075
DQCK(4)=0.015
DQCK(5)=0.025
DQCK(6)=0.035
DQCK(7)=0.05
DQCK(8)=0.07
DQCK(9)=0.09
DQCK(10)=0.125
DQCK(11)=0.175
DQCK(12)=0.25
DQCK(13)=0.35
DQCK(14)=0.5

```

```

DQCK(15)=0.7
DQCK(16)=0.9
DO 70 I=1,16
C GUMBEL FACTORS FOR 16 SPECIFIED FLOODS
  PN=1.0-(DQCK(I))
  TEMP=1.0/ALOG(1.0/PN)
70 Y(I)=ALOG(TEMP)
C GUMBEL FACTORS - POTENTIAL DESIGN FLOODS
  DO 90 I=1,NDF
  PN=1.00-(DF(I))
  TEMP=1./ALOG(1./PN)
  YY(I)=ALOG(TEMP)
90 CONTINUE
C GUMBEL FACTOR FOR TESTING FOR IN STAGE UPSTREAM CHANNELIZATION
  TEMP=1.0/ALOG(1.0/0.995)
  YCOMP=ALOG(TEMP)
C DETERMINING WHICH CHANNELS WERE IMPROVED PRIOR TO TIME OF STUDY
  DO 110 NW=1,MW
  IF(SIC(NW) .GE. LC(NW)) GO TO 100
  CHANEL(NW)=.FALSE.
  GO TO 110
100 CHANEL(NW)=.TRUE.
C FIX THE DIMENSIONS OF CHANNELS IMPROVED BEFORE BEGINNING OF PLANNING
C PERIOD FOR THE PURPOSE OF ESTIMATING THE COST OF CHANNEL
C ENLARGEMENT. EVEN IF THE DESIGN CRITERIA USED IN BUILDING
C THE EXISTING CHANNEL DO NOT CONFORM TO THOSE USED IN THIS
C PROGRAM, THIS SUBROUTINE CAUSES ALL COSTS TO BE BASED ON THE
C SAME DESIGN CRITERIA.
  CALL CHFIX
110 CONTINUE
C CALCULATE LOCATION COST IN EACH SUBWATERSHED-STAGE UNLESS IT IS
C NOT NEEDED
  IF (.NOT. LTF .OR. HOLDNG) CALL CALCLU
  NSTAGE=1
C POINT OF RETURN WITH NEW STAGE
C INITIALIZES VALUES FOR NEW STAGE
120 DO 130 NW=1,MW
  IHN(NW)=0
  IHE(NW)=0
  IRN(NW)=0
  IRE(NW)=0
  IMPROV(NW)=1
130 RC(NW)=-1.
  TSWCS=0.
  TSWCL=0.
  TSWCP=0.
  TSWCD=0.
  TSWCU=0.
  TSWCF=0.
  DO 140 I=1,MW
  DO 140 J=4,13
140 OUTPUT(I,J)=0.0

```

```

C   BEGINS WITH MOST UPSTREAM SUBWATERSHED AND PROCEEDS DOWNSTREAM
      IF (CHECK .AND. (.NOT. TRACE)) WRITE(6,5000)
5000 FORMAT(1H1//30X,42HFOLLOWING OPTIMIZATION THROUGH INNER LOOPS /1X
      14H BEG,13X,8HCHANNELS,16X,8HLOCATION,16X,8HPROOFING,12X,7HCOST OF,
      22X,7HCOST OF,5X,5HTOTAL/11X,2H S,9X,2HQS,8X,2HCS,1X,2H L,9X,2HQL,
      38X,2HCL,1X,2H P,9X,2HQP,8X,2HCP,4X,25HFLOODING UNCERTAINTY COST )
      NW=1
C   POINT OF RETURN WITH NEW SUBWATERSHED
C   DISCOUNTED AVERAGE URBANIZATION DURING SUBWATERSHED STAGE
150 UN=USUBW(NW,NSTAGE)+(GSF*(USUBW(NW,NSTAGE+1)-USUBW(NW,NSTAGE)))/
      TIME
C   URBANIZATION AT TIME LOCATION ALTERNATIVE FIRST IMPLEMENTED
      IF(LCC(NW) .GT. 0) GO TO 160
      UZ=USUBW(NW,NSTAGE)
      GO TO 170
160 MN=LCC(NW)
      UZ=USUBW(NW,MN)
C   FACTORS FOR COMPUTING FLOOD PROOFING COST
170 PA=CPF*(UN+VLAST/VLURST*(1.0-UN))*K2(NW)*K1(NW)**2
      PB=CPF*(UZ+VLAST/VLURST*(1.0-UZ))*K2(NW)*K1(NW)**2
      PC=PA-PB
C   SELECT URBANIZATION INTERVAL AND CORRESPONDING PER ACRE VALUES
C   OF AGRICULTURAL INCOME AND FLOOD DAMAGE
      IF (UN .LT. 1.00) GO TO 180
      FUQ=FRU(11)
      GO TO 190
C   INTERPOLATION IF LESS THAN FULL URBANIZATION
180 UR=10.0*UN+1.0
      I=UR
      UQ=I
      FUQ=FRU(I)+(UQ-UR)*(FRU(I)-FRU(I+1))
190 IA=FUQ*(FIA*D(1,NW)+FIB*D(2,NW)+FIC*D(3,NW))
      FA=FUQ*(CDA*D(1,NW)+CDB*D(2,NW)+CDC*D(3,NW))
      GA = FUQ*(CAV*D(1,NW)+CBV*D(2,NW)+CCV*D(3,NW))
      IF (LTF .AND. .NOT. HOLDNG) GO TO 240
C   CALCULATE LOCATION COST MULTIPLE OF Q**0.375
      LA=CLOC(NW,NSTAGE)*K1(NW)*K2(NW)
C   DETERMINE WHETHER RIGHT-OF-WAY SHOULD BE HELD FOR LATER USE
      IF(.NOT. HOLDNG) GO TO 240
      IF (CHANEL(NW)) GO TO 200
      RBEG=VALUE(NW,NSTAGE)+VLURST*USUBW(NW,NSTAGE)/3.0
      REND=VALUE(NW,NSTAGE+1)+VLURST*USUBW(NW,NSTAGE+1)/3.0
      GO TO 210
C   NO ADDITIONAL RIGHT-OF-WAY NEEDED IF IMPROVED CHANNEL IS
C   RECTANGULAR REINFORCED CONCRETE
200 IF (LINING(NW).EQ.4) GO TO 230
      RBEG=VALUE(NW,NSTAGE)+VLURST*USUBW(NW,NSTAGE)
      REND=VALUE(NW,NSTAGE+1)+VLURST*USUBW(NW,NSTAGE+1)
C   HOLD EXTRA RIGHT-OF-WAY ONLY IF COST OF LAND AND BUILDINGS
C   THEREON INCREASING FASTER THAN DISCOUNT RATE
210 IF (REND.LE.RBEG*(1.0+R)**TIME) GO TO 230
C   RIGHT-OF-WAY SHOULD BE HELD

```

```

      CHU=CLOC(NW,NSTAGE)+IA+IPP*UN-CLEN
      IF (IHOLD(NW).LE.0) GO TO 220
      ITEMP=IHOLD(NW)
      GO TO 240
220  ITEMP=NSTAGE
      GO TO 240
C   RIGHT-OF-WAY SHOULD NOT BE HELD
230  CHU=0.0
      ITEMP=0
C   ESTABLISH FLOW-FREQUENCY RELATIONSHIPS AND DETERMINE OPTIMUM
C   STRUCTURAL MEASURES
240  CALL CHHYDR
      CALL CHOPTM
C   PROVIDE FOR MEASURES WHICH DID NOT PROVE WORTHWHILE DURING SUB-
C   WATERSHED STAGE JUST ANALYZED BUT SHOULD BE CONSIDERED
C   DURING THE NEXT ONE
      IF(PTF) GO TO 260
      PP=.FALSE.
260  IF(LTF) GO TO 280
      LL=.FALSE.
C   SETS STAGE IN WHICH LAND USE RESTRICTION BEGAN
      IF(OUTPUT(NW,5) .GT. 0.) GO TO 270
      LOC(NW)=-1
      GO TO 280
270  IF(LOC(NW) .LT. 0) LOC(NW)=NSTAGE
280  IF(STF) GO TO 420
      SS=.FALSE.
C   FIX SUBWATERSHED CONDITIONS FOR NEW CHANNELS CONSTRUCTED
      IHN(NW)=HTEMP
      IHE(NW)=HETEMP
      IRE(NW)=RETEMP
      IRN(NW)=RTEMP
      LINING(NW)=LGTEMP
      NDT(NW)=NDTEMP
      FDA(NW)=FDTEMP
C   ADD CONTINUING COST OF CHANNEL IMPROVEMENTS MADE DURING A
C   PREVIOUS STAGE
      OUTPUT(NW,4)=OUTPUT(NW,4)+ADDCS(NW)
      OUTPUT(NW,13)=OUTPUT(NW,13)+ADDCS(NW)
      ADDCS(NW)=OUTPUT(NW,4)
      IF(STEMP .LE. 0.0) GO TO 380
C   DETERMINES WHETHER CHANNEL WAS IMPROVED FOR THE FIRST TIME OR WAS
C   ENLARGED DURING CURRENT STAGE
      IF(QO(NW) .LT. OUTPUT(NW,3) .AND. .NOT. CHANEL(NW)) IMPROV(NW)=2
      IF(QO(NW) .LT. OUTPUT(NW,3) .AND. CHANEL(NW)) IMPROV(NW)=3
C   SETS NEW CHANNEL SIZE AND CAPACITY
      QO(NW)=OUTPUT(NW,3)
      TO(NW)=TTEMP
      WO(NW)=WTEMP
      AO(NW)=ATEMP
      CHANEL(NW)=.TRUE.
C   ADJUSTS CHANNELIZATION FOR COMPUTING DOWNSTREAM FLOOD PEAKS

```



```

N=INDEX(NW,1)
J=INDEX(NW,2)
IF(N .EQ. 0) GO TO 310
DO 300 I=N,J
NWD=ID(I)
TIC(NWD)=TIC(NWD)+(LC(NW)-SIC(NW))
C ADJUSTS CHANNELIZATION FOR COMPUTING SUBWATERSHED FLOOD PEAKS
300 CONTINUE
310 TIC(NW)=TIC(NW)+(LC(NW)-SIC(NW))
SIC(NW)=LC(NW)
C ACCOUNTS FOR BRIDGE CHANGES
C CAP(9) - NUMBER OF HIGHWAY BRIDGES BUILT AND/OR ENLARGED WITHIN
C PROGRAM
C CAP(10) - NUMBER OF RAILWAY BRIDGES BUILT AND/OR ENLARGED WITHIN
C PROGRAM
C CAP(11) - CAPACITY OF ALL CHANGED BRIDGES IN CFS
CAP(NW,11)=OUTPUT(NW,3)
IF(CAP(NW,9) .LT. HTEMP) GO TO 320
CAP(NW,9)=CAP(NW,9)+HTEMP
GO TO 330
320 CAP(NW,9)=HTEMP+HTEMP
330 CAP(NW,10)=CAP(NW,10)+RTEMP
DO 350 I=1,6
IF(CAP(NW,I) .LT. 0.) GO TO 360
350 IF((CAP(NW,I) .LT. OUTPUT(NW,3)*FQ(NW)) .AND. (.NOT. LINED))
1 CAP(NW,I)=-1.0
360 DO 370 I=7,8
IF(CAP(NW,I) .LT. 0.) GO TO 380
370 IF((CAP(NW,I) .LT. OUTPUT(NW,3)*FQ(NW)) .AND. (.NOT. LINED))
1 CAP(NW,I)=-1.0
C IF HOLDING OF RIGHT-OF-WAY FOR FUTURE CHANNELS IS DESIRED, THE WIDTH
C AND COST OF HOLDING THE LAND IS CALCULATED
380 IF (.NOT. HOLDNG) GO TO 420
C CASES WHERE HOLDING NOT WARRANTED
IF (LINING(NW).EQ.4.AND.(CHANEL(NW).OR.STEMP.GT.0.0)) ITEMP=0
IF (OUTPUT(NW,2) .LE. 0.025 .AND. CHANEL(NW)) ITEMP=0
IF (ITEMP.EQ.0) GO TO 410
IF (WT(NW).NE.0.0) GO TO 390
Q=QQ(2,NDF)*FQ(NW)
IF (LINING(NW).EQ.3) Q=Q*MANNNT/MANNU
C WIDTH OF EXTRA RIGHT-OF WAY
IF (LINING(NW).NE.4) WT(NW)=SAFC*(30.0+0.822*((Q/SQRT(S(NW)))**0.4
115))
IF (LINING(NW).EQ.4) WT(NW)=SAFC*(20.0+BDMIN*((Q*MANNR*(X+2.0)**0.
1667/(SQRT(S(NW))*1.49*BDMIN**1.667))**0.375))
390 IF (WT(NW) .GE. WO(NW)) GO TO 400
C HAVE ENOUGH WITHOUT HOLDING EXTRA
ITEMP=0
GO TO 410
C COST OF HOLDING EXTRA RIGHT-OF-WAY
400 CH(NW)=CHU*(WT(NW)*LC(NW)-WO(NW)*SIC(NW))*0.1212
C NO NEED TO HOLD RIGHT-OF-WAY WHERE FLOOD DAMAGES ARE SO SMALL

```

```

C           CHANNEL IMPROVEMENT CAN PROBABLY NEVER BE JUSTIFIED
           IF(CH(NW) .GE. 0.333*OUTPUT(NW,13)) ITEMP=0
410 IHOLD(NW)=ITEMP
           IF (IHOLD(NW) .NE. 0) GO TO 420
           WT(NW)=0.0
           CH(NW)=0.0
420 NW=NW+1
C RETURN TO NEXT SUBWATERSHED UNLESS ALL HAVE BEEN ANALYZED
           IF(NW .LE. MW) GO TO 150
C ADD HOLDING COSTS TO OTHER COSTS
           IF (HOLDNG) OUTPUT(NW,13)=OUTPUT(NW,13)+CH(NW)
C WRITE SUMMARY OF MEASURES EMPLOYED DURING STAGE
           WRITE(6,5010) NSTAGE
5010 FORMAT(1H1/////////18H SUMMARY FOR STAGE: I2)
           WRITE(6,5020)
5020 FORMAT(1H ,43X,29HSUMMARY OF MEASURES AND COSTS/1X,4HUNIT,1X,4H BE
           1G,13X,8HCHANNELS,16X,8HLOCATION,16X,8HPROOFING,8X,7HCOST OF,2X,7HC
           2COST OF,5X,5HTOTAL/15X,2H S,5X,2HQS,8X,2HCS,5X,2H L,5X,2HQL,8X,2HCL
           3,5X,2H P,5X,2HQP,8X,2HCP,4X,28H FLOODING UNCERTAINTY COST )
           DO 440 NW=1,MW
           WRITE(6,5030) NW,(OUTPUT(NW,I),I=1,13)
5030 FORMAT(1X,I2,2PF7.2,2X,F6.3,0P2F8.0,2X,2PF6.3,0P2F8.0,2X,2PF6.3,0P
           12F8.0,3F11.0/)
440 CONTINUE
           DO 450 NW=1,MW
C SUM ALL THE INDIVIDUAL SUBWATERSHED COSTS
           TSWCS=TSWCS+OUTPUT(NW,4) +CH(NW)
           TSWCL=TSWCL+OUTPUT(NW,7)
           TSWCP=TSWCP+OUTPUT(NW,10)
           TSWCD=TSWCD+OUTPUT(NW,11)
           TSWCU=TSWCU+OUTPUT(NW,12)
           TSWCF=TSWCP+TSWCL+TSWCS+TSWCU+TSWCD
450 CONTINUE
C WRITE TOTALS AT BOTTOM OF TABLE
           WRITE (6,5040) TSWCS, TSWCL,TSWCP,TSWCD,TSWCU,TSWCF
5040 FORMAT(1X,11HTOTAL COSTS,14X,F8.0,16X,F8.0,16X,F8.0,3X,F8.0,3X,F8.
           10,3X,F8.0////)
           IF (HOLDNG) WRITE(6,5050)
5050 FORMAT(5X,76HTOTAL COST OF CHANNELS AND GRAND TOTAL COST INCLUDE H
           OLDING COST SHOWN BELOW )
C SUM PRESENT WORTH OF COSTS FOR STAGES STUDIED THUS FAR
           RNSTMX = NSTEMX
           XTIME=NSTAGE-1
           PWFAC=1./((1.+R)**(TIME*XTIME))
           PSUM=(SPWFAC*PWFAC)/(TIME*RNSTMX)
           IF(R .GT. 0.0001) PSUM=(R*(1.+R)**(TIME*RNSTMX))/((1.+R)**(TIME*
           1 RNSTMX)-1.)*SPWFAC*PWFAC
           ACP=ACP+PSUM*TSWCP
           ACS=ACS+PSUM*TSWCS
           ACU=ACU+PSUM*TSWCU
           ACD=ACD+PSUM*TSWCD
           ACL=ACL+PSUM*TSWCL

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C WRITE OUT SUMMARY TABLE OF CHANNEL IMPROVEMENTS
  IF (.NOT. STF) CALL STROUT
C WRITE OUT SUMMARY TABLE OF LOCATION MEASURES
  IF(LTF) GO TO 480
  K=1
  DO 470 NW=1,MW
  IF(LOC(NW) .LT. 0) GO TO 470
  K=K+1
  IF (K .EQ. 2) WRITE (6,5060)
5060 FORMAT(1H ///,40X,28HSUMMARY OF LOCATION MEASURES//,35X,4HUNIT,10X
1,27HAREA OF RESTRICTED LAND USE )
  AREA=K1(NW)*K2(NW)*{(OUTPUT(NW,6)-OUTPUT(NW,3))*0.375
  WRITE(6,5070) NW,AREA
5070 FORMAT(36X,I2,15X,F10.0,6H ACRES)
  470 CONTINUE
  IF (K .EQ. 1) WRITE (6,5080)
5080 FORMAT(1H ///,10X,67HNO LAND USE ADJUSTMENT CAN BE JUSTIFIED ECONO
MICALLY IN THIS STAGE )
C WRITE OUT SUMMARY TABLE OF FLOOD PROOFING MEASURES
480 IF(PTF) GO TO 500
  K=1
  DO 490 NW=1,MW
  IF(OUTPUT(NW,9) .EQ. 0.) GO TO 490
  K=K+1
  IF (K .EQ. 2) WRITE (6,5090)
5090 FORMAT(1H ///,40X,34HSUMMARY OF FLOOD PROOFING MEASURES//,35X,4HUN
1IT,10X,14HAREA PROTECTED )
  AREA=K1(NW)*K2(NW)*{(OUTPUT(NW,9)-OUTPUT(NW,3))*0.375
  WRITE(6,5100) NW,AREA
5100 FORMAT(36X,I2,15X,F10.0,6H ACRES )
  490 CONTINUE
  IF (K .EQ. 1) WRITE (6,5110)
5110 FORMAT(1H ///,10X,67HNO FLOOD PROOFING CAN BE JUSTIFIED ECONOMICAL
ILY IN THIS STAGE )
  500 NSTAGE=NSTAGE+1
  IF(NSTAGE .GT. NSTEMX) GO TO 510
C RETURN TO NEXT STAGE UNLESS ALL STAGES HAVE BEEN ANALYZED
GO TO 120
C WRITE DISCOUNTED ANNUAL COSTS FOR ENTIRE STUDY PERIOD
510 ACF=ACP+ACL+ACS+ACU+ACD
  WRITE(6,5120) ACS,ACL,ACP,ACD,ACU,ACF
5120 FORMAT(1H1,40X,35HAVERAGE ANNUAL COST OVER ALL STAGES//45X,4HITEM,
118X,12HDOLLARS/YEAR/35X,27HCOST OF CHANNEL IMPROVEMENT,7X,F8.0/35X
2,16HCOST OF LAND USE,18X,F8.0/35X,22HCOST OF FLOOD PROOFING,12X,F8
3.0/35X,25HCOST OF RESIDUAL FLOODING,9X,F8.0/35X,19HCOST OF UNCERTA
4INTY,15X,F8.0/35X,10HTOTAL COST,24X,F8.0)
  STOP
  END

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SUBROUTINE BRIDGE(Q)

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C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
C DETERMINES NUMBER OF BRIDGES TO BE ENLARGED OR REPLACED. EXISTING
C BRIDGES WHICH BECOME TOO SMALL ARE REPLACED. BRIDGES BUILT
C IN PROGRAM ARE ENLARGED. HIGHWAY BRIDGES BUILT TO SERVE
C NEW URBAN DEVELOPMENT ARE ENLARGED AS NECESSARY, BUT INITIAL
C CONSTRUCTION COST IS NOT CHARGED TO FLOOD CONTROL.
C Q IS THE CURRENT REQUIRED CHANNEL CAPACITY
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),I HOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFD,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL LC
LOGICAL CHANEL
C FORGET OLD VALUES
HA=0.
RE = 0.
HE = 0.
RN = 0.
HN = 0.
C COUNT ADEQUATE (HA) AND INADEQUATE (HN) HIGHWAY BRIDGES. INADEQUATE
C HIGHWAY BRIDGES ARE TO BE REPLACED.
DO 20 J=1,6
IF(CAP(NW,J) .LT. 0.) GO TO 30
IF(CAP(NW,J) .GE. Q) GO TO 10
HN = HN+1.
GO TO 20
10 HA=HA+1.
20 CONTINUE
C COUNT RAILWAY BRIDGES NEEDING REPLACEMENT (RN)
30 DO 40 J=7,8
IF(CAP(NW,J) .LT. 0.) GO TO 50
IF(CAP(NW,J) .GE. Q) GO TO 40
RN = RN+1.
40 CONTINUE
C NUMBER OF BRIDGES BUILT IN PROGRAM TO BE EXTENDED
50 IF(CAP(NW,11) .GT.0. .AND. CAP(NW,11) .LT. Q) GO TO 60
GO TO 70
60 HE = CAP(NW,9)

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      RE = CAP(NW,10)
      70 IF(NSTAGE .EQ. 1) RETURN
C     ESTIMATE NUMBER OF HIGHWAY CROSSINGS WHICH WILL BE BUILT FOR FUTURE
C     URBANIZATION BUT BEFORE THE BEGINNING OF THE STAGE UNDER
C     ANALYSIS
      IF(USUBW(NW,NSTAGE) .LT. .25) RETURN
C     IF SUBWATERSHED IS BETWEEN 25 PER CENT AND 50 PER CENT URBANIZED
C     THERE SHOULD BE AT LEAST TWO HIGHWAY BRIDGES PER MILE
C     OF CHANNEL
      IF(USUBW(NW,NSTAGE) .LT. .50) GO TO 80
C     IF SUBWATERSHED IS MORE THAN 50 PER CENT URBANIZED THERE SHOULD
C     BE AT LEAST THREE HIGHWAY BRIDGES PER MILE OF CHANNEL
      NBR = LC(NW)*3.0 + 0.5
      GO TO 90
      80 NBR = LC(NW)*2.0 + 0.5
      90 BRN = NBR
      IF(.NOT. CHANEL(NW)) GO TO 100
      IF (BRN .GT. HN+HE+HA) HE=BRN-(HN+HA)
      RETURN
      100 IF (BRN .GT. HN+HE+HA) HN=BRN-(HE+HA)
      RETURN
      END

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      SUBROUTINE CALCLU
C     UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C     VERSION OF JANUARY 27, 1968
C     CALCULATES LOCATION COST PER ACRE FOR EACH SUBWATERSHED IN EACH
C     STAGE AND MAKES SURE THAT LOCATION COST WILL INCREASE AS THE
C     SUBWATERSHED BECOMES MORE URBANIZED
      COMMON AO(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
      1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
      2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
      3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
      4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),QO(25),
      5 QO5(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
      6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
      7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
      8 YY(10)
      COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
      1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
      2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
      3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
      4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
      5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
      6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
      7 XF,YCOMP,ZT,ZU
      REAL LF,IPP,IA
      LOGICAL CHECK
C     FILLS ARRAY OF PER ACRE LOCATION ADJUSTMENT COST FOR ALL SUB-
C     WATERSHED STAGES

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      DO 30 NSTAGE=1,NSTEMX
      DO 30 NW=1,MW
C     DISCOUNTED URBANIZATION OVER THE STAGE
      OUN=USUBW(NW,NSTAGE)+(GSF*(USUBW(NW,NSTAGE+1)-USUBW(NW,NSTAGE)))/TIME
      IF (UN .LT. 1.00) GO TO 10
      FUQ=FRU(11)
      GO TO 20
C     INTERPOLATION
10    UR=10.0*UN+1.0
      I=UR
      UQ=I
      FUQ=FRU(I)+(UQ-UR)*(FRU(I)-FRU(I+1))
C     AGRICULTURAL INCOME
20    IA=FUQ*(FIA*D(1,NW)+FIB*D(2,NW)+FIC*D(3,NW))
      OCLUT=LF*CRF*(VALUE(NW,NSTAGE)-PWF*VALUE(NW,NSTAGE+1)-SPWF*(IA+IPP*
      IUN))
      IF (CLUT.LT.0.0) CLUT=0.0
C     TOTAL LOCATION COST, INCLUDING COST OF ENFORCING LAND USE
C     RESTRICTIONS
30    CLOC(NW,NSTAGE)=CLUT+CLEN
      IF (NSTEMX.EQ.1) RETURN
C     IF IT IS HIGHER, REDUCES SUBWATERSHED VALUE TO THAT IN NEXT STAGE
      DO 50 NW=1,MW
      DO 50 NRS=2,NSTEMX
      NRT=NSTEMX+1-NRS
50    IF(CLOC(NW,NRT).GT. CLOC(NW,NRT+1)) CLOC(NW,NRT)=CLOC(NW,NRT+1)
      IF (.NOT. CHECK) RETURN
      WRITE (6,80)
80    FORMAT (1H1,15X,56HLOCATION ADJUSTMENT COST IN $/ACRE BY SUBWATERS
      1HED-STAGE/10X,2HNW,2X,7HSTAGE 1,2X,7HSTAGE 2,2X,7HSTAGE 3,2X,7HSTA
      2GE 4,2X,7HSTAGE 5)
      DO 70 NW=1,MW
70    WRITE (6,60) NW,(CLOC(NW,NSTAGE), NSTAGE=1,NSTEMX)
60    FORMAT (10X,12,5(2X,F7.2))
      RETURN
      END

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SUBROUTINE CDI(NN)

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C     UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C     VERSION OF JANUARY 27, 1968
C     EVALUATES AVERAGE ANNUAL VALUES FOR FLOOD DAMAGE AND UNCERTAINTY
C     DAMAGE FOR CASES WHERE LAND USE ADJUSTMENT IS NOT INVOLVED.
C     FLOOD DAMAGE IS EVALUATED BY SEPARATING STRUCTURAL FROM CROP
C     DAMAGE. CROP DAMAGE EQUALS $FA PER ACRE PLUS $GA
C     PER ACRE PER FOOT OF FLOOD DEPTH. STRUCTURAL DAMAGE EQUALS
C     COEFD*DEPTH*AREA*(MARKET VALUE) UNTIL THE FLOOD DEPTH IS GREAT
C     ENOUGH TO DESTROY 0.25*(MARKET VALUE). STRUCTURAL DAMAGE THEN
C     INCREASES AT HALF THIS RATE WITH ADDITIONAL DEPTH UNTIL THE FLOOD
C     DEPTH IS GREAT ENOUGH TO DESTROY 0.75*(MARKET VALUE). NO

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C   ADDITIONAL DAMAGE IS ADDED FOR STILL GREATER DEPTHS.  DAMAGES
C   ARE SEPARATELY DETERMINED FOR AREAS IN EACH OF THE THREE DEPTH
C   RANGES AND THEN ADDED.
COMMON AO(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1  AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2  DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3  IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4  K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),QO(25),
5  QO5(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6  TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7  VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8  YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1  CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2  FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3  LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4  PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5  RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6  STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7  XF,YCOMP,ZT,ZU
REAL K1,K2
LOGICAL UNC
C   DESIGN FLOWS LESS CHANNEL CAPACITY
QSS=QS-QO(NW)
QPP=QP-QO(NW)
C   UNIT DAMAGE FACTORS
C   URBAN STRUCTURES WITH FLOOD PROOFING
C1=0.1111*VLURST*UN*COEFDM
C   ADDITIONAL FOR URBAN STRUCTURES WITHOUT FLOOD PROOFING
C2=8.0*C1
C   AGRICULTURAL STRUCTURES WITH FLOOD PROOFING
C3=0.1111*VLAGST*(1.0-UN)*COEFDM
C   ADDITIONAL FOR AGRICULTURAL STRUCTURES WITHOUT FLOOD PROOFING
C4=8.0*C3
C   CROP DAMAGE
C5=FA*(1.0-UN)
C5G = GA*(1.0-UN)
C   COMBINED STRUCTURES WITH FLOOD PROOFING
C6=C1+C3
C   ADDITIONAL FOR COMBINED STRUCTURES WITHOUT FLOOD PROOFING
C7=C2+C4
C   EVALUATE DAMAGES FOR 16 FLOODS BEGINNING WITH THE BIGGEST
DO 100 J=1,ITOP
C   NO DAMAGE IF FLOOD CONTAINED IN CHANNEL
DFQR(J)=0.0
I = 1
CA=C6
CB=C5
CBG = C5G
IF (QSS .GE. QX(NN,J)) GO TO 100
C   EXCESS FLOW
QXC=QX(NN,J)-QSS

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C ESTIMATE MAXIMUM DEPTH OF FLOODING
  2 DMAX=K1(NW)*QXC**0.375
C TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.25
  FMAX=COEFDM*DMAX
  AZ1=0.0
  AZ2=0.0
  AZ3=0.0
  DZ1=0.0
  DZ2=0.0
  DZ3=0.0
  IF (FMAX .LE. 0.25) GO TO 4
C DEPTH AND AREA OF FLOODING IN ZONE 1
  DZ1=0.25/COEFDM
  GO TO 6
  4 DZ1=DMAX
  6 AZ1=K2(NW)*DZ1
C DAMAGE IN ZONE 1
  DFQR(J) = DFQR(J) + 0.5*(CA+CBG)*DZ1*AZ1 + CB*AZ1
  IF (FMAX .LE. 0.25) GO TO 50
C TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.75
  FMAX = 0.25 + 0.5*COEFDM*(DMAX-DZ1)
  IF (FMAX .LE. 0.75) GO TO 8
C DEPTH AND AREA OF FLOODING IN ZONE 2
  DZ2 = DZ1 + 1.0/COEFDM
  GO TO 10
  8 DZ2 = DMAX
  10 AZ2 = K2(NW)*DZ2 - AZ1
C DAMAGE IN ZONE 2
  DFQR(J) = DFQR(J) + CA*(DZ1+0.25*(DZ2-DZ1))*AZ2+(CB+5.0*CBG)*AZ2
  IF (FMAX .LE. 0.75) GO TO 50
C DEPTH AND AREA OF FLOODING IN ZONE 3
  DZ3 = DMAX
  AZ3 = K2(NW)*DZ3 - AZ2
C DAMAGE IN ZONE 3
  DFQR(J) = DFQR(J) + CA*(DZ1+0.5*(DZ2-DZ1))*AZ3+(CB+5.0*CBG)*AZ3
C NO ADDITIONAL DAMAGE IF ALL STRUCTURES IN FLOODED AREA ARE FLOOD
C PROOFED
  50 CONTINUE
  IF (I .EQ. 2) GO TO 100
  I = 2
  IF (QPP .GE. QX(NN,J)) GO TO 100
C RETURNS TO FIGURE ADDITIONAL DAMAGE IF FLOOD PROOFING IS OVERTOPPED
  QXC = QX(NN,J) - QSS
  CB = 0.0
  CBG = 0.0
  CA = C7
  GO TO 2
100 CONTINUE
C MEAN ANNUAL DAMAGE FROM FLOODS OF 16 SPECIFIED FREQUENCIES
  OCD=0.2*(DFQR(16)+DFQR(15)+DFQR(14))+0.1*(DFQR(13)+DFQR(12))+0.05*(
  1DFQR(11)+DFQR(10))+0.02*(DFQR(9)+DFQR(8)+DFQR(7))+0.01*(DFQR(6)+DF
  2QR(5)+DFQR(4))+0.005*DFQR(3)+0.004*DFQR(2)+0.001*DFQR(1)

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CU=0.0
IF(.NOT. UNC) RETURN
C STANDARD DEVIATION OF FLOODS OF 16 SPECIFIED FREQUENCIES
OSIGMA=SQRT(0.2*((DFQR(16)-CD)**2+(DFQR(15)-CD)**2+(DFQR(14)-CD)**2
1)+0.1*((DFQR(13)-CD)**2+(DFQR(12)-CD)**2)+0.05*((DFQR(11)-CD)**2+(
2DFQR(10)-CD)**2)+0.02*((DFQR(9)-CD)**2+(DFQR(8)-CD)**2+(DFQR(7)-CD
3)**2)+0.01*((DFQR(6)-CD)**2+(DFQR(5)-CD)**2+(DFQR(4)-CD)**2)+0.005
4*((DFQR(3)-CD)**2+0.004*((DFQR(2)-CD)**2+0.001*((DFQR(1)-CD)**2)
C COST OF UNCERTAINTY BASED ON THOMAS UNCERTAINTY FUND
CU=VA*SIGMA*CRFSM/SQRT(2.0*R)
RETURN
END

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SUBROUTINE CD2(NN)
C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF FEBRUARY 26, 1968
C EVALUATES AVERAGE ANNUAL VALUES FOR FLOOD DAMAGE AND UNCERTAINTY
C DAMAGE FOR CASES WHERE LAND USE ADJUSTMENT IS INVOLVED.
C FLOOD DAMAGE IS EVALUATED BY SEPARATING STRUCTURAL FROM CROP
C DAMAGE. CROP DAMAGE EQUALS $FA PER ACRE PLUS $GA
C PER ACRE PER FOOT OF FLOOD DEPTH. STRUCTURAL DAMAGE EQUALS
C COEFDM*DEPTH*AREA*(MARKET VALUE) UNTIL THE FLOOD DEPTH IS GREAT
C ENOUGH TO DESTROY 0.25*(MARKET VALUE). STRUCTURAL DAMAGE THEN
C INCREASES AT HALF THIS RATE WITH ADDITIONAL DEPTH UNTIL THE FLOOD
C DEPTH IS GREAT ENOUGH TO DESTROY 0.75*(MARKET VALUE). NO
C ADDITIONAL DAMAGE IS ADDED FOR STILL GREATER DEPTHS. DAMAGES
C ARE SEPARATELY DETERMINED FOR AREAS IN EACH OF THE THREE DEPTH
C RANGES AND THEN ADDED.
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 T0(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),W0(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL K1,K2
LOGICAL UNC
C DESIGN FLOWS LESS CHANNEL CAPACITY
QSS=QS-Q0(NW)
QPP=QP-Q0(NW)

```

QLL=QL-Q0(NW)  
 C UNIT DAMAGE FACTORS  
 C URBAN STRUCTURES WITH FLOOD PROOFING  
   C1=0.1111\*VLURST\*UZ\*COEFDM  
 C ADDITIONAL FOR URBAN STRUCTURES WITHOUT FLOOD PROOFING  
   C2=8.0\*C1  
 C AGRICULTURAL STRUCTURES WITH FLOOD PROOFING  
   C3=0.1111\*VLAGST\*(1.0-UZ)\*COEFDM  
 C ADDITIONAL FOR AGRICULTURAL STRUCTURES WITHOUT FLOOD PROOFING  
   C4=8.0\*C3  
 C CROP DAMAGE  
   C5=FA\*(1.0-UZ)  
   C5G = GA\*(1.0-UZ)  
 C COMBINED STRUCTURES WITH FLOOD PROOFING  
   C6=C1+C3  
 C ADDITIONAL FOR COMBINED STRUCTURES WITHOUT FLOOD PROOFING  
   C7=C2+C4  
 C URBAN STRUCTURES WITH FLOOD PROOFING OUTSIDE THE RESTRICTED LAND USE  
   C8 = 0.1111\*VLURST\*(UN-UZ)\*COEFDM  
 C ADDITIONAL FOR URBAN STRUCTURES WITHOUT FLOOD PROOFING OUTSIDE THE  
 C RESTRICTED LAND USE AREA  
   C9 = 8.0\*C8  
 C CORRECTION FOR AGRICULTURAL STRUCTURES DISPLACED BY URBAN STRUCTURES  
 C OUTSIDE THE RESTRICTED AREA (FLOOD PROOFING)  
   C10 = -0.1111\*VLAGST\*(UN-UZ)\*COEFDM  
 C CORRECTION FOR AGRICULTURAL STRUCTURES DISPLACED BY URBAN STRUCTURES  
 C OUTSIDE THE RESTRICTED AREA (NO FLOOD PROOFING)  
   C11 = 8.0\*C10  
 C CORRECTION FOR CROPS DISPLACED BY URBAN STRUCTURES OUTSIDE THE  
 C RESTRICTED AREA  
   C12 = -FA\*(UN - UZ)  
   C12G = -GA\*(UN - UZ)  
 C COMBINED ACCOUNTING FOR FLOOD PROOFED STRUCTURES OUTSIDE THE RESTRICT  
   C13 = C8 + C10  
 C COMBINED ACCOUNTING FOR STRUCTURES NOT FLOOD PROOFED OUTSIDE THE  
 C RESTRICTION  
   C14 = C9 + C11  
 C EVALUATE DAMAGES FOR 16 FLOODS BEGINNING WITH THE BIGGEST  
   DO 100 J=1,ITOP  
 C NO DAMAGE IF FLOOD CONTAINED IN CHANNEL  
   DFQR(J)=0.0  
   CA = C6  
   CB = C5  
   CBG = C5G  
   I = 1  
   IF (QSS .GE. QX(NN,J)) GO TO 100  
 C EXCESS FLOW  
   QXC=QX(NN,J)-QSS  
 C ESTIMATE MAXIMUM DEPTH OF FLOODING  
   2 DMAX=KI(NW)\*QXC\*\*0.375  
 C TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.25  
   FMAX=COEFDM\*DMAX

```

AZ1 = 0.0
AZ2 = 0.0
AZ3 = 0.0
DZ1 = 0.0
DZ2 = 0.0
DZ3 = 0.0
IF (FMAX .LE. 0.25) GO TO 4
C DEPTH AND AREA OF FLOODING IN ZONE 1
  DZ1=0.25/COEFD
  GO TO 6
  4 DZ1=DMAX
  6 AZ1=K2(NW)*DZ1
C DAMAGE IN ZONE 1
  IF (I.NE.4.AND.I.NE.6) GO TO 7
C SUBTRACTING OUT DAMAGES FROM AZS DEEPEST FLOODED ACRES WHICH DO NOT
C ACCRUE BECAUSE OF LAND USE RESTRICTION
  AZ11=AZ1
  IF (AZ1.GE.AZD) GO TO 201
  AZ1=0.0
  GO TO 7
201 AZ1=AZ11-AZD
  DZL=AZD/K2(NW)
  DFQR(J)=DFQR(J)+(0.5*(CA+CBG)*(DZ1+DZL)+CB)*AZ1
  GO TO 202
  7 DFQR(J) = DFQR(J) + 0.5*(CA+CBG)*DZ1*AZ1 + CB*AZ1
202 CONTINUE
  IF (FMAX .LE. 0.25) GO TO 50
C TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.75
  FMAX = 0.25 + 0.5*COEFD*(DMAX-DZ1)
  IF (FMAX .LE. 0.75) GO TO 8
C DEPTH AND AREA OF FLOODING IN ZONE 2
  DZ2 = DZ1 + 1.0/COEFD
  GO TO 10
  8 DZ2 = DMAX
  10 AZ2 = K2(NW)*DZ2 - AZ1
C DAMAGE IN ZONE 2
  IF (I.NE.4.AND.I.NE.6) GO TO 203
  AZ21=K2(NW)*DZ2-AZ11
  AZ2=AZ21
  IF (AZ11.GE.AZD) GO TO 203
  IF (AZ11+AZ21.GE.AZD) GO TO 204
  AZ2=0.0
  GO TO 203
204 DZL=AZD/K2(NW)
  AZ2=AZ11+AZ21-AZD
  DFQR(J)=DFQR(J)+(CA*(DZ1+0.25*(DZL+DZ2-2.0*DZ1))+CB+5.0*CBG)*AZ2
  GO TO 205
203 DFQR(J) = DFQR(J) + CA*(DZ1+0.25*(DZ2-DZ1))*AZ2+(CB+5.0*CBG)*AZ2
205 CONTINUE
  IF (FMAX .LE. 0.75) GO TO 50
C DEPTH AND AREA OF FLOODING IN ZONE 3
  DZ3 = DMAX

```

```

      AZ3 = K2(NW)*DZ3 - AZ2
C   DAMAGE IN ZONE 3
      IF (I.NE.4.AND.I.NE.6) GO TO 206
      AZ31=K2(NW)*DZ3-AZ21
      AZ3=AZ31
      IF (AZ11+AZ21.GE.AZD) GO TO 206
      AZ3=AZ11+AZ21+AZ31-AZD
206 DFQR(J) = DFQR(J) + CA*(DZ1+0.5*(DZ2-DZ1))*AZ3+(CB+5.0*CBG)*AZ3
C   NO ADDITIONAL DAMAGE IF ALL STRUCTURES IN FLOODED AREA ARE FLOOD
C   PROOFED
      50 CONTINUE
      IF (I .NE. 1) GO TO 60
      I = 2
      IF (QPP .GE. QX(NN,J)) GO TO 60
C   RETURNS TO FIGURE ADDITIONAL DAMAGE IF FLOOD PROOFING IS OVERTOPPED
      QXC = QX(NN,J) - QSS
      CB = 0.0
      CBG = 0.0
      CA = C7
      GO TO 2
      60 IF (I .NE. 2) GO TO 70
      I = 3
C   NO FLOODING OUTSIDE RESTRICTED AREA
      IF (QX(NN,J) .LE. QLL) GO TO 100
C   RETURNS TO FIGURE DAMAGE TO URBAN STRUCTURES (FLOOD PROOFED)
C   OUTSIDE THE RESTRICTED AREA
      QXC = QX(NN,J) - QSS
      CB = C12
      CBG = C12G
      CA = C13
      GO TO 2
      70 IF(I .NE. 3) GO TO 75
      I = 4
C   RETURNS TO REDUCE DAMAGE TOTAL BECAUSE OF RESTRICTED AREA
      IF (QSS .GE. QLL) GO TO 75
      QXCS = QLL - QSS
      AZS=K2(NW)*K1(NW)*QXCS**0.375
      AZL=K2(NW)*K1(NW)*QXC**0.375
      AZD=AZL-AZS
      CB = -C12
      CBG = -C12G
      CA = -C13
      GO TO 2
      75 IF(I .NE. 4) GO TO 80
      I = 5
C   DETERMINE IF FLOOD PROOFING IS OVERTOPPED
      IF (QPP .GT. QX(NN,J)) GO TO 100
C   RETURNS TO FIGURE DAMAGE TO URBAN STRUCTURES WITH FLOOD PROOFING
C   OVERTOPPED OUTSIDE THE RESTRICTED AREA
      QXC = QX(NN,J) - QSS
      CB = 0.0
      CBG = 0.0

```

```

      CA = C14
      GO TO 2
80 IF(I .GE. 6) GO TO 100
      I = 6
C RETURNS TO REDUCE DAMAGE TOTAL BECAUSE OF RESTRICTED AREA
      IF (QSS .GE. QLL) GO TO 100
      QXCS = QLL - QSS
      AZS=K2(NW)*K1(NW)*QXCS**0.375
      AZL=K2(NW)*K1(NW)*QXC**0.375
      AZD=AZL-AZS
      CA = -C14
      GO TO 2
100 CONTINUE
C MEAN ANNUAL DAMAGE FROM FLOODS OF 16 SPECIFIED FREQUENCIES
      OCD=0.2*(DFQR(16)+DFQR(15)+DFQR(14))+0.1*(DFQR(13)+DFQR(12))+0.05*(
1DFQR(11)+DFQR(10))+0.02*(DFQR(9)+DFQR(8)+DFQR(7))+0.01*(DFQR(6)+DF
2QR(5)+DFQR(4))+0.005*DFQR(3)+0.004*DFQR(2)+0.001*DFQR(1)
      CU=0.0
      IF(.NOT. UNC) RETURN
C STANDARD DEVIATION OF FLOODS OF 16 SPECIFIED FREQUENCIES
      OSIGMA=SQRT(0.2*((DFQR(16)-CD)**2+(DFQR(15)-CD)**2+(DFQR(14)-CD)**2
1)+0.1*((DFQR(13)-CD)**2+(DFQR(12)-CD)**2)+0.05*((DFQR(11)-CD)**2+(
2DFQR(10)-CD)**2)+0.02*((DFQR(9)-CD)**2+(DFQR(8)-CD)**2+(DFQR(7)-CD
3)**2)+0.01*((DFQR(6)-CD)**2+(DFQR(5)-CD)**2+(DFQR(4)-CD)**2)+0.005
4*((DFQR(3)-CD)**2+0.004*(DFQR(2)-CD)**2+0.001*(DFQR(1)-CD)**2)
C COST OF UNCERTAINTY BASED ON THOMAS UNCERTAINTY FUND
      CU=VA*SIGMA*CRFSM/SQRT(2.0*R)
      RETURN
      END

```

```

      SUBROUTINE CHDATA
C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
C READS IN DATA REQUIRED TO OPTIMIZE CHANNEL IMPROVEMENT IN CONJUNCTION
C WITH NONSTRUCTURAL MEASURES
      COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),I HOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),W0(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
      COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFD,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,

```

```
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,  
7 XF,YCOMP,ZT,ZU
```

```
REAL K1,K2,MANNU,MANNR,MANNT,IPP,LC,MFP,MIN,MCH,NIN,MTLCH,LF  
LOGICAL UNC,PTF,LTF,STF,TRACE,CHECK,HOLDNG  
DIMENSION QK12(25),AK12(25),DK12(25)
```

```
C INFORMATION IS READ USING A SPECIAL READ SUBROUTINE WHICH ALLOWS  
C GREATER FORMAT FREEDOM AND ALSO ALLOWS COMMENTS TO BE  
C WRITTEN ON THE DATA CARDS.
```

```
C PROGRAM CONTROL PARAMETERS
```

```
CALL READ (L1,L2,L3,L4,L5,L6,L7,NSTEMX,MW)
```

```
IF (L1 .EQ. 1) UNC=.TRUE.  
IF (L1 .NE. 1) UNC=.FALSE.  
IF (L2 .NE. 1) PTF=.TRUE.  
IF (L2 .EQ. 1) PTF=.FALSE.  
IF (L3 .NE. 1) LTF=.TRUE.  
IF (L3 .EQ. 1) LTF=.FALSE.  
IF (L4 .NE. 1) STF=.TRUE.  
IF (L4 .EQ. 1) STF=.FALSE.  
IF (L5 .EQ. 1) TRACE=.TRUE.  
IF (L5 .NE. 1) TRACE=.FALSE.  
IF (L6 .EQ. 1) CHECK=.TRUE.  
IF (L6 .NE. 1) CHECK=.FALSE.  
IF (L7 .EQ. 1) HOLDNG=.TRUE.  
IF (L7 .NE. 1) HOLDNG=.FALSE.
```

```
C SIZE AND ARRANGEMENT OF WATERSHED
```

```
DO 80 K=1,MW
```

```
80 CALL READ (AW(K))
```

```
DO 110 J=1,2
```

```
DO 110 K=1,MW
```

```
110 CALL READ (INDEX(K,J))
```

```
CALL READ (NID)
```

```
DO 120 K=1,NID
```

```
120 CALL READ (ID(K))
```

```
DO 140 K=1,MW
```

```
140 CALL READ (LC(K))
```

```
DO 190 K=1,MW
```

```
190 CALL READ (SIC(K))
```

```
DO 200 K=1,MW
```

```
200 CALL READ (TCL(K))
```

```
DO 220 K=1,MW
```

```
220 CALL READ (TIC(K))
```

```
C HYDROLOGY
```

```
CALL READ (QB43,QB05)
```

```
DO 50 IC =1,11
```

```
DO 50 JU =1,11
```

```
50 CALL READ (Q43(IC,JU))
```

```
DO 60 IC =1,11
```

```
DO 60 JU =1,11
```

```
60 CALL READ (Q05(IC,JU))
```

```
DO 30 I=1,3
```

```
DO 30 J=1,11
```

```
30 CALL READ (AFCTR(I,J))
```

```

C FLOOD DAMAGES - GENERAL
  DO 160 K=1,MW
160 CALL READ (QO(K))
C READ MAGNITUDE OF ANY KNOWN FLOOD PEAK AND ASSOCIATED MAXIMUM
C DEPTH OF FLOODING AND AREA FLOODED
  DO 130 K=1,MW
130 CALL READ (QK12(K),AK12(K),DK12(K))
  CALL READ (VA)
C FLOOD DAMAGES - URBAN
  CALL READ (VLURST,COEFD)
C FLOOD DAMAGES - AGRICULTURAL
  DO 20 K=1,MW
  DO 20 J=1,3
20 CALL READ (D(J,K))
  CALL READ (CDA,CDB,CDC,CDAV,CDBV,CDCV)
  DO 10 I=1,11
10 CALL READ (FRU(I))
  CALL READ (VLAGST)
C GENERAL DESIGN VARIABLES
  CALL READ (R,TIMST,TIME,NDF)
  DO 40 I=1,NDF
40 CALL READ (DF(I))
C CHANNEL IMPROVEMENT - PHYSICAL FACTORS
  DO 70 K=1,MW
70 CALL READ (AO(K))
  DO 150 K=1,MW
150 CALL READ (LINING(K))
  DO 100 K=1,MW
100 CALL READ (FQ(K))
  CALL READ (MANNU,MANNT,MANNR,ZU,ZT)
  DO 170 K=1,MW
170 CALL READ (S(K))
  DO 210 K=1,MW
210 CALL READ (TF(K))
  CALL READ (BDMAX,BDMIN,HMAX,NIN)
  DO 90 K=1,MW
  DO 90 J=1,8
90 CALL READ (CAP(K,J))
  CALL READ (BW)
C CHANNEL IMPROVEMENT - COST FACTORS
  CALL READ (CX,FM,CIN,CLSF,CCY,CBR,CRR,AQR,SAFC,RWF,CSM,ESM,MIN,MCH
1,MTLCH,SF)
C FLOOD PROOFING - COST FACTORS
  CALL READ (FP,VF,DD,MFP,PF)
C LOCATION ADJUSTMENT - COST FACTORS
  CALL READ (CLEN,RPI,FIA,FIB,FIC,IPP,LF)
C DEGREE OF URBANIZATION
  NDF=NSTEMX+1
  DO 230 K=1,MW
  DO 230 J=1,NDF
230 CALL READ (USUBW(K,J))
  DO 240 K=1,MW

```

```

      DO 240 J=1,NDFF
240 CALL READ (UTOTR(K,J))
C   LAND VALUE
      DO 250 K=1,MW
      DO 250 J=1,NDFF
250 CALL READ (VALUE(K,J))
C   DISCOUNTING CORRECTION TO RIGHT-OF-WAY COST
      AQR = AQR + RPI/R - 1.0
C   CALCULATE COMPOUND INTEREST FACTORS (SPECIAL FORMULAS FOR ZERO
C   DISCOUNT RATE)
      PWF=1./((1.+RPI)**TIME)
      SPWF=((1.+RPI)**TIME-1.)/(RPI*(1.+RPI)**TIME)
      IF (R .GE. 0.0001) GO TO 260
      CRF=1./TIME
      CRFSM=1./TIMST
      GSF=-0.5+TIME/2.0
      SPWFAC=TIME
      GO TO 270
260 CRF=(R*(1.+R)**TIME)/((1.+R)**TIME-1.)
      CRFSM=(R*(1.+R)**TIMST)/((1.+R)**TIMST-1.)
      GSF=1./R-(TIME*R)/(R*((1.+R)**TIME-1.))
      SPWFAC=1./CRF
C   CALCULATE FACTORS FOR COMPUTING COST OF STRUCTURAL MEASURES
270 SK1=195.6*CSM*ESM*FM*CX*(CRFSM+MCH)*SF
      SK2=NIN*CIN*ESM*CSM*(CRFSM+MIN)*SF
      SK3=0.121*AQR*CRFSM*RWF
      SK4=BW*CBR*CSM*CRFSM*SF
      SK5=CRR*CSM*CRFSM*SF
      SK6=0.037*CSM*ESM*FM*CCY*(CRFSM+MIN)*SF
      SK7=5280.*CLS*CSM*ESM*(CRFSM+MTLCH)*SF
      SK8=5280.*SK6/FM
C   CALCULATE FACTOR FOR COMPUTING COST OF FLOOD PROOFING
      CPF=0.5*DD*VF*FP*(CRF+MFP)*VLURST*PF
C   CALCULATE SUBWATERSHED VALUES OF
C   K1 = (MAXIMUM FLOODING DEPTH)/(Q**0.375)
C   K2 = (ACRES FLOODED)/(MAXIMUM FLOODING DEPTH)
      DO 280 K = 1,MW
      K1(K) = DK12(K)/((QK12(K)- Q0(K))**0.375)
280 K2(K) = AK12(K)/DK12(K)
      RETURN
      END

```

#### SUBROUTINE CHFIX

```

C   UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C   VERSION OF JANUARY 27, 1968
C   FIX THE DIMENSIONS OF CHANNELS IMPROVED BEFORE BEGINNING OF PLANNING
C   PERIOD FOR THE PURPOSE OF ESTIMATING THE COST OF CHANNEL
C   ENLARGEMENT. EVEN IF THE DESIGN CRITERIA USED IN BUILDING
C   THE EXISTING CHANNEL DO NOT CONFORM TO THOSE USED IN THIS
C   PROGRAM, THIS SUBROUTINE CAUSES ALL COSTS TO BE BASED ON THE

```



```

C      SAME DESIGN CRITERIA.
      COMMON AO(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1     AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2     DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3     IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4     K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),QO(25),
5     QO5(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6     TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7     VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8     YY(10)
      COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1     CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2     FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3     LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4     PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5     RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6     STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7     XF,YCOMP,ZT,ZU
      REAL MANNU,MANNR,MANNT
      Q=QO(NW)*FQ(NW)
      IF (LINING(NW) .GE. 3) GO TO 30
C     FIX FOR UNLINED CHANNELS
      X=BDMIN
10    H=({Q*MANNU*(X+2.*(SQRT(1.+ZU*ZU)))**0.667}/(SQRT(S(NW))*1.49*(X+Z
      IU)**1.667))**0.375
      IF(H .LE. HMAX .OR. X .GE. BDMAX) GO TO 20
      X=X+0.5
      GO TO 10
20    TO(NW)=H*(X+2.0*ZU)
      AO(NW)=0.5*H*(X*H+TO(NW))
      WO(NW)=H*(X+2.4*ZU)+30.0
      RETURN
30    IF(LINING(NW) .EQ. 4) GO TO 60
C     FIX FOR TRAPEZOIDAL LINED CHANNELS
      X=BDMIN
40    H=({Q*MANNT*(X+2.*(SQRT(1.+ZT*ZT)))**0.667}/(SQRT(S(NW))*1.49*(X+Z
      1T)**1.667))**0.375
      IF(H.LE. HMAX .OR. X .GE. BDMAX) GO TO 50
      X=X+0.5
      GO TO 40
50    TO(NW)=H*(X+2.0*ZT)
      AO(NW)=0.5*H*(X*H+TO(NW))
      WO(NW)=H*(X+2.4*ZT)+25.0
      RETURN
C     FIX FOR RECTANGULAR LINED CHANNELS
60    X=BDMIN
      H=(Q*MANNR*(X+2.0)**0.667 / (SQRT(S(NW))*1.49*X**1.667))**0.375
      TO(NW)=X*H
      AO(NW)=H*TO(NW)
      WO(NW)=TO(NW)+20.0
      RETURN
      END

```

```

SUBROUTINE CHHYDR
C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
C DETERMINES RELATIONSHIP BETWEEN FLOOD PEAK AND FREQUENCY AND
C FREQUENCY AT WHICH FLOODING BEGINS
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),W0(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFD,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIG,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL LC
LOGICAL CHANEL
C FLOOD FLOWS IN CFS ARE CALCULATED FOR THE 16 FREQUENCIES
C SPECIFIED IN ARRAY DQCK(16) AND ALSO THE 10 FREQUENCIES
C SPECIFIED IN ARRAY DF(10). FLOWS ARE CALCULATED AT THE
C BEGINNING AND END OF EACH STAGE AND DISCOUNTED TO OBTAIN
C MEAN FLOWS DURING THE STAGE.
IF(NSTAGE .EQ. 1) GO TO 20
IF(CHANEL(NW)) GO TO 10
C CONVERTING END OF STAGE FLOWS FOR PRECEDING STAGE TO BEGINNING OF
C STAGE FLOWS FOR CURRENT STAGE BY CHANGING GUMBEL FACTORS
XF3(NW)=XF4(NW)
A3(NW)=A4(NW)
10 XF1(NW)=XF2(NW)
A1(NW)=A2(NW)
C NO NEED TO DETERMINE UNIMPROVED CHANNEL FLOW IF CHANNEL IS
C ALREADY IMPROVED.
20 IF(CHANEL(NW)) GO TO 30
C CALCULATE END OF STAGE GUMBEL FACTORS FOR UNIMPROVED
C CHANNEL CONDITIONS BASED ON CURRENT DEGREE OF URBANIZATION
C AND CHANNELIZATION
C=TIC(NW)/TCL(NW)
U=UTOTR(NW,NSTAGE+1)
CALL PLACEA(QX1,U,C,Q43)
CALL PLACEA(QY1,U,C,Q05)
QXX= AW(NW)*AFW(1,NW)*QX1 *QB43
QY= AW(NW)*AFW(2,NW)*QY1*QB05

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XF4(NW)=((QY*0.579)-(QXX*5.296))/(-4.718)
A4(NW)=(4.718)/(QY-QXX)
C CALCULATE BEGINNING OF STAGE GUMBEL FACTORS FOR
C UNIMPROVED CHANNEL CONDITIONS BASED ON CURRENT DEGREE OF
C URBANIZATION AND CHANNELIZATION
U=UTOTR(NW,NSTAGE)
CALL PLACEA(QY1,U,C,Q05)
C TESTING TO SEE WHETHER UPSTREAM CHANNELS HAVE BEEN IMPROVED IN
C THIS STAGE. IF THEY HAVE, GUMBEL FACTORS AT END OF
C PREVIOUS STAGE NO LONGER APPLY
IF (NSTAGE .NE. 1) QYC=YCOMP/A3(NW)+XF3(NW)
QY= AW(NW)*AFW(2,NW)*QY1*QB05
IF(NSTAGE .NE. 1 .AND. QYC .GE. 0.999*QY) GO TO 30
CALL PLACEA(QX1,U,C,Q43)
QXX= AW(NW)*AFW(1,NW)*QX1 *QB43
XF3(NW)=((QY*0.579)-(QXX*5.296))/(-4.718)
A3(NW)=(4.718)/(QY-QXX)
C CALCULATE END OF STAGE GUMBEL FACTORS FOR IMPROVED
C CHANNEL CONDITIONS BASED ON CURRENT DEGREE OF URBANIZATION
C AND CHANNELIZATION
30 C=(TIC(NW)+LC(NW)-SIC(NW))/TCL(NW)
U=UTOTR(NW,NSTAGE+1)
CALL PLACEA(QX1,U,C,Q43)
CALL PLACEA(QY1,U,C,Q05)
QXX= AW(NW)*AFW(1,NW)*QX1 *QB43
QY= AW(NW)*AFW(2,NW)*QY1*QB05
XF2(NW)=((QY*0.579)-(QXX*5.296))/(-4.718)
A2(NW)=(4.718)/(QY-QXX)
C CALCULATE BEGINNING OF STAGE GUMBEL FACTORS FOR IMPROVED
C CHANNEL CONDITIONS BASED ON CURRENT DEGREE OF URBANIZATION
C AND CHANNELIZATION
U=UTOTR(NW,NSTAGE)
CALL PLACEA(QY1,U,C,Q05)
IF (NSTAGE .NE. 1) QYC=YCOMP/A1(NW)+XF1(NW)
QY= AW(NW)*AFW(2,NW)*QY1*QB05
IF(NSTAGE .NE. 1 .AND. QYC .GE. 0.999*QY) GO TO 40
CALL PLACEA(QX1,U,C,Q43)
QXX= AW(NW)*AFW(1,NW)*QX1 *QB43
XF1(NW)=((QY*0.579)-(QXX*5.296))/(-4.718)
A1(NW)=(4.718)/(QY-QXX)
40 IF(CHANEL(NW)) GO TO 60
C CALCULATE FLOWS FOR USE IN ESTIMATING FLOOD DAMAGES
C CALCULATE DISCOUNTED FLOWS IN EXCESS OF CHANNEL CAPACITY FOR
C UNIMPROVED CHANNELS.
DO 50 I=1,ITOP
Q3=Y(I)/A3(NW)+XF3(NW)
Q4=Y(I)/A4(NW)+XF4(NW)
QDIS=Q3+(GSF*(Q4-Q3))/TIME
QX(1,I)=QDIS-Q0(NW)
IF(QX(1,I) .LT. 0.) QX(1,I)=0.
50 CONTINUE
C CALCULATE DISCOUNTED FLOWS IN EXCESS OF CHANNEL CAPACITY FOR

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C   IMPROVED CHANNELS.
60  DO 70 I=1,ITOP
    Q1=Y(I)/A1(NW)+XF1(NW)
    Q2=Y(I)/A2(NW)+XF2(NW)
    QDIS=Q1+(GSF*(Q2-Q1))/TIME
    QX(2,I)=QDIS-Q0(NW)
    IF(QX(2,I) .LT. 0.) QX(2,I)=0.
70  CONTINUE
C   CALCULATE DISCOUNTED DESIGN FLOOD FLOWS FOR SELECTED ALTERNATIVE
C   LEVELS OF PROTECTION. IF CHANNEL IS UNIMPROVED CALCULATE FLOWS
C   FOR BOTH UNIMPROVED AND IMPROVED CONDITIONS, IF CHANNEL IS
C   IMPROVED CALCULATE FLOWS FOR IMPROVED CONDITIONS ONLY.
    IF(CHANEL(NW)) GO TO 90
    DO 80 I=1,NDF
    Q4=YY(I)/A4(NW)+XF4(NW)
    Q3=YY(I)/A3(NW)+XF3(NW)
80  QQ(1,I)=Q3+(GSF*(Q4-Q3))/TIME
90  DO 100 I=1,NDF
    Q2=YY(I)/A2(NW)+XF2(NW)
    Q1=YY(I)/A1(NW)+XF1(NW)
100 QQ(2,I)=Q1+(GSF*(Q2-Q1))/TIME
C   USING GUMBELS EQUATION CALCULATE THE FREQUENCY AT WHICH FLOODING
C   BEGINS.
    II=1
    IF(CHANEL(NW)) II=2
    YDIF=YY(1)-YY(NDF)
    XF=(QQ(II,NDF)*YY(1)/(YDIF))-(QQ(II,1)*YY(NDF)/(YDIF))
    AG=-YDIF/(QQ(II,NDF)-QQ(II,1))
    YF=AG*(Q0(NW)-XF)
    IF (YF .LT. FTOP) GO TO 110
    F=0.0
    GO TO 120
110 TEMP=EXP(-YF)
    PN=EXP(-TEMP)
    F=1.-PN
120 CONTINUE
    RETURN
    END

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SUBROUTINE CHOPTM

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C   UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C   VERSION OF JANUARY 27, 1968
C   PROCEDURE FOR OPTIMIZING CHANNEL IMPROVEMENT IN CONJUNCTION WITH
C   NONSTRUCTURAL MEASURES WITHIN A GIVEN SUBWATERSHED-STAGE
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1  AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2  DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3  IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4  K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5  Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),

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6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),W0(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFD,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL L,LA,ND
LOGICAL CHANEL,PP,LL,SS,CDSTE,LG,SG,PG,TRACE,CHECK,LINED,LINEX
C SETS INITIAL VALUES FOR SUBWATERSHED STAGE
C DESIGN CHANNEL DIMENSIONS AND KIND
ST=0.0
ND=0.0
FD=0.0
HN=0.0
HE=0.0
RN=0.0
RE=0.0
T=0.0
W=0.0
A=0.0
NDTEMP=NDT(NW)
FDTEMP=FDA(NW)
ATEMP=0.
HETEMP=0.
HTEMP=0.
RTEMP=0.
RETEMP=0.
STEMP=0.
TTEMP=0.
WTEMP=0.
LGTEMP=LINING(NW)
QP=QO(NW)
QL=QO(NW)
QS=QO(NW)
CTT=0.
C SETS WHETHER DOWNSTREAM COSTS HAVE BEEN CALCULATED AND LOCATION,
C STRUCTURAL, AND FLOOD PROOFING MEASURES HAVE BEEN PROVEN
C TO BE ECONOMICAL DURING SUBWATERSHED STAGE
CDSTE=.FALSE.
LINEX=.FALSE.
LG=.FALSE.
SG=.FALSE.
PG=.FALSE.
C FLOOD FREQUENCY AND DISCHARGE EXISTING CHANNEL WILL CONTAIN
OUTPUT(NW,1)=F
IF(CHANEL(NW)) OUTPUT(NW,2)=F
OUTPUT(NW,3)=QO(NW)

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C CALCULATE DAMAGES DUE TO UNRESTRICTED FLOODING BY USE OF SUB-
C ROUTINE CD1.
  NN=1
  IF(CHANEL(NW)) NN=2
  CALL CD1(NN)
  CF=CD+CU
  CT=CF
  OUTPUT(NW,11)=CD
  OUTPUT(NW,12)=CU
  OUTPUT(NW,13)=CT
C PRINT SUMMARY OF COSTS (DAMAGES, UNCERTAINTY AND TOTAL) DUE TO
C UNRESTRICTED FLOODING
  IF (TRACE) WRITE(6,5000)
5000 FORMAT(1H1//30X,42HFOLLOWING OPTIMIZATION THROUGH INNER LOOPS /1X
14H BEG,13X,8HCHANNELS,16X,8HLOCATION,16X,8HPROOFING,12X,7HCOST OF,
22X,7HCOST OF,5X,5HTOTAL/11X,2H S,9X,2HQS,8X,2HCS,1X,2H L,9X,2HQL,
38X,2HCL,1X,2H P,9X,2HQP,8X,2HCP,4X,25HFLOODING UNCERTAINTY COST )
  IF(CHECK) WRITE(6,5010) NW,(OUTPUT(NW,I),I=1,13)
5010 FORMAT(1X,I2,2HBG,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
  IF(CT .LE. 0.) GO TO 510
C DETERMINE THE OPTIMUM LEVEL OF FLOOD PROOFING
  IF(PP) GO TO 80
  PT=1.
  DO 70 IP=1,NDF
  IF(TRACE) WRITE(6,5020) NW
5020 FORMAT (1X,I2,3H P)
  P=DF(IP)
C NO MEASURES TAKEN IF FLOW OF THE FREQUENCY BEING CONSIDERED DOES
C NOT CAUSE FLOODING
  IF(F .LT. P) GO TO 70
  QP=QQ(1,IP)
  IF(CHANEL(NW)) QP=QQ(2,IP)
  CP= PA*(QP-QS)**0.75
  IF(CP .LE. 0.) GO TO 80
C IF FLOOD PROOFING FOR FREQUENCY BEING CONSIDERED IS MORE COSTLY
C THAN UNRESTRICTED FLOODING, NO NEED TO CONSIDER FLOOD
C PROOFING AGAINST LARGER FLOWS
  IF(CP .GT. CT) GO TO 10
  GO TO 20
10 PP=.TRUE.
  GO TO 80
20 PG=.TRUE.
  NN=1
  IF(CHANEL(NW)) NN=2
C CALCULATE RESIDUAL DAMAGES
  CALL CD1(NN)
C EXPERIENCE HAS SHOWN PROOFING WILL NOT MAKE IT LATER ON IF IT MISSES
C THE FIRST TWO TIMES
  IF(PT .GE. 2. .AND. CTT .GT. 0.) GO TO 30
  GO TO 40
C IF COST OF MEASURES BEING CONSIDERED EXCEEDS COST OF CURRENTLY
C OPTIMUM MEASURES, NO NEED TO CONSIDER THESE MEASURES AGAINST

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C      EVEN LARGER FLOWS
30 IF(CTT .LT. CD+CP+CU) GO TO 80
40 CTT=CD+CP+CU
C      IF TOTAL COST ASSOCIATED WITH MEASURES BEING CONSIDERED IS LESS
C      THAN COST OF PREVIOUS OPTIMUM, PRINTS SUMMARY OF THESE NEW
C      OPTIMUM MEASURES
      IF(CTT .LT. CT) GO TO 50
      GO TO 60
50 CT=CTT
   OUTPUT(NW,5)=0.0
   OUTPUT(NW,6)=0.0
   OUTPUT(NW,7)=0.0
   OUTPUT(NW,8)=P
   OUTPUT(NW,9)=QP
   OUTPUT(NW,10)=CP
   OUTPUT(NW,11)=CD
   OUTPUT(NW,12)=CU
   OUTPUT(NW,13)=CT
   IF(CHECK) WRITE(6,5030) NW,(OUTPUT(NW,I),I=1,13)
5030 FORMAT(1X,I2,2H P,1X,2PF7.3,3(1X,2PF6.3,OPF8.0,F8.0),3F10.0)
60 PT=PT+1.
70 CONTINUE
C      DETERMINE THE OPTIMUM LEVEL OF LAND USE ADJUSTMENT
80 IF(LL) GO TO 170
   DO 160 IL=1,NDF
   IF(TRACE) WRITE(6,5040) NW
5040 FORMAT(1X,I2,3H L)
   L=DF(IL)
   IF(F .LT. L) GO TO 160
   QP=QO(NW)
   QL=QQ(1,IL)
   IF(CHANEL(NW)) QL=QQ(2,IL)
   CL= LA*(QL-QS)**0.375
   IF(CL .GT. CT .AND. .NOT. LG) LL=.TRUE.
   IF(CL .GT. CT) GO TO 170
   LG=.TRUE.
   NN=1
   IF(CHANEL(NW)) NN=2
   CALL CD2(NN)
   CTT=CD+CL+CU
   IF(CTT .LT. CT) GO TO 90
   GO TO 100
90 CT=CTT
   OUTPUT(NW,5)=L
   OUTPUT(NW,6)=QL
   OUTPUT(NW,7)=CL
   OUTPUT(NW,8)=0.0
   OUTPUT(NW,9)=0.0
   OUTPUT(NW,10)=0.0
   OUTPUT(NW,11)=CD
   OUTPUT(NW,12)=CU
   OUTPUT(NW,13)=CT

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        IF(CHECK) WRITE(6,5050) NW,(OUTPUT(NW,I),I=1,13)
5050  FORMAT(1X,I2,2H L,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
C   DETERMINE THE OPTIMUM COMBINATION OF FLOOD PROOFING AND LAND USE
C   ADJUSTMENT
100  IF(PP) GO TO 160
      PT=1.
      DO 150 IP=1,NDF
        IF(TRACE) WRITE(6,5060) NW
5060  FORMAT (1X,I2,5H L+P)
        P=DF(IP)
        IF(F .LT. P) GO TO 150
        QP=QQ(1,IP)
        IF(CHANEL(NW)) QP=QQ(2,IP)
        CP= PB*(QP-QS)**0.75
        IF(QP .GT. QL) CP=CP+ PC*(((QP-QS)**0.375-(QP-QL)**0.375)**2
        IF(CP .LE. 0.) GO TO 160
        IF(CP+CL .GT. CT .AND. .NOT. PG) PP=.TRUE.
        IF(CP+CL .GT. CT) GO TO 160
        PG=.TRUE.
        NN=1
        IF(CHANEL(NW)) NN=2
        CALL CDZ(NN)
        IF(PT .GE. 2.) GO TO 110
        GO TO 120
110  IF(CTT .LT. CP+CL+CD+CU) GO TO 160
120  CTT=CD+CL+CP+CU
        IF(CTT .LT. CT) GO TO 130
        GO TO 140
130  CT=CTT
        OUTPUT(NW,5)=L
        OUTPUT(NW,6)=QL
        OUTPUT(NW,7)=CL
        OUTPUT(NW,8)=P
        OUTPUT(NW,9)=QP
        OUTPUT(NW,10)=CP
        OUTPUT(NW,11)=CD
        OUTPUT(NW,12)=CU
        OUTPUT(NW,13)=CT
        IF(CHECK) WRITE(6,5070) NW,(OUTPUT(NW,I),I=1,13)
5070  FORMAT(1X,I2,2HLP,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
140  PT=PT+1.
150  CONTINUE
      IF(LL) GO TO 170
160  CONTINUE
C   DETERMINE THE OPTIMUM LEVEL OF CHANNEL IMPROVEMENT
170  IF(SS) GO TO 510
      DO 500 IS=1,NDF
        IIS=IS+1
        IF(TRACE) WRITE(6,5080) NW
5080  FORMAT (1X,I2,3H S)
        ST=DF(IS)
        IF(F .LT. ST) GO TO 500

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QP=QQ(2,IS)
QL=QP
QS=QP
C SELECTS LEAST COSTLY TYPE OF CHANNEL IMPROVEMENT, CALCULATES
C COSTS AND DIMENSIONS
CALL STR
IF(CS .GT. CT) GO TO 510
C RESIDUAL DAMAGES ALREADY CALCULATED IN "STR" IF LINED = .TRUE.
IF (.NOT. LINED) CALL CD1(2)
IF(CS+CD+CU .GT. CT) GO TO 230
IF(CHANEL(NW) .OR. SG) GO TO 180
GO TO 190
180 CDST=0.0
GO TO 200
190 IF(CDSTE) GO TO 200
C CALCULATES COST INCURRED IN DOWNSTREAM SUBWATERSHEDS DUE TO
C CHANNELIZATION IN CURRENT SUBWATERSHED, UNLESS THIS WAS
C ALREADY CALCULATED
CALL COST
CDSTE=.TRUE.
200 CTT=CS+CD+CU
IF (CS+CDST .GT. CT) GO TO 510
IF(CTT+CDST .LT. CT) GO TO 210
GO TO 230
C LINING OF PREVIOUSLY CONSTRUCTED CHANNELS
210 IF (LINED) GO TO 520
CT=CTT
SG=.TRUE.
LINEX=.FALSE.
OUTPUT(NW,2)=ST
OUTPUT(NW,3)=QS
OUTPUT(NW,4)=CS
DO 220 M=5,10
220 OUTPUT(NW,M)=0.
OUTPUT(NW,11)=CD
OUTPUT(NW,12)=CU
OUTPUT(NW,13)=CT
C PRESERVES DIMENSIONS OF OPTIMUM CHANNEL IN ORDER TO RETURN TO THEM
C IF SUBSEQUENT TRIAL CHANNEL DOES NOT WORK OUT
LGTEMP=LINING(NW)
STEMP=ST
NDTEMP=ND
FDTEMP=FD
HTEMP=HN
HETEMP=HE
RTEMP=RN
RETEMP=RE
TTEMP=T
WTEMP=W
ATEMP=A
IF(CHECK) WRITE(6,5090) NW,(OUTPUT(NW,I),I=1,13)
5090 FORMAT(1X,I2,2H S,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)

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C EVALUATE FLOOD PROOFING TO SUPPLEMENT CHANNEL IMPROVEMENT

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230 IF(IIS .EQ. NDF) GO TO 510
    IF(PP) GO TO 330
    PT=1.
    DO 320 IP=IIS,NDF
    IF(TRACE) WRITE(6,5100) NW
5100 FORMAT (1X,I2,5H S+P)
    P=DF(IP)
    QP=QQ(2,IP)
    CP= PA*(QP-QS)**0.75
    IF(CP .LE. 0.) GO TO 330
    IF(CP+CS .GT. CT) GO TO 330
    CALL CD1(2)
    IF(PT .GE. 2.) GO TO 240
    GO TO 250
240 IF(CTT .LT. CD+CP+CS+CU) GO TO 330
250 CTT=CD+CP+CS+CU
    IF(SG .OR. CHANEL(NW)) GO TO 260
    GO TO 270
260 IF(CTT .LT. CT) GO TO 300
    GO TO 310
270 IF(.NOT. CDSTE) GO TO 280
    GO TO 290
280 CALL CDST
    CDSTE=.TRUE.
    IF (CS+CDST .GT. CT) GO TO 510
290 IF(CTT+CDST .LT. CT) GO TO 300
    GO TO 310
300 CT=CTT
    SG=.TRUE.
    LINEX=.FALSE.
    OUTPUT(NW,2)=ST
    OUTPUT(NW,3)=QS
    OUTPUT(NW,4)=CS
    OUTPUT(NW,5)=0.0
    OUTPUT(NW,6)=0.0
    OUTPUT(NW,7)=0.0
    OUTPUT(NW,8)=P
    OUTPUT(NW,9)=QP
    OUTPUT(NW,10)=CP
    OUTPUT(NW,11)=CD
    OUTPUT(NW,12)=CU
    OUTPUT(NW,13)=CT
    LGTEMP=LINING(NW)
    STEMP=ST
    NDTEMP=ND
    FDTEMP=FD
    HTEMP=HN
    HETEMP=HE
    RTEMP=RN
    RETEMP=RE
    TTEMP=T

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WTEMP=W
ATEMP=A
IF(CHECK) WRITE(6,5110) NW,(OUTPUT(NW,1),I=1,13)
5110 FORMAT(1X,I2,2HSP,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
310 PT=PT+1.
320 CONTINUE
C EVALUATE LOCATION ADJUSTMENT TO SUPPLEMENT CHANNEL IMPROVEMENT
330 IF(LL) GO TO 500
DO 490 IL=IIS,NDF
IF(TRACE) WRITE(6,5120) NW
5120 FORMAT(1X,I2,5H S+L)
L=DF(IL)
QP=QS
QL=QQ(2,IL)
CL= LA*(QL-QS)**0.375
IF(CL+CS .GT. CT) GO TO 500
CALL CD2(2)
CTT=CD+CL+CS+CU
IF(SG .OR. CHANEL(NW)) GO TO 340
GO TO 350
340 IF(CTT .LT. CT) GO TO 380
GO TO 390
350 IF(.NOT. CDSTE) GO TO 360
GO TO 370
360 CALL COST
CDSTE=.TRUE.
IF(CS+CDST .GT. CT) GO TO 510
370 IF(CTT+CDST .LT. CT) GO TO 380
GO TO 390
380 CT=CTT
SG=.TRUE.
LINEX=.FALSE.
OUTPUT(NW,2)=ST
OUTPUT(NW,3)=QS
OUTPUT(NW,4)=CS
OUTPUT(NW,5)=L
OUTPUT(NW,6)=QL
OUTPUT(NW,7)=CL
OUTPUT(NW,8)=0.0
OUTPUT(NW,9)=0.0
OUTPUT(NW,10)=0.0
OUTPUT(NW,11)=CD
OUTPUT(NW,12)=CU
OUTPUT(NW,13)=CT
LGTEMP=LINING(NW)
STEMP=ST
NDTEMP=ND
FDTEMP=FD
HTEMP=HN
HETEMP=HE
RTEMP=RN
RETEMP=RE

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TTEMP=T
WTEMP=W
ATEMP=A
IF(CHECK) WRITE(6,5130) NW,(OUTPUT(NW,I),I=1,13)
5130 FORMAT(1X,I2,2HSL,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
C EVALUATE ALL THREE TYPES OF MEASURES IN COMBINATION
390 IF(PP) GO TO 490
PT=1.
DO 480 IP=IIS,NDF
IF(TRACE) WRITE(6,5140) NW
5140 FORMAT (1X,I2,7H S+L+P)
P=DF(IP)
QP=QQ(2,IP)
CP= PB*(QP-QS)**0.75
IF(QP .GT. QL) CP=CP+ PC*((QP-QS)**0.375-(QP-QL)**0.375)**2
IF(CP .EQ. 0.) GO TO 490
IF(CP+CL+CS .GT. CT) GO TO 490
CALL CD2(2)
IF(PT .GE. 2.) GO TO 400
GO TO 410
400 IF(CTT .LT. CD+CP+CL+CS+CU) GO TO 490
410 CTT=CD+CP+CS+CL+CU
IF (SG .OR. CHANEL(NW)) GO TO 420
GO TO 430
420 IF(CTT .LT. CT) GO TO 460
GO TO 470
430 IF (.NOT. CDSTE) GO TO 440
GO TO 450
440 CALL COST
CDSTE=.TRUE.
IF (CS+CDST .GT. CT) GO TO 510
450 IF (CTT+CDST .LT. CT) GO TO 460
GO TO 470
460 CT=CTT
SG=.TRUE.
LINEX=.FALSE.
OUTPUT(NW,2)=ST
OUTPUT(NW,3)=QS
OUTPUT(NW,4)=CS
OUTPUT(NW,5)=L
OUTPUT(NW,6)=QL
OUTPUT(NW,7)=CL
OUTPUT(NW,8)=P
OUTPUT(NW,9)=QP
OUTPUT(NW,10)=CP
OUTPUT(NW,11)=CD
OUTPUT(NW,12)=CU
OUTPUT(NW,13)=CT
LGTEMP=LINING(NW)
STEMP=ST
NDTEMP=ND
FDTEMP=FD

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```

      HTEMP=HN
      HETEMP=HE
      RTEMP=RN
      RETEMP=RE
      TTEMP=T
      WTEMP=W
      ATEMP=A
      IF(CHECK) WRITE(6,5150) NW,(OUTPUT(NW,I),I=1,13)
5150  FORMAT(1X,I2,3HSLP,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)
      470 PT=PT+1.
      480 CONTINUE
      490 CONTINUE
C   END OF CHANNEL IMPROVEMENT LOOPS
      500 CONTINUE
C   POINT OUTSIDE ALL MEASURE ANALYSIS LOOPS
      510 CONTINUE
      IF (LINEX).LINED = .TRUE.
      RETURN
C   SET OUTPUT IF LINING PREVIOUSLY CONSTRUCTED CHANNEL
      520 OUTPUT(NW,3)=QLINED
      OUTPUT(NW,4)=CS
      DO 530 K=5,10
      530 OUTPUT(NW,K)=0.0
C   DETERMINE FREQUENCY OF WATER LEAVING LINED CHANNEL
      YF=AG*(QLINED-XF)
C   OUTPUT WITH CHANNEL OF VERY LARGE CAPACITY
      IF (YF .LT. FTOP) GO TO 540
      OUTPUT(NW,2)=0.0005
      OUTPUT(NW,11)=0.0
      OUTPUT(NW,12)=0.0
      OUTPUT(NW,13)=CS
      GO TO 550
C   OUTPUT WITH SMALLER CHANNEL
      540 TEMP=EXP(-YF)
      OUTPUT(NW,2)=1.0-EXP(-TEMP)
      OUTPUT(NW,11)=CD
      OUTPUT(NW,12)=CU
      OUTPUT(NW,13)=CTT
      550 LGTEMP=3
      CT=OUTPUT(NW,13)
      STEMP=OUTPUT(NW,2)
      NDTEMP=0.0
      FDTEMP=0.0
      HTEMP=0.0
      HETEMP=0.0
      RTEMP=0.0
      RETEMP=0.0
      TTEMP=T
      WTEMP=W
      ATEMP=A
      IF(CHECK) WRITE(6,5160) NW,(OUTPUT(NW,I),I=1,13)
5160  FORMAT(1X,I2,2HLN,1X,2PF7.3,3(1X,2PF6.3,0PF8.0,F8.0),3F10.0)

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C RETURN TO SEE IF ENLARGING TO A GREATER DESIGN FREQUENCY IS MORE
C ECONOMICAL THAN LINING TO A SMALLER ONE
  F=DF(IS)
  ISX=IS+2
  IF (ISX .LE. NDF) F=DF(ISX)
  LINEX = .TRUE.
  GO TO 170
  END

```

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SUBROUTINE COST
C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
C CALCULATE COSTS INCURRED IN DOWNSTREAM SUBWATERSHEDS WHEN UPSTREAM
C SUBWATERSHEDS ARE CHANNELIZED. COST INCURRED IS ESTIMATED
C FROM THE COST WHICH WOULD BE REQUIRED TO ENLARGE DOWNSTREAM
C CHANNELS TO HANDLE THE INCREASE IN THE PEAK OF THE DESIGN
C FLOOD OR THE INCREASE IN EXPECTED FLOOD DAMAGE WROUGHT BY
C THE LARGER FLOWS, WHICHEVER OF THE TWO IS SMALLER.
  COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
  1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
  2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
  3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
  4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
  5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
  6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
  7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
  8 YY(10)
  COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
  1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
  2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
  3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
  4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
  5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
  6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
  7 XF,YCOMP,ZT,ZU
  REAL MANNU,MANNR,MANNT,LC,ND
  LOGICAL CHANEL,LLL,HOLDNG,CHECK
C LOOK UP NUMBER OF DOWNSTREAM SUBWATERSHEDS
  JL = INDEX(NW,1)
  JH = INDEX(NW,2)
  CDST = 0.
  IF(JL.EQ. 0) RETURN
  LLL=.FALSE.
C SUM DOWNSTREAM SUBWATERSHEDS ONE AT A TIME
  DO 220 I = JL, JH
  CPRT=0.0
  DPRT=0.0
  NWD = ID(I)
C DOWNSTREAM FLOW INCREASED BY CHANGE IN CHANNELIZATION FROM C TO CI
  C = TIC(NWD)/TCL(NWD)

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      U=UTOTR(NWD,NSTAGE)
      CI=(TIC(NWD)+(LC(NW)-SIC(NW)))/TCL(NWD)
C   RECTANGULAR CHANNELS WILL NOT REQUIRE LARGER BRIDGES OR MORE
C   RIGHT-OF-WAY.
      IF(LINING(NWD).EQ.4) GO TO 50
C   SUMS AFFECTED BRIDGES IN DOWNSTREAM SUBWATERSHEDS
      BH = 0.
      BR = 0.
      DO 10 J=1,6
10  IF(CAP(NWD,J).GE.0.) BH=BH+1.
      DO 20 J=7,8
20  IF(CAP(NWD,J).GE.0.) BR=BR+1.
      BH = BH+CAP(NWD,9)
      BR = BR+CAP(NWD,10)
C   RIGHT-OF-WAY COST
      IF (RC(NWD).GE.0.0) GO TO 50
      LTA=NSTAGE
      LTB=NSTAGE
      IF (LOC(NWD).GT.0) LTB=LOC(NWD)
      IF(.NOT. HOLDNG) GO TO 30
      IF (IHOLD(NWD).LE.0) GO TO 30
      LTA=IHOLD(NWD)
      LTB=LTA
30  IF(CHANEL(NWD)) GO TO 40
      RC(NWD)=VALUE(NWD,LTA)+VLURST*USUBW(NWD,LTB)/3.0
      GO TO 50
40  RC(NWD)=VALUE(NWD,LTA)+VLURST*USUBW(NWD,LTB)
C   FLOW FREQUENCY RELATIONSHIP IF UPSTREAM WERE NOT CHANNELIZED
50  CALL PLACEA(QX1,U,C,Q43)
      CALL PLACEA(QY1,U,C,Q05)
      QXX=AW(NWD)*AFW(1,NWD)*QX1*QB43
      QY=AW(NWD)*AFW(2,NWD)*QY1*QB05
      XF=((QY*0.578)-(QXX*5.296))/(-4.718)
      AF=(4.718)/(QY-QXX)
C   SAVES PARAMETERS FOR ESTIMATING DOWNSTREAM DAMAGES
      XFL=XF
      AFL=AF
C   'LRG' SUFFIX INDICATES ENLARGED CHANNEL REQUIRED TO HANDLE FLOW
C   AS INCREASED BY UPSTREAM CHANNELIZATION
C   'SML' SUFFIX INDICATES CHANNEL REQUIRED TO HANDLE FLOW WITH NO
C   UPSTREAM CHANNELIZATION
C   LOOKS UP DIMENSIONS IF CHANNEL WAS IMPROVED
      IF(.NOT. CHANEL(NWD)) GO TO 60
      YF=AF*(QO(NWD)-XF)
      IF (YF.GT.FTOP) GO TO 210
      QSML=QO(NWD)*FQ(NWD)
      ASML=AO(NWD)
      TSML=TO(NWD)
      WSML=WO(NWD)
      GO TO 100
C   IF CHANNEL NOT IMPROVED, PICKS A LIKELY CHANNEL DESIGN FLOW BASED ON
C   THE EXTENT OF URBAN DEVELOPMENT

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60 PN=0.96
   IF(U-0.07 .GT. 0.) PN=0.99
   IF (U-0.20 .GT. 0.) PN=0.995
   TEMP=1./ALOG(1./PN)
   YF=ALOG(TEMP)
   QSML=(YF/AF+XF)*FQ(NWD)
   Q=QSML
C   SIZES CHANNEL FOR THIS DESIGN FLOW
70 X=BDMIN
80 H=((Q*MANNU*(X+2.*(SQRT(1.+ZU*ZU)))*0.667)/((SQRT(S(NWD))*1.49*(X+
   1ZU)**1.667))**0.375
   IF(H .LE. HMAX .OR. X .GE. BDMAX) GO TO 90
   X=X+0.5
   GO TO 80
90 B=X*H
   IF(LLL) GO TO 110
   TSML=B+2.0*ZU*H
   ASML=0.5*H*(B+TSML)
   WSML=B+2.4*ZU*H+30.0
C   FLOW FREQUENCY RELATIONSHIP IF UPSTREAM WERE CHANNELIZED
100 CALL PLACEA(QX1,U,CI,Q43)
   CALL PLACEA(QY1,U,CI,Q05)
   QXX=AW(NWD)*AFW(1,NWD)*QX1*QB43
   QY=AW(NWD)*AFW(2,NWD)*QY1*QB05
   XF=((QY*0.579)-(QXX*5.296))/(-4.718)
   AF=(4.718)/(QY-QXX)
C   FINDS DPRT = INCREASE IN DOWNSTREAM FLOOD DAMAGES
   CALL QCST(NWD,AF,AFL,XFL,DPRT,U)
C   FINDS DESIGN FREQUENCY FLOOD PEAK IF UPSTREAM CHANNELIZED
   QLRG=(YF/AF+XF)*FQ(NWD)
   IF(LINING(NWD) .GE. 2 .AND. CHANEL(NWD)) GO TO 120
   LLL=.TRUE.
   Q=QLRG
C   BACK TO SIZE CHANNEL FOR LARGER FLOW
   GO TO 70
110 LLL=.FALSE.
   IF(LINING(NWD) .EQ. 2 .AND. CHANEL(NWD)) GO TO 130
   TLRG=B+2.0*ZU*H
   ALRG=0.5*H*(B+TLRG)
   WLRG=B+2.4*ZU*H+30.0
C   COST FOR UNLINED CHANNEL - NO DROPS
   CPRT = SK1*LC(NWD)*(ALRG-ASML)+SK3*RC(NWD)*LC(NWD)*(WLRG-WSML)+
   1(SK4*BH+SK5*BR)*(TLRG-TSML)
   GO TO 210
120 IF(LINING(NWD) .NE. 2) GO TO 150
C   UNLINED CHANNEL WITH DROPS
   LLL=.TRUE.
   Q=QLRG
C   BACK TO SIZE CHANNEL FOR LARGER FLOW
   GO TO 70
130 SLOPE=S(NWD)
C   ADJUST CHANNEL SLOPE AND B/H RATIO IF NECESSARY TO AVOID EXCEEDING

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C          ALLOWABLE TRACTIVE FORCE
140 X=1.05*X
    SLOPE=0.95*SLOPE
    H=((Q*MANNU*(X+2.*(SQRT(1.+ZU*ZU)))**0.667)/(SQRT(SLOPE)*1.49*(X+Z
    IU)**1.667))**0.375
    TFF=62.4*H*SLOPE
    IF(TFF .GT. TF(NWD)) GO TO 140
    B=X*H
    TLRG=B+2.0*ZU*H
    ALRG=0.5*H*(B+TLRG)
    WLRG=B+2.4*H*ZU+30.
C . DETERMINING NUMBER AND FALL OF DROP STRUCTURES
    FT=5280.*LC(NWD)*(S(NWD)-SLOPE)
    ND=AINT(0.25*FT+0.5)
    IF(ND .EQ. 0.) ND=1.0
    FD=F/ND
    HSML=(TSML-SQRT(TSML*TSML-4.0*ZU*ASML))/(2.0*ZU)
    BSML=TSML-2.0*ZU*HSML
    CPRT = SK1*LC(NWD)*(ALRG-ASML)+SK3*RC(NWD)*LC(NWD)*(WLRG-WSML)+
    1*(SK4*BH+SK5*BR)*(TLRG-TSML)
    CPRT=CPRT+SK6*ND*(5.2*B*H+4.3*B*FD+9.5*B+5.5*ZU*H*H+2.0*ZU*H*FD+32
    1.0*ZU*H+2.0*ZU*FD+13.0*ZU+14.1*H*H+14.6*H*FD+3.3*FD*FD+14.1*H+0.05
    26*B*H*H+0.188*H*H*H+0.132*FD*H*H+9.9)
    H=HSML
    B=BSML
    CPRT=CPRT-SK6*ND*(5.2*B*H+4.3*B*FD+9.5*B+5.5*ZU*H*H+2.0*ZU*H*FD+32
    1.0*ZU*H+2.0*ZU*FD+13.0*ZU+14.1*H*H+14.6*H*FD+3.3*FD*FD+14.1*H+0.05
    26*B*H*H+0.188*H*H*H+0.132*FD*H*H+9.9)
    GO TO 210
C . TRAPEZOIDAL LINED CHANNEL
150 IF(LINING(NWD) .EQ. 4) GO TO 180
    HSML=(TSML-SQRT(TSML*TSML-4.0*ZT*ASML))/(2.0*ZT)
    BSML=TSML-2.0*ZT*HSML
    PSML=BSML+2.2*HSML*SQRT(1.+ZT*ZT)
    Q5=QSML
    HT=HSML
    H1=1.05*HSML
160 Q6=(1.49*SQRT(S(NWD))*((BSML+ZT*H1)*H1)**1.667)/(MANNT*(BSML+2.*H1
    1*SQRT(1.+ZT*ZT))**0.667)
    IF(Q6 .GE. QLRG) GO TO 170
    Q5=Q6
    HT=H1
    H1=1.05*H1
    GO TO 160
170 HLRG=HT+((H1-HT)*(QLRG-Q5))/(Q6-Q5)
    TLRG=BSML+2.*ZT*HLRG
    ALRG=0.5*HLRG*(BSML+TLRG)
    WLRG=BSML+2.4*HLRG*ZT+25.
    PLRG=BSML+2.2*HLRG*SQRT(1.+ZT*ZT)
    CPRT = SK1*LC(NWD)*(ALRG-ASML)+SK3*RC(NWD)* LC(NWD)*(WLRG-WSML)
    1+(SK4*BH+SK5*BR)*(TLRG-TSML)+SK7*(PLRG-PSML)*LC(NWD)
    GO TO 210

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C  RECTANGULAR LINED CHANNEL
180 HSML=ASML/TSML
    Q5=QSML
    HT=HSML
    H1=1.1*HSML
190 Q6=(1.49*SQRT(S(NW))*(TSML*H1)**1.667)/(MANNR*(TSML+2.0*H1)**0.667
    1)
    IF (Q6 .GE. QLRG) GO TO 200
    Q5=Q6
    HT=H1
    H1=1.1*H1
    GO TO 190
200 HLRG=HT+((H1-HT)*(QLRG-Q5))/(Q6-Q5)
    CPRT = SK8*2.0*(HLRG-HSML)*LC(NWD)
C  DETERMINES LESSER COST - INCREASED FLOOD DAMAGES OR ENLARGING CHANNEL
C  (CPRT IS LESS THAN 0.0 WHEN LINING IS ADDED BECAUSE ITS EVALUATION
C  DOES NOT RECOGNIZE USE OF SIDE SLOPE ZU FOR A LINED CHANNEL).
210 IF(DPRT .LT. CPRT .OR. CPRT .LT. 0.0) CPRT = DPRT
C  END OF LOOP SUMMING DOWNSTREAM SUBWATERSHEDS
    IF (CHECK) WRITE(6,5000) NW,NWD,CPRT
5000 FORMAT(10X,3HNW=,I2,5X,4HNWD=,I2,5X,16HDOWNSTREAM COST=,F8.2)
220 CDST=CDST+CPRT
    RETURN
    END

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SUBROUTINE PLACEA(QR,UU,CC,X)
C  UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C  VERSION OF JANUARY 27, 1968
C  ARITHMETIC INTERPOLATION SUBROUTINE. UU=TOTAL TRIBUTARY
C  URBANIZATION, CC=TOTAL TRIBUTARY CHANNELIZATION, X=TWO DIMENSIONAL
C  ARRAY WITH FLOW AS A FUNCTION OF CC AND UU, 'QR'=VALUE RETURNED TO
C  MAIN PROGRAM. UU AND CC ARE DECIMAL VALUES. 'QR' IS IN CFS.
U=UU
C=CC
DIMENSION X(11,11)
U=U*10.+1.
C=C*10.+1.
I=C
J=U
CI=I
UJ=J
QA=X(I,J)+(C-CI)*(X(I+1,J)-X(I,J))
QB=X(I,J+1)+(C-CI)*(X(I+1,J+1)-X(I,J+1))
QR=QA+(U-UJ)*(QB-QA)
RETURN
END

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SUBROUTINE QCST(NWD,AF,AFL,XFL,DPRT,U)

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C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C VERSION OF JANUARY 27, 1968
C ESTIMATES INCREASE IN FLOOD DAMAGE IN DOWNSTREAM SUBWATERSHED NWD
C WHICH WOULD RESULT IF THE CHANNELS IN UPSTREAM SUBWATERSHED
C NW WERE IMPROVED ASSUMING NO DAMAGE REDUCTION MEASURES WERE
C TAKEN
C RESULT IS COMPARED WITH COST OF DOWNSTREAM CHANNEL IMPROVEMENT IN
C SUBROUTINE COST, THE SMALLER OF THE TWO COSTS IS TAKEN
COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),I HOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),QO(25),
5 QO5(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BD MAX,BD MIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QBO5,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL K1,K2
LOGICAL UNC
C UNIT DAMAGE FACTORS
C STRUCTURES
C6 = (VLURST*U + VLAGST*(1.0-U))*COEFDM
C CROPS
C5 = FA*(1.0 - U)
C5G = GA*(1.0-U)
C EVALUATE DAMAGES FOR 16 FLOODS BEGINNING WITH THE BIGGEST
DO 100 J=1,ITOP
C NO DAMAGE IF FLOOD CONTAINED IN CHANNEL
DFQR(J)=0.0
I = 1
C FLOW AND FLOOD DAMAGE WITH UPSTREAM CHANNEL IMPROVED
QLRG = Y(J)/AF + XF - QO(NWD)
IF (QLRG .LE. 0.0) GO TO 100
QXC = QLRG
C ESTIMATE MAXIMUM DEPTH OF FLOODING
2 DMAX=K1(NW)*QXC**0.375
C TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.25
FMAX=COEFDM*DMAX
IF (FMAX .LE. 0.25) GO TO 4
C DEPTH AND AREA OF FLOODING IN ZONE 1
DZ1=0.25/COEFDM
GO TO 6
4 DZ1=DMAX
6 AZ1=K2(NW)*DZ1

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C  DAMAGE IN ZONE 1
    DFQR(J) = DFQR(J) + 0.5*(C6+C5G)*DZ1*AZ1 + C5*AZ1
    IF (FMAX .LE. 0.25) GO TO 50
C  TEST WHETHER MAXIMUM FRACTION OF MARKET VALUE DESTROYED EXCEEDS 0.75
    FMAX = 0.25 + 0.5*COEFDM*(DMAX-DZ1)
    IF (FMAX .LE. 0.75) GO TO 8
C  DEPTH AND AREA OF FLOODING IN ZONE 2
    DZ2 = DZ1 + 1.0/COEFDM
    GO TO 10
    8 DZ2 = DMAX
    10 AZ2 = K2(NW)*DZ2 - AZ1
C  DAMAGE IN ZONE 2
    DFQR(J) = DFQR(J) + C6*(DZ1+0.25*(DZ2-DZ1))*AZ2+(C5+5.0*C5G)*AZ2
    IF (FMAX .LE. 0.75) GO TO 50
C  DEPTH AND AREA OF FLOODING IN ZONE 3
    DZ3 = DMAX
    AZ3 = K2(NW)*DZ3 - AZ2
C  DAMAGE IN ZONE 3
    DFQR(J) = DFQR(J) + C6*(DZ1+0.5*(DZ2-DZ1))*AZ3+(C5+5.0*C5G)*AZ3
    50 CONTINUE
    IF (I .EQ. 2) GO TO 100
    I = 2
    QSML = Y(J)/AFL + XFL - QO(NWD)
    IF (QSML .LE. 0.0) GO TO 100
    QXC = QSML
    C6 = -C6
    C5 = -C5
    C5G = -C5G
    GO TO 2
    100 CONTINUE
C  MEAN ANNUAL FLOOD DAMAGE FROM FLOODS OF 16 SPECIFIED FREQUENCIES
    ODY=0.2*(DFQR(16)+DFQR(15)+DFQR(14))+0.1*(DFQR(13)+DFQR(12))+0.05*(
    1DFQR(11)+DFQR(10))+0.02*(DFQR(9)+DFQR(8)+DFQR(7))+0.01*(DFQR(6)+DF
    2QR(5)+DFQR(4))+0.005*DFQR(3)+0.004*DFQR(2)+0.001*DFQR(1)
    IF(.NOT. UNC) GO TO 150
C  STANDARD DEVIATION OF FLOODS OF 16 SPECIFIED FREQUENCIES
    OSIGMA=SQRT(0.2*((DFQR(16)-CD)**2+(DFQR(15)-CD)**2+(DFQR(14)-CD)**2
    1)+0.1*((DFQR(13)-CD)**2+(DFQR(12)-CD)**2)+0.05*((DFQR(11)-CD)**2+(
    2DFQR(10)-CD)**2)+0.02*((DFQR(9)-CD)**2+(DFQR(8)-CD)**2+(DFQR(7)-CD
    3)**2)+0.01*((DFQR(6)-CD)**2+(DFQR(5)-CD)**2+(DFQR(4)-CD)**2)+0.005
    4*((DFQR(3)-CD)**2+0.004*(DFQR(2)-CD)**2+0.001*(DFQR(1)-CD)**2)
C  TOTAL DAMAGE INCLUDING UNCERTAINTY
    DY=DY+VA*SIGMA*CRFSM/SQRT(2.0*R)
    150 DPRT = DY
    RETURN
    END

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SUBROUTINE STR

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C  UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II
C  VERSION OF JANUARY 27, 1968

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C SELECT THE LEAST COSTLY TYPE OF CHANNEL IMPROVEMENT AND DETERMINE THE
C RESULTING DESIGN DIMENSIONS AND COSTS
COMMON AO(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),KI(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),QO(25),
5 QO5(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)
COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFD,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIC,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU
REAL MANNU,MANNR,MANNT,LC,ND
LOGICAL CHANEL,LINED,HOLDNG
LINED=.FALSE.
ND=NDT(NW)
FD=FDA(NW)
C CALCULATE RIGHT-OF-WAY COST IN $/ACRE IF THIS WAS NOT DONE PREVIOUSLY
IF(RC(NW).GE.0.0) GO TO 30
LTA=NSTAGE
LTB=NSTAGE
C DETERMINE STAGE WHEN NEW BUILDING FIRST RESTRICTED FROM FLOOD PLAIN
IF(LOC(NW).GT.0) LTB=LOC(NW)
C DETERMINE STAGE WHEN LAND PURCHASED FOR HOLDING
IF(.NOT. HOLDNG) GO TO 10
IF(IHOLD(NW).LE.0) GO TO 10
LTA=IHOLD(NW)
LTB=LTA
10 IF(CHANEL(NW)) GO TO 20
C RIGHT-OF-WAY COST = LAND VALUE + STRUCTURES' VALUE
C IF NEW CHANNEL IS BEING BUILT, CAN SELECT ALINEMENT TO AVOID DIS-
C PLACING BUILDINGS. THUS ASSUME 1/3 OF REGULAR VALUE OF
C STRUCTURES
RC(NW)=VALUE(NW,LTA)+VLURST*USUBW(NW,LTB)/3.0
GO TO 30
C IF CHANNEL IS ALREADY IMPROVED, ALINEMENT IS FIXED, MORE STRUC-
C TURES DISPLACED. THUS ASSUME FULL VALUE OF STRUCTURES
20 RC(NW)=VALUE(NW,LTA)+VLURST*USUBW(NW,LTB)
C DETERMINE SUBWATERSHED WEIGHTED AVERAGE DESIGN FLOW
30 Q=QS*FQ(NW)
C CALL BRIDGE UNLESS RECTANGULAR LINED CHANNEL HAS ALREADY BEEN BUILT
IF(LINING(NW) .NE. 4 .OR. .NOT. CHANEL(NW)) CALL BRIDGE(Q)
C GO TO SECTION ON CHANNEL TYPE DESIRED
IF(LINING(NW) .EQ. 3) GO TO 160
IF(LINING(NW) .EQ. 4) GO TO 230

```

```

C SELECT DIMENSIONS FOR UNLINED CHANNEL
  X=BDMIN
40 H=((Q*MANNU*(X+2.*(SQRT(1.+ZU*ZU))))**0.667)/(SQRT(S(NW))*1.49*(X+Z
  1U)**1.667)**0.375
  IF(H .LE. HMAX .OR. X .GE. BDMAX) GO TO 50
  X=X+0.5
  GO TO 40
C CHECK DEVELOPED AGAINST CRITICAL TRACTIVE FORCE
50 TFF=62.4*H*S(NW)
  IF(TFF .GT. TF(NW)) GO TO 90
C CALCULATE FINAL UNLINED CHANNEL DIMENSIONS
  B=X*H
  T=B+2.*ZU*H
  A=0.5*H*(B+T)
  AEXTRA = A - AO(NW)
  IF (AEXTRA .LT. 0.2*A) AEXTRA = 0.2*A
  W=B+2.4*H*ZU+30.
C CALCULATE UNLINED CHANNEL COST
  CS=SK1*LC(NW)* AEXTRA +SK2*LC(NW)+SK3*RC(NW)*(W-WO(NW))*LC(NW)+
  1SK4*(HN*T+HE*(T-TO(NW)))+SK5*(RN*T+RE*(T-TO(NW)))
  IF (LINING(NW).EQ.1) GO TO 60
  LINING(NW)=1
  TT=T
  AA=A
  WW=W
C IF NOT COMMITTED TO CHANNEL TYPE, TRY OTHERS TO SEE IF THEY ARE LESS
C EXPENSIVE
  GO TO 160
60 IF(.NOT. CHANEL(NW)) RETURN
C IT MAY BE LESS EXPENSIVE TO INCREASE CHANNEL CAPACITY BY LINING THAN
C BY ENLARGING
  AZ=A
  A=AO(NW)
  SLOPE=S(NW)
  HU=(TO(NW)-SQRT(TO(NW)**2 -4.0*ZU*A))/(2.0*ZU)
  BU=TO(NW)-2.0*ZU*HU
70 PUI=2.0*HU*SQRT(1.0+ZU*ZU)
  PU=BU+1.1*PUI
C CAPACITY OF CHANNEL IF LINED
  QLINED=(1.49*A*((A/(BU+PUI))**0.667)*SQRT(SLOPE))/MANNT
C LINING ALSO REDUCES RESIDUAL DAMAGES BY INCREASING CAPACITY MORE
C THAN DOES ENLARGING
  QSS=QS
  QPP=QP
  QLL=QL
  CALL CD1(2)
  CDZ=CD
  CUZ=CU
  QS=QLINED
  QP=QS
  QL=QS
  CALL CD1(2)

```

```

C GO BACK TO ENLARGING IF THAT IS LESS EXPENSIVE
  IF (CS.LE.SK7*PU*LC(NW)+CD+CU-CDZ-CUZ) GO TO 80
C SET COSTS AND CONSTANTS FOR LINED CHANNEL
  CS=SK7*PU*LC(NW)
  T=TO(NW)
  W=WO(NW)
  A=AO(NW)
  LINED=.TRUE.
  RETURN
C RESTORE FLOWS ALTERED TO ESTIMATE RESIDUAL DAMAGES
80 QS=QSS
  QL=QLL
  QP=QPP
  A=AZ
  RETURN
C DETERMINE SLOPE REDUCTION REQUIRED TO REDUCE TRACTIVE FORCE TO
C CRITICAL
90 SLOPE=S(NW)
100 WRITE(6,313) TFF
313 FORMAT(10X,5HTFF =,F5.2)
  X=1.05*X
  SLOPE=0.95*SLOPE
  H=((Q*MANNU*(X+2.*(SQRT(1.+ZU*ZU)))**0.667)/(SQRT(SLOPE)*1.49*(X+Z
  1U)**1.667))**0.375
  TFF=62.4*H*SLOPE
  IF(TFF .GT. TF(NW)) GO TO 100
C CALCULATE FINAL DIMENSION OF UNLINED CHANNEL WITH DROP STRUCTURES
  B=X*H
  T=B+2.*ZU*H
  A=0.5*H*(B+T)
  AEXTRA = A - AO(NW)
  IF (AEXTRA .LT. 0.2*A) AEXTRA = 0.2*A
  W=B+2.4*H*ZU+30.0
C AMOUNT OF FALL PROVIDED BY AND NUMBER OF DROP STRUCTURES
  FT=5280.*LC(NW)*(S(NW)-SLOPE)
C FALL LIMITED TO FIVE FEET PER DROP STRUCTURE
  IF (FT .GT. 5.0) GO TO 110
  FD=FT
  ND=1.0
  GO TO 130
110 IF (FT .GT. 10.0) GO TO 120
  FD=0.5*FT
  ND=2.0
  GO TO 130
120 ND=AIN(0.25*FT+0.5)
  FD=FT/ND
C COST OF BUILDING NEW OR ENLARGING OLD DROP STRUCTURES
130 CS=SK1*LC(NW)* AEXTRA +SK2*LC(NW)+SK3*RC(NW)*((W-WO(NW))*LC(NW)+
  1SK4*(HN*T+HE*(T-TO(NW))))+SK5*((RN*T+RE*(T-TO(NW))))
C FORMULA FOR COST OF SCS TYPE C DROP STRUCTURE
  CS=CS+SK6*ND*(5.2*B*H+4.3*B*FD+9.5*B+5.5*ZU*H*H+2.0*ZU*H*FD+32.0*Z
  1U*H+2.0*ZU*FD+13.0*ZU+14.1*H*H+14.6*H*FD+3.3*FD*FD+14.1*H+0.056*B*

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```

2H*H+0.188*H*H*H+0.132*FD*H*H+9.9)
IF(.NOT. CHANEL(NW) .OR. LINING(NW) .NE. 2) GO TO 140
H=(TO(NW)-SQRT(TO(NW)*TO(NW)-4.0*ZU*AO(NW)))/(2.0*ZU)
B=TO(NW)-2.0*ZU*H
CS=CS-SK6*ND*(5.2*B*H+4.3*B*FD+9.5*B+5.5*ZU*H*H+2.0*ZU*H*FD+32.0*Z
1U*H+2.0*ZU*FD+13.0*ZU+14.1*H*H+14.6*H*FD+3.3*FD*FD+14.1*H+0.056*B*
2H*H+0.188*H*H*H+0.132*FD*H*H+9.9)
C SEE IF LESS EXPENSIVE TO INCREASE CAPACITY BY LINING
IF (.NOT. CHANEL(NW)) GO TO 140
AZ=A
HU=H
BU=B
A=AO(NW)
GO TO 70
140 IF(LINING(NW) .EQ. 2) RETURN
IF(LINING(NW) .EQ. 0) GO TO 150
LINING(NW) =2
RETURN
150 LINING(NW)=2
TT=T
AA=A
WW=W
C TRAPEZOIDAL LINED CHANNELS
160 IF(CHANEL(NW)) GO TO 200
C BUILDING NEW ONES
C MAKE X (B/H) AS SMALL AS POSSIBLE WITHIN LIMITS TO HOLD DOWN
C RIGHT-OF-WAY COST
X=BDMIN
170 H=((Q*MANNT*(X+2.*(SQRT(1.+ZT*ZT))))**0.667)/(SQRT(S(NW))*1.49*(X+Z
1T)**1.667)**0.375
IF(H.LE. HMAX .OR. X .GE. BDMAX) GO TO 180
X=X+0.5
GO TO 170
180 B=X*H
T=B+2.*ZT*H
A=0.5*H*(B+T)
AEXTRA = A - AO(NW)
IF (AEXTRA .LT. 0.2*A) AEXTRA = 0.2*A
W=B+2.4*H*ZT+25.
PR=B+2.2*H*SQRT(1.+ZT*ZT)
CSL=SK1*LC(NW)* AEXTRA +SK2*LC(NW)+SK3*RC(NW)*{W-WO(NW)}*LC(NW)+
1SK4*(HN*T+HE*(T-TO(NW)))+SK5*(RN*T+RE*(T-TO(NW)))
CSL=CSL+SK7*PR*LC(NW)
IF(CSL.GT.CS .AND. LINING(NW).EQ.1 .OR. LINING(NW).EQ.2) GO TO 270
IF (LINING(NW) .EQ. 3) GO TO 190
LINING(NW)=3
TT=T
AA=A
WW=W
CS=CSL
GO TO 230
190 CS=CSL

```



```

RETURN
C ENLARGING TRAPEZOIDAL LINED CHANNELS
200 HO=(TO(NW)-SQRT(TO(NW)*TO(NW)-4.0*ZT*AO(NW)))/(2.0*ZT)
BO=TO(NW)-2.0*ZT*HO
PO=BO+2.2*HO*SQRT(1.+ZT*ZT)
Q5=QO(NW)
HT=HO
C ENLARGE IN FIVE PERCENT INCREMENTS AND TEST TO SEE IF LARGE ENOUGH
H1=1.05*HO
210 Q6=(1.49*SQRT(S(NW))*((BO+ZT*H1)*H1)**1.667)/(MANNT*(BO+2.0*H1*SQRT(1.+ZT*ZT))**0.667)
IF (Q6 .GE. Q) GO TO 220
Q5=Q6
HT=H1
H1=1.05*H1
GO TO 210
C INTERPOLATION FOR PROPER DEPTH ONCE IT HAS BEEN BOUNDED
220 H=HT+((H1-HT)*(Q-Q5))/(Q6-Q5)
B=BO
T=B+2.*ZT*H
A=0.5*H*(B+T)
W=B+2.4*H*ZT+25.
PR=B+2.2*H*SQRT(1.+ZT*ZT)
WEXTRA=W-WO(NW)
IF (WEXTRA .LT. 0.0) WEXTRA=0.0
CS=SK1*LC(NW)*(A-AO(NW))+SK2*LC(NW)+SK3*RC(NW)*WEXTRA *LC(NW)+
1SK4*(HN*T+HE*(T-TO(NW)))+SK5*(RN*T+RE*(T-TO(NW)))
CS=CS+SK7*(PR-PO)*LC(NW)
RETURN
C RECTANGULAR LINED CHANNELS
230 IF(CHANEL(NW)) GO TO 240
C BUILDING NEW ONES
X=BDMIN
H=(Q*MANNR*(X+2.0)**0.667 / (SQRT(S(NW))*1.49*X**1.667))**0.375
T=X*H
A=H*T
AEXTRA = A - AO(NW)
IF (AEXTRA .LT. 0.2*A) AEXTRA = 0.2*A
W=T+20.0
PR=T+2.1*H
CSR=SK1*LC(NW)* AEXTRA +SK2*LC(NW)+SK3*RC(NW)*(W-WO(NW))*LC(NW)+
1SK4*(HN*T+HE*(T-TO(NW)))+SK5*(RN*T+RE*(T-TO(NW)))
CSR=CSR+SK8*(PR+2.0)*LC(NW)
IF (CSR .GT. CS .AND. LINING(NW) .NE. 4) GO TO 270
LINING(NW)=4
CS=CSR
RETURN
C ENLARGING RECTANGULAR LINED CHANNELS
240 HO=AO(NW)/TO(NW)
BO=TO(NW)
Q5=QO(NW)
HT=HO

```

```

H1=1.05*H0
250 Q6=(1.49*SQRT(S(NW))*(B0*H1)**1.667)/(MANNR*(B0+2.0*H1)**0.667)
IF (Q6 .GE. Q) GO TO 260
Q5=Q6
HT=H1
H1=1.05*H1
GO TO 250
260 H=HT+((H1-HT)*(Q-Q5))/(Q6-Q5)
CS=SK8*2.0*(H-H0)*LC(NW)
T=TO(NW)
W=WO(NW)
A=H*T
RETURN
270 T=TT
A=AA
W=WW
RETURN
END

```

SUBROUTINE STROUT

C UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II  
C VERSION OF JANUARY 27, 1968  
C PRINTS OUT SUMMARY OF CHANNEL IMPROVEMENTS

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COMMON A0(25),A1(25),A2(25),A3(25),A4(25),ADDCS(25),AFCTR(3,11),
1 AFW(2,25),AW(25),CAP(25,11),CH(25),CHANEL(25),CLOC(25,5),D(3,25),
2 DF(10),DFQR(16),DQCK(16),FDA(25),FQ(25),FRU(11),ID(100),IHE(25),
3 IHN(25),IHOLD(25),IMPROV(25),INDEX(25,2),IRE(25),IRN(25),K1(25),
4 K2(25),LC(25),LINING(25),LOC(25),NDT(25),OUTPUT(25,13),Q0(25),
5 Q05(11,11),Q43(11,11),QQ(2,10),QX(2,16),RC(25),S(25),SIC(25),
6 TO(25),TCL(25),TF(25),TIC(25),USUBW(25,6),UTOTR(25,6),
7 VALUE(25,6),WO(25),WT(25),XF1(25),XF2(25),XF3(25),XF4(25),Y(16),
8 YY(10)

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COMMON A,AG,ATEMP,BDMAX,BDMIN,CD,CDA,CDAV,CDB,CDBV,CDC,CDCV,CDST,
1 CHECK,CLEN,COEFDM,CPF,CRF,CRFSM,CS,CU,F,FA,FD,FDTEMP,FIA,FIB,FIG,
2 FTOP,GA,GSF,HE,HETEMP,HMAX,HN,HOLDNG,HTEMP,IPP,ITOP,LA,LF,LGTEMP,
3 LINED,LL,LTF,MANNR,MANNT,MANNU,MW,ND,NDF,NDTEMP,NSTAGE,NSTEMX,NW,
4 PA,PB,PC,PP,PTF,PWF,QB05,QB43,QL,QLINED,QP,QS,R,RE,RETEMP,RN,
5 RTEMP,SAFC,SK1,SK2,SK3,SK4,SK5,SK6,SK7,SK8,SPWF,SPWFAC,SS,STEMP,
6 STF,T,TIME,TIMST,TRACE,TTEMP,UN,UNC,UZ,VA,VLAGST,VLURST,W,WTEMP,
7 XF,YCOMP,ZT,ZU

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REAL LC

LOGICAL CHANEL,HOLDNG

WRITE(6,5000)

```

5000 FORMAT(1H1,40X,3IH SUMMARY OF CHANNEL IMPROVEMENTS//128H UNIT      T
1 IYPE OF          STAGE          CAPACITY  X-SECTION  TOP      ROW  DEPTH  D
2 ROP STRUCTURES  HIGHWAY BRIDGES  RAILROAD BRIDGES  )
WRITE(6,5010)

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```

5010 FORMAT(10X,7HCHANNEL,7X,7H ACTION,16X,4HAREA,5X,12HWIDTH  WIDTH,9X
1,55HNUMBER HEIGHT  SAME BUILT EXTEND  SAME BUILT EXTEND      )
WRITE(6,5020)

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5020 FORMAT(37X,4HCFS.,5X,7HSQ. FT.,4X,3HFT.,4X,3HFT.,4X,3HFT.,12X,3HFT
1./)
DO 260 NW=1,MW
C IF CHANNEL NOT IMPROVED, NO CHANNEL IMPROVEMENT SUMMARY WRITTEN
IF(.NOT. CHANEL(NW)) GO TO 260
ND=NDT(NW)
FD=FDA(NW)
C DEPTH OF FLOW DEPENDS ON CHANNEL TYPE
IF(LINING(NW) .LE. 2) HO=(TO(NW)-SQRT(TO(NW)**2-4.0*ZU*AO(NW)))/(
12.0*ZU)
IF(LINING(NW) .EQ. 3) HO=(TO(NW)-SQRT(TO(NW)**2-4.0*ZT*AO(NW)))/(
12.0*ZT)
IF(LINING(NW) .EQ. 4) HO=AO(NW)/TO(NW)
ICAP9=CAP(NW,9)
ICDIF=IHN(NW)+IHE(NW)
IUH = IABS(ICAP9 - ICDIF)
DO 10 I=1,6
IF (CAP(NW,I) .LT. 0.0) GO TO 20
10 IUH=IUH+1
20 IF (NSTAGE .EQ. 1 .OR. USUBW(NW,NSTAGE) .LT. 0.25) GO TO 50
C IF SUBWATERSHED IS BETWEEN 25 PER CENT AND 50 PER CENT URBANIZED
C THERE SHOULD BE AT LEAST TWO BRIDGES PER MILE OF CHANNEL
IF (USUBW(NW,NSTAGE) .LT. 0.50) GO TO 30
C IF SUBWATERSHED IS MORE THAN 50 PER CENT URBANIZED THERE SHOULD
C BE AT LEAST THREE BRIDGES PER MILE OF CHANNEL
NBR=3.0*LC(NW)+0.5
GO TO 40
30 NBR=2.0*LC(NW)+0.5
40 IF (IUH+ICDIF .LT. NBR) IUH=NBR-ICDIF
50 IUR=0
IF (IMPROV(NW) .EQ. 1) IUR=CAP(NW,10)
DO 60 I=7,8
IF(CAP(NW,I) .LT. 0.) GO TO 70
60 IUR=IUR+1
70 III=LINING(NW)
C PRINT SUMMARY OF CHANNEL IMPROVEMENTS DEPENDING ON TYPE OF LINING
C AND WHETHER CHANNEL WAS UNCHANGED, BUILT, ENLARGED OR
C LINED DURING THE CURRENT SUBWATERSHED STAGE
GO TO (80,90,100,110),III
80 IF(IMPROV(NW)-2) 120,130,140
90 IF(IMPROV(NW)-2) 150,160,170
100 IF(IMPROV(NW)-2) 180,190,200
110 IF(IMPROV(NW)-2) 230,240,250
120 WRITE(6,5030) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5030 FORMAT(1X,I2,2X,17HUNLINED W/O DROPS,2X,9HUNCHANGED,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
130 WRITE(6,5040) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5040 FORMAT(1X,I2,2X,17HUNLINED W/O DROPS,2X,9HBUILT ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)

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GO TO 260
140 WRITE(6,5050) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5050 FORMAT(1X,I2,2X,17HUNLINED W/O DROPS,2X,9HENLARGED ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
150 WRITE(6,5060) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5060 FORMAT(1X,I2,2X,17HUNLINED W DROPS ,2X,9HUNCHANGED,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
160 WRITE(6,5070) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5070 FORMAT(1X,I2,2X,17HUNLINED W DROPS ,2X,9HBUILT ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
170 WRITE(6,5080) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5080 FORMAT(1X,I2,2X,17HUNLINED W DROPS ,2X,9HENLARGED ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
180 WRITE(6,5090) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5090 FORMAT(1X,I2,2X,17HTRAPEZOIDAL LINED,2X,9HUNCHANGED,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
190 WRITE(6,5100) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5100 FORMAT(1X,I2,2X,17HTRAPEZOIDAL LINED,2X,9HBUILT ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
C TRAPEZOIDAL LINING ADDED - DISCOVERED BY A DESIGN FREQUENCY
C NOT IN ARRAY DF
200 DO 210 KDF=1,NDF
IF (OUTPUT(NW,2) .EQ. DF(KDF)) GO TO 220
210 CONTINUE
WRITE(6,5110) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5110 FORMAT(1X,I2,2X,28HTRAPEZOIDAL LINING ADDED ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
220 WRITE(6,5120) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5120 FORMAT(1X,I2,2X,17HTRAPEZOIDAL LINED,2X,9HENLARGED ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
230 WRITE(6,5130) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5130 FORMAT(1X,I2,2X,17HRECTANGULAR LINED,2X,9HUNCHANGED,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
240 WRITE(6,5140) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),

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1 IHE(NW),IUR,IRN(NW),IRE(NW)
5140 FORMAT(1X,I2,2X,17HRECTANGULAR LINED,2X,9HBUILT      ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
GO TO 260
250 WRITE(6,5150) NW,QO(NW),AO(NW),TO(NW),WO(NW),HO,ND,FD,IUH,IHN(NW),
1 IHE(NW),IUR,IRN(NW),IRE(NW)
5150 FORMAT(1X,I2,2X,17HRECTANGULAR LINED,2X,9HENLARGED ,F8.0,F11.1,F9.
11,F7.1,F6.1,5X,I2,F8.1,4X,I2,3X,I2,5X,I2,5X,I2,3X,I2,5X,I2)
260 CONTINUE
C WRITE OUT SUMMARY TABLE OF HOLDING COST
IF (.NOT. HOLDNG) RETURN
K=1
DO 270 NW=1,MW
IF (IHOLD(NW).EQ.0) GO TO 270
ACH={WT(NW)*LC(NW)-WO(NW)*SIC(NW)}*0.1212
CHU=CH(NW)/ACH
IF (K.EQ.1) WRITE (6,5160) NSTAGE
5160 FORMAT(1H ///,
1 15X,76H SUMMARY OF RIGHT-OF-WAY PRESERVED FOR FUTURE CHANNE
2L CONSTRUCTION IN STAGE I2//2X,4HUNIT,3X,14H HOLDING WIDTH,2X,14H
3CHANNEL WIDTH,6X,10H AREA HELD,2X,17HUNIT HOLDING COST,2X,18HTOTAL
4 HOLDING COST/16X,4HFEET,12X,4HFEET,12X,5HACRES,5X,16HDOLLARS PER
5ACRE,7X,7HDOLLARS)
WRITE (6,5170) NW,WT(NW),WO(NW),ACH,CHU,CH(NW)
5170 FORMAT (4X,I2,10X,F4.0,12X,F4.0,11X,F6.2,10X,F6.0,13X,F6.0)
K=K+1
270 CONTINUE
C SUM ALL SUBWATERSHED HOLDING COSTS
TOTHOD=0.0
DO 280 NW=1,MW
280 TOTHOD=TOTHOD+CH(NW)
WRITE(6,5180) TOTHOD
5180 FORMAT(2X,25HTOTAL ANNUAL HOLDING COST,55X,F6.0)
RETURN
END

```

```

CDSKIP  CSECT
        SAVE  (14,12),,*          ENTRY ROUTINE
        BALR  12,0                  *
        USING *,12                  *
        LR    11,13                  *
        LA    13,SAVE                *
        ST    13,8(11)              *
        ST    11,4(13)              *
        L     6,=V(CARDSW)          LOAD GR6 WITH ENTRY POINT IN READ
        MVI   0(6),X'0'             SET THE SWITCH TO FORCE READING OF
*                                     NEW CARD
        L     13,SAVE+4              RETURN
        L     14,12(13)             *
        MVI   12(13),X'FF'         *

```

```

SAVE      RETURN (15,12)      *
          DS      18F
          END
READ      CSECT
          ENTRY CARDSW
          SAVE (14,12),,*      *
          BALR 12,0             *
          USING *,12           * ENTRY- LINKAGE SETUP
          MVI  TRANSTAB+92,X'FF' REMOVE THIS CARD TO READ PAST '**
          LR   11,13           *
          LA   13,AREA         *
          ST   13,8(11)        *
          ST   11,4(13)        *
          B    PROBLEM         *
AREA      DS      18F         * THIS PROGRAM'S SAVE AREA
DSRN      DC      AL4(5)
PROBLEM   LR      4,1         SAVE CONTENTS OF ARG. PTR.
          LA      5,INAREA    SET UP ORIG. CARD PTR.
          LA      6,BUFFER    SET UP TRANS. CARD PTR.
          L       7,COLPTR
          CLI    CARDSW,X'1'   *
          BE     NONEWC       * LINKAGE
GETACARD  LA      2,DSRN      LOAD ADDRESS OF DATA SET REF NO
          LA      7,1
          L       1,=V(FIOCS#) LINK TO
          BALR 0,1            FORTRAN IOCS
          DC     AL2(240)     ROUTINE
          SR     3,7
          STC   3,MOVE+1
          MVI   INAREA,C' '   CLEAN OUT THE
          MVC   INAREA+1(255),INAREA INPUT AREA
X         EQU    1
MOVE      MVC   INAREA(X),0(2)
          MVC   BUFFER(256),INAREA DUPLICATE THE CARD IN BUFFER
          TR   BUFFER(256),TRANSTAB TRANSLATE THE DUPLICATED CARD
          AR   3,7
          LA   2,0(3,6)
          MVI  0(2),X'FF'     PUT END OF RECORD CHARACTER AFTER THE CARD
NONNEWC   MVI  CARDSW,X'1'    TURN ON THE GOT-A-CARX SWITCH
          LA   8,0(7,6)      PUT INDEXED COLUMN PTR. IN 8
          CLI  0(8),X'0'     CHECK CURRENT COL FOR SIGNIF.
          BNE  FOUND        BRANCH IF SIGNIFICANT
          LA   7,1(0,7)      INCREMENT COL PTR.
          B    NONEWC       GO TRY AGAIN
FOUND     CLI  0(8),X'FF'    HAVE WE FINISHED THE CARD
          BE   GETACARD     YES, GO GET ONE
          CLC  0(1,8),TRY1   START OF A LEGAL NO(DIGIT)
          BE   YESITIS      YES, ELSE
          CLC  0(2,8),TRY2   START OF A LEGAL NO(SIGN,DIGIT)
          BE   YESITIS      YES, ELSE
          CLC  0(3,8),TRY3   STRT OF A LEGAL NO(SIGN,PTR,DIG)
          BE   YESITIS      YES, ELSE

```

```

CLC      0(2,8),TRY4
BE       SETFT
B        NONEWC+12
SETFT    MVI     FLTSW,X'1'
YESITIS  MVI     DATA,X'1'
         ST      8,START
         MVC     OLD(1),0(8)
         LA      7,1(7)
         SR      9,9
         IC      9,OLD
         LA      8,0(6,7)
         CLI     0(8),X'FF'
         BE      NOTVALID
         CLI     ESW,X'1'
         BNE     *+12
         LA      10,OLDTABED
         B       OUT
         CLI     DSW,X'1'
         BNE     *+12
         LA      10,OLDTABED
         B       OUT
         CLI     FLTSW,X'1'
         BNE     *+12
         LA      10,OLDTABFT
         B       OUT
OUT       LA      10,OLDTABNO
         MVC     HOLDER(5),0(10)
         SR      10,10
         IC      10,0(0,8)
         LA      11,NEWTAB-1
         LA      11,0(10,11)
         MVC     INST+1(1),0(11)
INST      LA      9,HOLDER-1(9)
         TM      0(9),X'0'
         BZ      NOTVALID
         CLI     0(8),X'3'
         BNE     T2
         MVI     ESW,X'1'
         B       YESITIS+8
T2        CLI     0(8),X'4'
         BNE     T3
         MVI     DSW,X'1'
         B       YESITIS+8
T3        CLI     0(8),X'2'
         BNE     YESITIS+8
         MVI     FLTSW,X'1'
         B       YESITIS+8
NOTVALID  CLI     0(8),X'FF'
         BNE     STATRAN
         CLI     DATA,X'1'
         BNE     GETACARD
         MVI     CARDSW,X'0'

```

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START OF A LEGAL NUMBER(DPT,DIG)
YES, ELSE
GO BACK AND LOOK AGAIN

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WE HAVE FOUND LEGAL DATA

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CLEAR GR9 AND
STICK THE OLD TRANS CHAR IN 18
STORE THE NEW INDEXED COL PTR IN 8

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HAVE WE FOUND AN 'E'
NO ELSE
PUT 'ED' TABLE ADD IN 10
AND GO ON
HAVE WE FOUND AN 'D'
NO ELSE
PUT 'FT' TABLE ADD IN 10
AND GO ON
ELSE LOAD 'NO' TABLE ADD
NO. ELSE
PUT 'FT' TABLE ADD IN 10
AND GO ON
ELSE LOAD 'NO' TABLE ADD
MOVE PROPER TABLE TO HOLDER
CLEAR GR10
AND PUT THE NEW CHAR IN TI
PUT ADDRESS OF NEW CHAR IN 11
PUT INDEXED NEWTAB ADDR IN 11
PUT PROP. MASK IN TM INST
PUT INDEXED HOLDER ADDR IN GR9
TM INSTRUCTION
BRANCH IF NOT A VALID CHAR
IS THIS AN 'E'
BRANCH IF NOT
TURN ON 'E' SWITCH
GO GET NEXT CHAR
IS THIS A 'D'
BRANCH IF NOT
TURN ON 'D' SWITCH
GO GET NEXT CHAR
IS THIS A '.'
GET NEXT CHAR IF NOT
TURN ON FLTSW
GET NEXT CHAR
IS THIS END-OF-CARD?
NO, GO CONVERT DATA
HAVE WE OFUND DATA
NO, THEN GET A CARD
WE NEED A CARD

```

STATRAN	ST	8,STOP	STORE STOPPING ADDRESS
	S	8,START	COMPUTE LENGTH
	STC	8,LENGTH	PUT LENGTH IN 'LENGTH'
	L	2,0(0,4)	SET PTR TO CORR ARG IN GR2
	L	3,START	PUT START ADDR IN 3
	S	3,=F*256'	
	L	1,=V(ADCON#)	MOVE LINK ADDR IN GR1
	CLI	ESW,X*1'	'E' SWITCH ON?
	BE	PERFEC	BRANCH IF YES
	CLI	DSW,X*1'	
	BE	PERFDC	BRANCH IF YES
	CLI	FLTSW,X*1'	'.' SWITCH ON
	BE	PERFFC	BRANCH IF YES
PERFIG	MVC	CON1+1(1),LENGTH	PERFORM I CONVERSION
	L	1,40(1)	PUT LENGTH IN CONSTANT
	BALR	0,1	
CON1	DC	XL2*0400'	
	B	DONECONV	LEAVE
PERFEC	MVC	CON2+1(1),LENGTH	PERFORM E CONVERSION
	L	1,8(1)	PUT LENGTH IN CONSTANT
	BALR	0,1	
CON2	DC	XL4*04000000'	
	B	DONECONV	LEAVE
PERFDC	MVC	CON3+1(1),LENGTH	PERFORM D CONVERSION
	L	1,8(1)	PUT LENGTH IN CONSTANT
	BALR	0,1	
CON3	DC	XL4*08000000'	
	B	DONECONV	LEAVE
PERFFC	MVC	CON4+1(1),LENGTH	PERFORM F CONVERSION
	L	1,0(1)	PUT LENGTH IN CONSTANT
	BALR	0,1	
CON4	DC	XL4*04000000'	
DONECONV	MVI	FLTSW,X*0'	TUNR OFF '.'
	MVI	ESW,X*0'	TURN OFF 'E'
	MVI	DATA,X*0'	
	MVI	DSW,X*0'	TRUN OFF 'D' SWITCH
	LA	4,4(4)	INCREMENT POINTER TO ARG LIST
	LTR	2,2	CURRENTY ARG LAST ARG
	BP	GETACARD-8	
	B	TURNOFF+4	
TURNOFF	MVI	CARDSW,X*0'	TURN ON NEW CARD SWITCH
	ST	7,COLPTR	
	L	13,AREA+4	LOAD RETURN AREA
	L	14,12(13)	
	MVI	12(13),X*FF'	
	RETURN	(15,12)	
FORMAT	DC	CL8*(20A4) ..'	
	DS	0F	
INAREA	DS	CL256	
BUFFER	DS	CL256	
	DC	X*FF'	
	DS	3X	



TRANSTAB	DC	75X'0'
	DC	X'2'
	DC	2X'0'
	DC	X'1'
	DC	17X'0'
	DC	X'1'
	DC	99X'0'
	DC	X'0403'
	DC	42X'0'
	DC	10X'5'
	DC	6X'0'
TRY1	DC	X'5'
TRY2	DC	X'0105'
TRY3	DC	X'010205'
TRY4	DC	XL2'0205'
CARDSW	DC	X'0'
DATA	DC	X'0'
START	DS	1F
OLD	DS	CL1
COLPTR	DS	1F
STOP	DS	1F
OLDTABFT	DC	X'0838888838'
OLDTABNO	DC	X'4838888878'
OLDTABED	DC	X'0808888808'
FLTSW	DC	X'0'
ESW	DC	X'0'
DSW	DC	X'0'
NEWTAB	DC	X'8040201008'
HOLDER	DS	XL5
LENGTH	DS	CL1
END	READ	

APPENDIX B

DICTIONARY OF VARIABLES

USED IN

THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAMS

- ITEM 1 - VARIABLE NAME
- ITEM 2 - WHETHER VARIABLE IS USED IN PROGRAM 2, PROGRAM 3, OR IN BOTH PROGRAMS
- ITEM 3 - WHETHER VARIABLE IS REAL, INTEGER, OR LOGICAL
- ITEM 4 - VARIABLE DIMENSIONS
- ITEM 5 - UNITS
- ITEM 6 - DEFINITION OF THE VARIABLE

1	2	3	4	5	6
A	B	R	1	SF	CROSS-SECTIONAL AREA OF DESIGN CHANNEL
A0*	B	R	V	SF	ARRAY OF AVERAGE CROSS-SECTIONAL AREA OF CHANNEL IN SUBSCRIPTED SUBWATERSHED, TAKEN PERPENDICULAR TO DIRECTION OF FLOW
A1	2	R	25	-	SUBSCRIPTED SUBWATERSHED DISPERSION PARAMETER OF FLOWS USED IN THE GUMBEL ANALYSIS TO DETERMINE FLOW-FREQUENCY RELATIONSHIPS. "1" DENOTES BEGINNING OF STAGE FLOWS FOR IMPROVED CHANNELS
A2	2	R	25	-	DISPERSION PARAMETER LIKE A1 EXCEPT FOR END OF STAGE FLOWS FOR IMPROVED CHANNELS
A3	2	R	25	-	DISPERSION PARAMETER LIKE A2 EXCEPT FOR BEGINNING OF STAGE FLOWS FOR UNIMPROVED CHANNELS
A4	2	R	25	-	DISPERSION PARAMETER LIKE A3 EXCEPT FOR END OF STAGE FLOWS FOR UNIMPROVED CHANNELS
A5	3	R	1	-	NUMBER OF SUBWATERSHED TIME INCREMENTS TO CURRENT POINT ON SUBWATERSHED TIME BASE HYDROGRAPH
A7	3	R	1	SF	TEMPORARY LOCATION FOR STORING A9 TO PRINT AS OUTPUT
A8	3	R	15	SF	CROSS SECTIONAL AREA OF OPTIMUM CHANNEL IN

FOOTNOTES

- \* - INITIAL VALUE READ
- V - VALUE = 25 IN PROGRAM 2, 15 IN PROGRAM 3.

SUBSCRIBED SUBWATERSHED ASSOCIATED WITH LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES TRIED THUS FAR

A9 3 R 15 SF CROSS SECTIONAL AREA OF OPTIMUM CHANNEL IN SUBSCRIBED SUBWATERSHED DOWNSTREAM FROM RESERVOIR STORAGE CURRENTLY BEING EVALUATED

AA B R 1 SF VALUE OF A HELD WHILE OTHER SECTION TYPES ARE TRIED TO SEE IF THEY COST LESS

ACD 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL RESIDUAL FLOOD DAMAGE COSTS FOR STAGES STUDIED THUS FAR

ACF 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL FLOOD COSTS FOR STAGES STUDIED THUS FAR. TOTAL COST OF THE PLANNING PROGRAM TO PRESENT

ACH B R 1 AC AREA OF EXTRA RIGHT-OF-WAY BEING HELD FOR CHANNEL CONSTRUCTION IN FUTURE STAGES

ACL 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL LAND USE ADJUSTMENT FOR STAGES STUDIED THUS FAR

ACP 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL FLOOD PROOFING FOR STAGES STUDIED THUS FAR

ACS 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL CHANNEL IMPROVEMENT FOR STAGES STUDIED THUS FAR

ACU 2 R 1 \$/YR SUM OF THE ANNUAL COST OVER TIMST YEARS OF ALL UNCERTAINTY FOR STAGES STUDIED THUS FAR

ADD 3 R 1 FT DEPTH OF WATER ADDED TO CURRENT RESERVOIR SURFACE ELEVATION TO DETERMINE THE NEXT SURFACE ELEVATION (RESEL) FOR THE RESERVOIR ROUTING CURVE

ADDC8 3 R 15 \$/YR CONTINUING (CARRYOVER) COST OF OPTIMUM CHANNEL IMPROVEMENT IN SUBSCRIBED SUBWATERSHED FOR LEAST COST COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR - SAVED FOR ADDING TO TOTAL COST IN SUBSEQUENT STAGES AS NEEDED

ADDC9 3 R 15 \$/YR CONTINUING (CARRYOVER) COST OF CHANNEL IMPROVEMENTS IN SUBSCRIBED SUBWATERSHED DOWNSTREAM FROM RESERVOIR STORAGE CURRENTLY UNDER CONSIDERATION

ADDCS B R V \$/YR CONTINUING COST OF CHANNEL IMPROVEMENTS MADE DURING A PREVIOUS STAGE WITHIN THE SUBSCRIBED SUBWATERSHED

AEXTRA B R 1 SF CROSS-SECTIONAL AREA OF EXCAVATION REQUIRED FOR INITIAL CHANNEL IMPROVEMENT

AF 2 R 1 - DISPERSION PARAMETER (GUMBEL) FROM FLOOD FREQUENCY RELATIONSHIP FOR COMPUTING DOWNSTREAM COST

AFCTR\* B R 3,11 - READ ARRAY EXPRESSING FOR THE 11 DRAINAGE AREAS IN SQ MI FOUND IN THE FIRST ROW, THE RATIOS OF THE FLOOD PEAK IN CFS/SQ MI TO THE CFS/SQ MI FROM 1.0 SQ MI FOR THE MEAN ANNUAL FLOOD (2ND ROW), AND THE 200-YEAR FLOOD (3RD ROW)

AFCTR\* 3 R 11 - RELATIONSHIP BETWEEN DRAINAGE AREA AND TIME-TO-PEAK - AFCTR = 1.0 FOR A DRAINAGE AREA OF ONE SM

AFCTRV*	3 R	2,11	AFCTRT > 1.0 FOR LARGER DRAINAGE AREAS - MULTIPLIERS USED TO RELATE AVERAGE VOLUME OF FLOW CAUSED BY 43% AND .5% FLOOD PEAKS TO DRAINAGE AREA - AFCTRV = 1.0 FOR AREA = ONE SM AFCTRV < 1.0 FOR LARGER AREAS
AFL	2 R	1	- DISPERSION PARAMETER -GUMBEL- WITHOUT CHANNELIZATION IN THE UPSTREAM SUBWATERSHED
AFT	3 R	15	- USED TO RELATE TIME-TO-PEAK FOR ONE SM TO TIME-TO-PEAK FOR THE TOTAL AREA OF THE SUBSCRIBED SUBWATERSHED AS INTERPOLATED FROM AFCTRT
AFV	3 R	2,15	- FACTOR USED TO RELATE AVERAGE VOLUME OF FLOW FROM 43% AND .5% FLOOD PEAKS TO THE AREA OF A SUBWATERSHED - INTERPOLATED FROM AFCTRV
AFW	B R	2,V	- FACTOR USED TO RELATE MAGNITUDE OF MEAN ANNUAL (FIRST ROW) AND 200-YEAR (SECOND ROW) FLOOD PEAKS, BOTH EXPRESSED IN CFS/SQ MI, OVER 1.0 SQ MI AREA TO MAGNITUDE OF THE SAME PEAKS FOR THE AREA OF THE SUBSCRIBED SUBWATERSHED
AG	B R	1	- DISPERSION PARAMETER -GUMBEL- USED TO CALCULATE FREQUENCY AT WHICH FLOODING BEGINS
AHN	3 R	1	- GUMBEL DISPERSION PARAMETER USED TO CALCULATE FLOWS FOR VARIOUS FREQUENCIES MORE RARE THAN THE RESERVOIR DESIGN FREQUENCY WHEN CHANNELS ARE NOT IMPROVED
AHY	3 R	1	- SAME AS AHN BUT FOR IMPROVED CHANNELS
AK12*	B R	V	AC ARRAY INTO WHICH IS READ THE AREA FLOODED IN THE SUBSCRIBED SUBWATERSHED DURING FLOOD WHOSE PEAK FLOW IS READ INTO QK12
ALN	3 R	1	- GUMBEL DISPERSION PARAMETER USED IN CALCULATING FLOWS FOR VARIOUS FREQUENCIES LESS RARE THAN THE RESERVOIR DESIGN FREQUENCY WHEN CHANNELS ARE NOT IMPROVED
ALRG	2 R	1	SF ENLARGED CHANNEL CROSS SECTIONAL AREA REQUIRED TO HANDLE INCREASED FLOW CAUSED BY UPSTREAM CHANNELIZATION
ALY	3 R	1	- SAME AS ALN BUT FOR IMPROVED CHANNELS
AMAX	3 R	1	SF CROSS SECTIONAL AREA OF THE LARGER DAM SECTION TO WHICH PRISMOIDAL FORMULA IS BEING APPLIED TO COMPUTE VOLUME
AMEAN	3 R	1	SF CROSS SECTIONAL AREA OF THE MEAN SECTION TO WHICH PRISMOIDAL FORMULA IS BEING APPLIED TO COMPUTE VOLUME
AMIN	3 R	1	SF CROSS SECTIONAL AREA OF THE SMALLER DAM SECTION TO WHICH PRISMOIDAL FORMULA IS BEING APPLIED TO COMPUTE VOLUME
AMINM	3 R	1	SF MINIMUM CHANNEL CROSS SECTION ENLARGEMENT
ANCOST	3 R	1	\$/YR DISCOUNTED ANNUAL COST OF INSTALLING DAM AND RESERVOIR
ANMAIN	3 R	1	\$/YR ANNUAL MAINTENANCE COST OF THE DAM AND RESERVOIR
APCHAR	3 R	1	SF AREA OF THE APPROACH CHANNEL AT THE SPILLWAY CREST SECTION
APCHEX	3 R	1	CY APPROACH CHANNEL EXCAVATION

APCHLG	3	R	1	FT	LENGTH OF APPROACH CHANNEL TO EMERGENCY SPILLWAY
AGR*	B	R	1	-	FACTOR MULTIPLIED BY RIGHT-OF-WAY COST TO INCLUDE COST OF ACQUISITION
AREA	B	R	1	AC	AREA PROTECTED BY FLOOD PROOFING OR LAND USE ADJUSTMENT MEASURES
ASML	2	R	1	SF	CHANNEL CROSS-SECTIONAL AREA REQUIRED TO HANDLE FLOW WITHOUT UPSTREAM CHANNELIZATION
ATEMP	B	R	1	SF	VALUE OF A FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR
AW*	2	R	25	SM	ARRAY INTO WHICH IS READ THE TOTAL AREA TRIBUTARY TO THE DOWNSTREAM END OF THE SUBSCRIBED SUBWATERSHED
AW*	3	R	15	SM	TRIBUTARY AREA ADDED - AREA TRIBUTARY TO DOWNSTREAM LESS AREA TRIBUTARY TO UPSTREAM END OF SUBWATERSHED
AWG*	3	R	1	SM	DRAINAGE AREA AT STREAM GAGE USED TO DEVELOP CUMULATIVE RUNOFF CURVE
AZ	B	R	1	SF	VALUE OF A FOR UNLINED CHANNEL WHILE LINING EXISTING CHANNEL IS TRIED
AZ1	B	R	1	AC	AREA FLOODED TO DEPTHS DESTROYING LESS THAN 0.25 OF THE MARKET VALUE OF STRUCTURES FLOODED
AZ11	B	R	1	AC	SAVED TOTAL AZ1 WHEN PARTIAL AZ1 IS BEING APPLIED
AZ2	B	R	1	AC	AREA FLOODED TO DEPTHS DESTROYING MORE THAN 0.25 BUT LESS THAN 0.75 OF THE MARKET VALUE OF STRUCTURES FLOODED
AZ21	B	R	1	AC	SAVED TOTAL AZ2 WHEN PARTIAL AZ2 IS BEING APPLIED
AZ3	B	R	1	AC	AREA FLOODED TO DEPTHS GREAT ENOUGH TO DESTROY 0.75 OF THE MARKET VALUE OF STRUCTURES FLOODED
AZ31	B	R	1	AC	SAVED TOTAL AZ3 WHEN PARTIAL AZ3 IS BEING APPLIED
AZD	B	R	1	AC	AREA FLOODED OUTSIDE BOUNDARY OF LAND USE RESTRICTION
AZL	B	R	1	AC	TOTAL AREA FLOODED
AZS	B	R	1	AC	AREA FLOODED WITHIN WHICH LAND USE RESTRICTION APPLIES
B	B	R	1	FT	BOTTOM WIDTH OF CHANNEL
BO	B	R	1	FT	BOTTOM WIDTH OF CHANNEL BEFORE ENLARGEMENT
BDMAX*	B	R	1	-	MAXIMUM RATIO OF BOTTOM WIDTH TO DEPTH ALLOWED IN CHANNEL DESIGN
BDMIN*	B	R	1	-	MINIMUM RATIO OF BOTTOM WIDTH TO DEPTH ALLOWED IN CHANNEL DESIGN
BH	2	R	1	-	NUMBER OF HIGHWAY BRIDGES IN DOWNSTREAM SUBWATERSHED AFFECTED BY UPSTREAM CHANNELIZATION
BLDNOW	3	L	1	-	TRUE IF RESERVOIR TO BE BUILT NOW FOR OTHER PURPOSES EVEN IF FLOOD CONTROL CANNOT BE JUSTIFIED
BNFDST	3	R	1	\$/YR	FLOOD CONTROL BENEFITS REALIZED DOWNSTREAM FROM AREA OF FORMAL ANALYSIS
BCTACR	3	R	1	AC	RESERVOIR AREA THAT IS MORE THAN 5 FT BELOW TOP OF PERMANENT POOL AND THUS IS NOT CLEARED OF VEGETATIVE GROWTH
BOTTOM	3	R	1	FT	BOTTOM ELEVATION OF EMERGENCY SPILLWAY STILLING BASIN (FIG. A)

BR B R	1	-	NUMBER OF RAILROAD BRIDGES IN DOWNSTREAM SUBWATERSHED AFFECTED BY UPSTREAM CHANNELIZATION
BRIDGE B SUBROUTINE			DETERMINES NUMBER OF BRIDGES TO BE ENLARGED OR REPLACED. EXISTING BRIDGES WHICH BECOME TOO SMALL ARE REPLACED. BRIDGES BUILT IN PROGRAM ARE ENLARGED. HIGHWAY BRIDGES BUILT TO SERVE NEW URBAN DEVELOPMENT ARE ENLARGED AS NECESSARY, BUT INITIAL CONSTRUCTION COST IS NOT CHARGED TO FLOOD CONTROL.
BRN B R	1	-	NUMBER OF HIGHWAY BRIDGES WITHIN A SUBWATERSHED
BSFLO5 3 R	1	CFS	EXPECTED FLOW AT BEGINNING OF 200-YEAR FLOOD
BSFL43 3 R	1	CFS	EXPECTED FLOW AT BEGINNING OF MEAN ANNUAL FLOOD
BSFLOW 3 R	1	CFS	EXPECTED FLOW AT BEGINNING OF RESERVOIR DESIGN FLOOD
BSML 2 R	1	FT	BOTTOM WIDTH OF CHANNEL REQUIRED TO HANDLE FLOW WITHOUT CHANNELIZATION IN A GIVEN UPSTREAM SUBWATERSHED
BTVOL 3 R	1	CY	VOLUME OF CONCRETE IN STILLING BASIN BOTTOM
BU B R	1	FT	BOTTOM WIDTH OF UNLINED CHANNEL
BUILD 3 SUBROUTINE			DETERMINES THE OPTIMUM FLOOD STORAGE FOR A GIVEN RESERVOIR SITE UPSTREAM FROM A GIVEN FLOOD PLAIN IN A GIVEN STAGE
BW* B R	1	FT	REQUIRED HIGHWAY BRIDGE WIDTH
BYVERT* 3 R	1	FT	VERTICAL DISTANCE ABOVE TOP OF DAM TO RIGHT-OF-WAY PURCHASE LINE
C B R	1	-	RATIO OF LENGTH OF IMPROVED CHANNEL TRIBUTARY TO DOWNSTREAM END OF SUBWATERSHED TO TOTAL LENGTH OF TRIBUTARY CHANNEL
C1 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR URBAN STRUCTURES WITH FLOOD PROOFING - INSIDE RESTRICTED AREA IN CD2
C2 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR ADDITIONAL DAMAGE TO URBAN STRUCTURES WITHOUT FLOOD PROOFING - INSIDE RESTRICTED AREA IN CD2
C3 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR AGRICULTURAL STRUCTURES WITH FLOOD PROOFING - INSIDE RESTRICTED AREA IN CD2
C4 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR ADDITIONAL DAMAGE TO AGRICULTURAL STRUCTURES WITHOUT FLOOD PROOFING - INSIDE RESTRICTED AREA IN CD2
C5 B R	1	\$/AC	UNIT DAMAGE FACTOR FOR CROP DAMAGE
C5G B R	1	\$/FT/AC	VARIABLE UNIT CROP DAMAGE FACTOR
C6 B R	1	\$/FT/AC	C1 & C3
C7 B R	1	\$/FT/AC	C2 & C4
C8 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR ADDITIONAL DAMAGE TO URBAN STRUCTURES WITH FLOOD PROOFING OUTSIDE THE RESTRICTED AREA
C9 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR FOR ADDITIONAL DAMAGE TO URBAN STRUCTURES WITHOUT FLOOD PROOFING OUTSIDE THE RESTRICTED AREA
C10 B R	1	\$/FT/AC	UNIT DAMAGE FACTOR CORRECTING FOR FLOOD PROOFED AGRICULTURAL STRUCTURES DISPLACED BY URBAN STRUCTURES OUTSIDE THE RESTRICTED AREA

C11 B R 1 \$/FT/AC UNIT DAMAGE FACTOR CORRECTING FOR AGRICULTURAL  
 STRUCTURES NOT FLOOD PROOFED DISPLACED BY URBAN  
 STRUCTURES OUTSIDE THE RESTRICTED AREA  
 C12 B R 1 \$/AC UNIT DAMAGE FACTOR CORRECTING FOR CROPS DISPLACED  
 BY URBAN STRUCTURES OUTSIDE THE RESTRICTED AREA  
 C12G B R 1 \$/FT/AC VARIABLE UNIT DAMAGE FACTOR FOR CROPS DISPLACED  
 BY URBAN STRUCTURES OUTSIDE THE RESTRICTED AREA  
 C13 B R 1 \$/FT/AC C8 & C10  
 C14 B R 1 \$/FT/AC C9 & C11  
 CA B R 1 \$/FT/AC COMBINATION OF STRUCTURAL DAMAGE FACTORS  
 RELATED TO BOTH DEPTH AND AREA OF FLOODING  
 CA7 3 R 11 - VALUE OF CA9 USED IN PRINTING OUTPUT  
 CA8 3 R 10,11 CFS ARRAY CONTAINING THE CAPACITIES OF HIGHWAY AND  
 RAILROAD BRIDGES IN THE SUBSCRIBED SUBWATERSHED  
 ASSOCIATED WITH THE LEAST COST COMBINATION OF  
 RESERVOIR STORAGE AND DOWNSTREAM MEASURES TRIED  
 THUS FAR  
 CA9 3 R 10,11 CFS ARRAY CONTAINING THE CAPACITIES OF HIGHWAY AND  
 RAILROAD BRIDGES IN THE SUBSCRIBED SUBWATERSHED  
 ASSOCIATED WITH THE RESERVOIR STORAGE CURRENTLY  
 BEING EVALUATED  
 CALCLU B SUBROUTINE CALCULATES LOCATION COST PER ACRE FOR EACH  
 SUBWATERSHED IN EACH STAGE AND MAKES SURE THAT  
 LOCATION COST WILL INCREASE AS THE SUBWATERSHED  
 BECOMES MORE URBANIZED  
 CAP\* B R V,11 CFS THE NUMBER AND CAPACITY OF HIGHWAY AND RAILROAD  
 BRIDGES IN SUBWATERSHED OF FIRST SUBSCRIPT  
 CAQR 3 R 1 \$ COST OF ACQUISITION OF RESERVOIR RIGHT-OF-WAY  
 CB B R 1 \$/FT COMBINATION OF CROP UNIT DAMAGE FACTORS RELATED  
 TO AREA ONLY  
 CBG \$/FT/AC COMBINATION OF VARIABLE CROP UNIT DAMAGE  
 FACTORS  
 CBOT 3 R 1 CY VOLUME OF CONCRETE IN THE EMERGENCY SPILLWAY  
 BOTTOM  
 CBR\* B R 1 \$/SF UNIT COST OF HIGHWAY BRIDGES  
 CC 3 R 1 - VALUE OF C USED IN INTERPOLATION  
 CCLR 3 R 1 \$ COST OF CLEARING VEGETATIVE GROWTH FROM RESERVOIR  
 SITE  
 CCY\* B R 1 \$/CY UNIT COST OF IN PLACE STRUCTURAL CONCRETE  
 CD B R 1 \$/YR AVERAGE ANNUAL DAMAGE DUE TO FLOODING. CALCULATED  
 BY CD2 IF LAND USE RESTRICTION IS BEING  
 EVALUATED AND BY CD1 IF IT IS NOT  
 CD1 B SUBROUTINE RESIDUAL DAMAGE PROCEDURE WHEN THE LOCATION  
 ALTERNATIVE IS NOT INCLUDED  
 CD2 B SUBROUTINE RESIDUAL DAMAGE PROCEDURE WHEN THE LOCATION  
 ALTERNATIVE IS NOT INCLUDED  
 CDA\* B R 1 \$/AC EXPECTED CROP DAMAGE WHEN MOST PRODUCTIVE SOIL IS  
 FLOODED TO MINIMUM DEPTH  
 CDAV\* B R 1 \$/AC/FT/YR INCREMENTAL CROP DAMAGE PER ADDITIONAL FOOT  
 OF DEPTH OF FLOODING IN MOST PRODUCTIVE SOIL  
 CDB\* B R 1 \$/AC EXPECTED CROP DAMAGE WHEN INTERMEDIATE SOIL IS  
 FLOODED TO MINIMUM DEPTH

CDBV*	B R	1	\$/AC/FT/YR INCREMENTAL CROP DAMAGE PER ADDITIONAL FOOT OF DEPTH OF FLOODING IN INTERMEDIATE SOIL
CDC*	B R	1	\$/AC EXPECTED CROP DAMAGE WHEN LEAST PRODUCTIVE SOIL IS FLOODED TO MINIMUM DEPTH
CDCV*	B R	1	\$/AC/FT/YR INCREMENTAL CROP DAMAGE PER ADDITIONAL FOOT OF DEPTH OF FLOODING IN LEAST PRODUCTIVE SOIL
CDF	B R	V	\$/AC/YR WEIGHTED MEAN CROP DAMAGE WHEN FLOODED FROM THE SOIL TYPES IN SUBSCRIBED SUBWATERSHED
CDST	2 R		\$/YR TOTAL COST OF INDUCED FLOODING IN ALL DOWNSTREAM SUBWATERSHEDS CAUSED BY CHANNELIZATION UPSTREAM
CDSTE	2 L	1	- SET TRUE WHEN CDST IS CALCULATED FOR A PARTICULAR SUBWATERSHED-STAGE TO PREVENT UNNECESSARY RECALCULATION
CDZ	B R	1	\$/YR VALUE OF CD FOR UNLINED CHANNELS WHILE CD1 FINDS LOWER RESIDUAL FLOODING COST (CD) WITH LINING
CEMB	3 R	1	\$ DAM EMBANKMENT COST INCLUDING THE DAM FILL, THE CUTOFF TRENCH AND THE RIPRAP
CENCN	3 R	1	\$ COST OF DAM ENGINEERING AND CONTINGENCIES
CF	B R	1	\$/YR TOTAL COST OF ALL FLOOD MEASURES AND DAMAGES
CG	B R	V	\$/AC/FT/YR WEIGHTED MEAN INCREMENTAL CROP DAMAGE PER ADDITIONAL FOOT OF DEPTH OF FLOODING FOR THE SOIL TYPES IN SUBSCRIBED SUBWATERSHED
CH	B R	V	\$/YR COST OF HOLDING RIGHT-OF-WAY IN SUBSCRIBED SUBWATERSHED FOR FUTURE CHANNELS
CH8	3 L	15	- SET TRUE TO INDICATE THAT THE LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES FOUND THUS FAR INCLUDES CHANNEL IMPROVEMENT
CH9	3 L	15	- SET TRUE TO INDICATE THAT CHANNEL IMPROVEMENT SHOULD BE IN EFFECT IN SUBSCRIBED SUBWATERSHED DOWNSTREAM FROM RESERVOIR STORAGE CURRENTLY BEING EVALUATED
CHANEL	B L	V	- SET TRUE IF THE ENTIRE CHANNEL LENGTH IN THE SUBSCRIBED SUBWATERSHED IS IMPROVED
CHANYZ	3	SUBROUTINE	PROCEEDS DOWNSTREAM ON MAIN LINE FROM RESERVOIR SITE TO SELECT OPTIMUM COMBINATION OF MEASURES IN EACH SUBWATERSHED
CHDATA	2	SUBROUTINE	READS IN DATA REQUIRED TO OPTIMIZE CHANNEL IMPROVEMENT IN CONJUNCTION WITH NONSTRUCTURAL MEASURES
CHECK	B L	1	- READ TRUE TO HAVE INTERMEDIATE OUTPUT PRINTED EACH TIME A NEW ALTERNATIVE IS FOUND TO BE LESS COSTLY THAN ANY CONSIDERED PREVIOUSLY
CHEX	3 R	1	CY EMERGENCY SPILLWAY CHUTE EXCAVATION
CHFIX	B	SUBROUTINE	FIX THE DIMENSIONS OF CHANNELS IMPROVED BEFORE THE BEGINNING OF THE PLANNING PERIOD FOR THE PURPOSE OF ESTIMATING THE COST OF CHANNEL ENLARGEMENT. EVEN IF THE DESIGN CRITERIA USED IN BUILDING THE EXISTING CHANNEL DO NOT CONFORM TO THOSE USED IN THIS PROGRAM, THIS SUBROUTINE CAUSES ALL COSTS TO BE BASED ON THE SAME DESIGN CRITERIA



CHFLDS	3	SUBROUTINE	FILLS ARRAYS PROVIDING FLOOD PEAKS FOR SELECTED FREQUENCIES
CHHYDR	2	SUBROUTINE	DETERMINES THE RELATIONSHIP BETWEEN FLOOD PEAK AND FREQUENCY AND FREQUENCY AT WHICH FLOODING BEGINS
CHK	3 R	1	- CALLING ARGUMENT FOR SUBROUTINE CHRTE REPRESENTING EITHER CHKN OR CHKY
CHKN*	3 R	15	HR MUSKINGUM CHANNEL ROUTING STORAGE CONSTANT (STORAGE/DISCHARGE) FOR UNIMPROVED CHANNELS - APPROXIMATELY EQUAL TO TRAVEL TIME THROUGH THE REACH
CHKY*	3 R	15	HR SAME AS CHKN BUT FOR IMPROVED CHANNELS
CHLNG	3 R	1	FT LENGTH OF RAISED WALL SECTION IN STILLING BASIN CHUTE (FIG. A)
CHOPTM	B	SUBROUTINE	PROCEDURE FOR OPTIMIZING CHANNEL IMPROVEMENT IN CONJUNCTION WITH NONSTRUCTURAL MEASURES
CHRTE	3	SUBROUTINE	ROUTES HYDROGRAPH THROUGH CHANNEL REACH
CHU	B R	1	\$/AC UNIT COST OF HOLDING RIGHT-OF-WAY FOR FUTURE CHANNELS
CHX	3 R	1	- CALLING ARGUMENT FOR SUBROUTINE CHRTE REPRESENTING EITHER CHXN OR CHXY
CHXN*	3 R	15	- VALUE USED IN MUSKINGUM METHOD OF CHANNEL ROUTING IN UNIMPROVED CHANNELS, EXPRESSING THE RELATIVE IMPORTANCE OF INFLOW AND OUTFLOW IN DETERMINING STORAGE
CHXY*	3 R	15	- SAME AS CHXN BUT FOR IMPROVED CHANNELS
CI	2 R	1	- VALUE OF C FOR DOWNSTREAM SUBWATERSHED IF CHANNEL IS IMPROVED IN UPSTREAM SUBWATERSHED FOR WHICH DOWNSTREAM COSTS ARE BEING CALCULATED
CI	B R	1	- VALUE OF C ROUNDED TO THE NEXT LOWER DECILE FOR THE PURPOSE OF INTERPOLATION
CIN*	B R	1	\$ COST PER DRAINAGE INLET
CK	3 R	1	CF AN INDEX OF VELOCITY HEAD PLUS HEAD LOSS FOR FLOW IN EMERGENCY SPILLWAY
CL	B R	1	\$/YR COST OF LAND USE ADJUSTMENT MEASURES
CLEN*	B R	1	\$/AC/YR ADMINISTRATIVE COST OF LAND USE RESTRICTION
CLOC	B R	V, 5	\$/AC/YR LOCATION COST WITHIN SUBWATERSHED OF FIRST SUBSCRIPT IN STAGE OF SECOND SUBSCRIPT
CLRBOT	3 R	1	FT THE ELEVATION 5 FT BELOW TOP OF PERMANENT POOL ABOVE WHICH VEGETATIVE GROWTH MUST BE CLEARED FROM THE RESERVOIR SITE
CLSF*	B R	1	\$/SF UNIT COST OF TRAPEZOIDAL PNEUMATIC LINING
CLUT	B R	1	\$/AC/YR PRELIMINARY ESTIMATE OF LOCATION COST NOT INCLUDING ADMINISTRATIVE COST
CM0	3 R	1	- MUSKINGUM ROUTING CONSTANT MULTIPLIED BY END OF PERIOD INFLOW
CM1	3 R	1	- MUSKINGUM ROUTING CONSTANT MULTIPLIED BY BEGINNING OF PERIOD INFLOW
CM2	3 R	1	- MUSKINGUM ROUTING CONSTANT MULTIPLIED BY BEGINNING OF PERIOD OUTFLOW
COEFD*	B R	1	\$/FT/\$ URBAN STRUCTURAL FLOOD DAMAGE PER FOOT OF FLOOD DEPTH PER DOLLAR OF MARKET VALUE OF BUILDING

CONBOT*	3 R	1	FT	THICKNESS OF CONCRETE CHUTE BOTTOM (FIG. A)
CONC1	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHT1
CONC2	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHT2
CONCB	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHTB
CONCCH	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHTCH - (MEAN OF WLHT1 AND WLHTD1)
CONCD1	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHTD1
CONCM	3 R	1	CY/FT	VOLUME OF CONCRETE PER LINEAR FOOT OF WALL OF HEIGHT WLHTM
CONCST	3 R	1	\$	CONSTRUCTION COST OF DAM
CONID	3 R	1	CY	VOLUME OF CONCRETE IN IMPACT DISSIPATOR
CONSTR	3 R	1	AF	TOTAL STORAGE IN THE RESERVOIR TO THE TOP OF THE FLOOD CONTROL POOL
CONWAL*	3 R	25	CY/FT	VOLUME OF RETAINING WALL CONCRETE FOR VARIOUS WALL HEIGHTS
COST	2			SUBROUTINE CALCULATES COSTS INCURRED IN DOWNSTREAM SUBWATERSHEDS WHEN UPSTREAM SUBWATERSHEDS ARE CHANNELIZED. COST INCURRED IS ESTIMATED FROM COST WHICH WOULD BE REQUIRED TO ENLARGE DOWNSTREAM CHANNELS TO HANDLE THE INCREASE IN THE PEAK OF THE DESIGN FLOOD
COSTCH	3 R	1	\$/YR	COST OF CHANNEL IMPROVEMENT
COSTDM	3 R	1	\$/YR	COST OF DAM AND RESERVOIR
COSTFM	3 R	1	\$/YR	TOTAL ECONOMIC COST (RESERVOIR AND FLOOD PLAIN) ASSOCIATED WITH THE MOST ECONOMICAL RESERVOIR TRIED THUS FAR
COSTFP	3 R	1	\$/YR	TOTAL COST OF FLOOD PLAIN MEASURES AND RESIDUAL DAMAGES
COSTFT	3 R	1	\$/YR	TOTAL ECONOMIC COST (RESERVOIR AND FLOOD PLAIN) ASSOCIATED WITH THE LAST RESERVOIR DESIGN TRIED
COSTSM	3 R	1	\$/YR	TOTAL ECONOMIC COST (RESERVOIR AND FLOOD PLAIN) ASSOCIATED WITH THE RESERVOIR CURRENTLY BEING TRIED
CP	B R	1	\$/YR	COST OF FLOOD PROOFING MEASURES
CPF	B R	1	-	FACTOR COMBINING TERMS USED IN COMPUTING THE ANNUAL COST OF FLOOD PROOFING
CPRSP	3 R	1	\$	COST OF PRINCIPAL SPILLWAY
CPRT	2 R	1	\$/YR	DOWNSTREAM COST INFLECTED BY UPSTREAM CHANNELIZATION. LESSER OF INCREASED DOWNSTREAM DAMAGES AND COST OF IMPROVING DOWNSTREAM CHANNELS TO HANDLE INCREASED FLOW
CRELO	3 R	1	\$	COST OF RELOCATION MADE NECESSARY BY THE RESERVOIR AS INTERPOLATED FROM CRELOC ARRAY
CRELOC*	3 R	25	\$	RELOCATION COSTS AS DEPENDING ON WATER SURFACE ELEVATION
CRF	B R	1	-	UNIFORM SERIES CAPITAL RECOVERY FACTOR FOR DURATION TIME AND DISCOUNT RATE R
CRFSM	B R	1	-	UNIFORM SERIES CAPITAL RECOVERY FACTOR FOR

				DURATION TIMST AND DISCOUNT RATE R
CROW	3 R	1	\$	COST OF RIGHT-OF-WAY PURCHASED FOR THE RESERVOIR SITE
CRR*	B R	1	\$/FT	UNIT COST OF RAILROAD BRIDGES
CS	B R	1	\$/YR	COST OF CHANNEL IMPROVEMENT
CSB	3 R	1	\$	COST OF STILLING BASIN
CSL	B R	1	\$/YR	COST OF BUILDING A NEW TRAPEZOIDAL LINED CHANNEL
CSM*	B R	1	-	FACTOR MULTIPLIED BY CHANNEL CONSTRUCTION COST TO ACCGUNT FOR CONTINGENCIES
CSMD*	3 R	1	-	FACTOR MULTIPLIED BY COST OF DAM AND RESERVOIR TO INCLUDE CONTINGENCIES
CSPL	3 R	1	\$	COST OF EMERGENCY SPILLWAY
CSR	B R	1	\$/YR	COST OF BUILDING A NEW RECTANGULAR LINED CHANNEL
CSTLOW	3 R	1	\$	LEAST COST OF DAM FOR ANY EMERGENCY SPILLWAY WIDTH TRIED THUS FAR
CT	B R	1	\$/YR	TOTAL COST OF ALL MEASURES PLUS RESIDUAL FLOODING FOR THE LEAST COST MEASURE COMBINATION FOUND SO FAR
CT2	3 R	1	MI	LENGTH OF IMPROVED CHANNEL DURING STAGE WITHIN TRIBUTARY AREA ADDED BUT NOT ON MAIN LINE STREAM TAKEN FROM ARRAY CTOTR
CTBW*	3 R	1	FT	WIDTH OF CUTOFF TRENCH BOTTOM (FIG. B)
CTOT	3 R	1	\$	TOTAL INSTALLATION COST OF DAM AND RESERVOIR
CTOT1	3 R	1	\$	FIRST SUBTOTAL OF CTOT VALUE, INCLUDING COSTS OF CONSTRUCTION, ENGINEERING, AND CONTINGENCIES
CTOT2	3 R	1	\$	SECOND SUBTOTAL OF CTOT VALUE, INCLUDING COSTS OF RIGHT-OF-WAY, RIGHT-OF-WAY ACQUISITION, AND RELOCATIONS
CTGTR*	3 R	15,5	MI	ARRAY OF LENGTHS OF IMPROVED CHANNEL WITHIN TRIBUTARY AREA ADDED BUT NOT ON MAIN LINE STREAM - ONE VALUE FOR EACH SUBWATERSHED (FIRST SUBSCRIPT) IN EACH STAGE (SECOND SUBSCRIPT)
CTT	B R	1	\$/YR	TOTAL COST OF ALL MEASURES PLUS RESIDUAL FLOODING FOR THE MEASURE COMBINATION CURRENTLY BEING TESTED
CU	B R	1	\$/YR	AVERAGE ANNUAL COST OF UNCERTAINTY AS CALCULATED BY THE THOMAS UNCERTAINTY FUND METHOD
CUMVOD	3 R	26	CFS	CUMULATIVE RUNOFF ARRAY FOR SPECIFIC DESIGN FREQUENCY AND KNOWN DEGREES OF CHANNELIZATION AND URBANIZATION - FLOW GIVEN IN CFS AS DEPENDING OF DURATION IN DAYS
CUMVCL*	3 R	26	CFS	CUMULATIVE RUNOFF ARRAY FOR MEAN ANNUAL FLOW AND 0.0 URBANIZATION AND CHANNELIZATION - AVERAGE FLOW IN CFS BY DURATION IN DAYS
CUZ	B R	1	\$/YR	VALUE OF CU WHILE CHANNEL IMPROVEMENT BY LINING IS BEING TRIED
CW1	3 R	1	CY/FT	WEIGHTED AVERAGE VOLUME OF CHUTE WALLS UPSTREAM FROM WLHT1 (FIG. A)
CW2	3 R	1	CY/FT	WEIGHTED AVERAGE VOLUME OF CHUTE WALLS BETWEEN WLHT1 AND WLHTD1 (FIG. A)
CWAL	3 R	1	CY	VOLUME OF CONCRETE IN EMERGENCY SPILLWAY WALLS

CWEIR*	3 R	1	-	EMERGENCY SPILLWAY WEIR COEFFICIENT
CX*	B R	1	\$/CY	UNIT COST OF CHANNEL EXCAVATION
D*	B R	3,V	-	THE FRACTION OF THE FLOOD PLAIN IN THE SUBWATERSHED INDICATED BY THE SECOND SUBSCRIPT WITHIN THREE SOIL PRODUCTIVITY CLASSIFICATIONS
D1	3 R	1	FT	DEPTH OF FLOW COMING INTO HYDRAULIC JUMP IN STILLING BASIN
D2	3 R	1	FT	DEPTH OF FLOW AT AN INTERMEDIATE POINT IN THE EMERGENCY SPILLWAY
DAMBLD	3		SUBROUTINE	DESIGNS AND DETERMINES THE COST OF A DAM
DAMLNG	3 R	1	FT	LENGTH OF CURRENT DAM SECTION FOR USE IN VOLUME COMPUTATIONS
DAMLTH	3 R	25	FT	LENGTH OF DAM AT CORRESPONDING ELEVATION ELEV
DAMSIZ	3		SUBROUTINE	DETERMINES DAM SIZE REQUIRED BY SPECIFIED NON-FLOOD CONTROL STORAGE AND SPECIFIED DESIGN FLOOD FREQUENCY
DAMVOL	3		SUBROUTINE	COMPUTES QUANTITIES ASSOCIATED WITH DAM EMBANKMENT
DD*	B R	1	-	FACTOR MULTIPLIED BY FLOOD PROOFING INSTALLATION COST TO ACCOUNT FOR DESIGN AND CONTINGENCIES
DENOM	3 R	1	HR	DENOMINATOR OF THE FRACTIONS GIVING THE VALUES OF CMO, CM1, AND CM2 IN THE MUSKINGUM CHANNEL ROUTING PROCEDURE
DF*	B R	10	-	THE FLOOD FREQUENCIES IN DECIMAL FORM CORRESPONDING TO LEVELS OF PROTECTION TO BE CONSIDERED FOR STRUCTURAL AND NONSTRUCTURAL FLOOD CONTROL MEASURES BEGINNING WITH THE SMALLEST FLOOD
DFQR	B R	16	\$	DAMAGE CAUSED BY FLOOD OF SPECIFIED FREQUENCY
DFR	3 R	1	1/YR	DESIGN FREQUENCY OF FLOOD AGAINST WHICH DAM IS BEING DESIGNED TO PROTECT
DK12*	B R	V	FT	MAXIMUM FLOOD DEPTH OCCURRING WITHIN SUBSCRIBED SUBWATERSHED DURING FLOOD WHOSE PEAK FLOW IS QK12
DMAX	B R	1	FT	MAXIMUM FLOOD DEPTH CAUSED BY FLOOD WHOSE DAMAGES ARE BEING ESTIMATED
DMBN*	3 R	2,10	\$	DOWNSTREAM BENEFITS (FIRST ROW) AS A FUNCTION OF FLOOD CONTROL STORAGE (SECOND ROW)
DMBNF*	3 R	5	-	STAGE MULTIPLIERS FOR DOWNSTREAM BENEFITS
DMCOST	3		SUBROUTINE	DETERMINES THE COST OF THE DAM AND RESERVOIR
DMDTLS	3 L	1	-	LOGICAL VARIABLE SET TRUE TO CAUSE PRINTING OF DAM DETAILS
DMFRBD*	3 R	1	FT	DAM FREEBOARD ABOVE PEAK OF EMERGENCY SPILLWAY FLOOD (FIG. B)
DMTPW*	3 R	1	FT	WIDTH OF TOP OF DAM (FIG. B)
DNWS	3 R	1	FT	WATER SURFACE ELEVATION DOWNSTREAM FROM THE STILLING BASIN (CHECKED TO MATCH TWELEV)
DPRCKH*	3 R	1	FT	DEPTH TO BEDROCK ON EMERGENCY SPILLWAY HILLSIDE (FIG. C)
DPRCKV*	3 R	1	FT	DEPTH TO BEDROCK UNDER DAM (FIG. B)
DPROCK	3 R	1	FT	DEPTH TO BEDROCK
DPRP*	3 R	1	FT	DEPTH OF RIPRAP ON DAM FACE (FIG. B)
DPRT	2 R	1	\$/YR	INCREASE IN FLOOD DAMAGE WITH UPSTREAM

CHANNELIZATION OVER DAMAGE WITH NO UPSTREAM CHANNELIZATION IN A GIVEN SUBWATERSHED (INCREASED FLOOD DAMAGE ATTRIBUTED TO SUBWATERSHED CHANNELIZATION)			
DGCK	B R	16	- FREQUENCY OF ITOP FLOODS USED IN COMPUTING AVERAGE ANNUAL FLOOD DAMAGES
DRQ	3 R	1	CFS PRINCIPAL SPILLWAY DESIGN DISCHARGE
DRQA	3 R	1	CFS AVERAGE DISCHARGE THROUGH PRINCIPAL SPILLWAY DURING THE DESIGN FLOOD
DY	2 R	1	\$/YR INCREASE IN EXPECTED FLOOD DAMAGE CAUSED BY UPSTREAM CHANNELIZATION INCLUDING UNCERTAINTY DAMAGE
DZ1	B R	1	FT MAXIMUM DEPTH OF FLOODING IN AREA AZ1
DZ2	B R	1	FT MAXIMUM DEPTH OF FLOODING IN AREA AZ2
DZ3	B R	1	FT MAXIMUM DEPTH OF FLOODING IN AREA AZ3
DZL	B R	1	FT DEPTH OF FLOODING AT OUTER BOUNDARY OF AREA IN WHICH LAND USE IS RESTRICTED
EL1	3 R	1	FT ELEVATION OF TOP OF DAM (FIG. C)
EL11	3 R	1	FT ELEVATION OF THE POINT AT WHICH THE EMERGENCY SPILLWAY CUT SLOPE INTERSECTS THE UPHILL GROUND SURFACE (FIG. C)
EL13	3 R	1	FT ELEVATION OF THE POINT AT WHICH THE EMERGENCY SPILLWAY APPROACH CHANNEL CUT SLOPE INTERSECTS THE UPHILL GROUND SURFACE (FIG. C)
EL2	3 R	1	FT ELEVATION OF EMERGENCY SPILLWAY CREST (FIG. C)
EL3	3 R	1	FT ELEVATION OF EMERGENCY SPILLWAY APPROACH CHANNEL BOTTOM (FIG. C)
EL4	3 R	1	FT ELEVATION OF THE POINT AT WHICH THE EMERGENCY SPILLWAY APPROACH CHANNEL CUT SLOPE INTERSECTS THE DOWNHILL GROUND SURFACE (FIG. C)
ELDMTP	3 R	1	FT ELEVATION OF DAM TOP (SAME AS TPELEV)
ELEVA*	3 R	25	FT ARRAY OF VALUES OF WATER SURFACE ELEVATIONS, EACH OF WHICH HAS A KNOWN CORRESPONDING VALUE OF THE FOLLOWING: RESACR, LGDAM, LGEMSP, LGAPCH, CRELOC, HLSIDL, HLSIDM, AND HLSIDH
ELFB05	3 R	1	FT ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF 200-YEAR FLOOD
ELFB43	3 R	1	FT ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF MEAN ANNUAL FLOOD
ELFDBG	3 R	1	FT ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF DESIGN FLOOD
ELG	3 R	1	FT ELEVATION AT THE BOTTOM OF THE SECTION OF RIPRAP ON THE DAM FACE WHOSE VOLUME IS BEING DETERMINED
ELPEAK	3 R	1	FT PEAK WATER SURFACE ELEVATION REACHED AS A FLOOD IS ROUTED THROUGH THE RESERVOIR
ELPRFL	3 R	1	FT ELEVATION OF PRINCIPAL SPILLWAY CREST (FIG. B)
ELRPBT	3 R	1	FT ELEVATION OF BOTTOM OF RIPRAP ON UPSTREAM FACE OF DAM (FIG. B)
ELRPTP	3 R	1	FT ELEVATION OF TOP OF RIPRAP ON UPSTREAM FACE OF DAM (FIG. B)

ELSPFL	3 R	1	FT	ELEVATION OF EMERGENCY SPILLWAY CREST (FIGS. A, B, C)
ELSPTP	3 R	1	FT	ELEVATION OF SAFETY FLOOD CREST (FIG. B)
ELT	3 R	1	FT	ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF DESIGN FLOOD IF WEIR CONTROL ON PRINCIPAL SPILLWAY
ELT05	3 R	1	FT	ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF 200-YEAR FLOOD IF WEIR CONTROL ON PRINCIPAL SPILLWAY
ELT43	3 R	1	FT	ELEVATION OF RESERVOIR WATER SURFACE AT BEGINNING OF MEAN ANNUAL FLOOD IF WEIR CONTROL ON PRINCIPAL SPILLWAY
EMSPLG	3 R	1	FT	LENGTH OF EMERGENCY SPILLWAY REQUIRED FOR GIVEN CONDITIONS AS INTERPOLATED FROM ARRAY LGEMSP (FIG. A)
EMSPVL	3		SUBROUTINE	DESIGNS AND DETERMINES QUANTITIES FOR THE EMERGENCY SPILLWAY
EREX	3 R	1	CY	EMERGENCY SPILLWAY EARTH EXCAVATION
ERROR	3 R	1	FT	ADJUSTMENT MADE TO D2 IN TRIAL AND ERROR SOLUTION OF ENERGY EQUATION
ESM*	B R	1	-	FACTOR MULTIPLIED BY CHANNEL CONSTRUCTION COST TO ACCOUNT FOR DESIGN, ADMINISTRATION, AND SUPERVISION OF CONSTRUCTION
ESMD*	3 R	1	-	FACTOR MULTIPLIED BY COST OF DAM AND RESERVOIR TO INCLUDE COST OF ENGINEERING
F	B R	1	-	FREQUENCY AT WHICH FLOODING BEGINS IN THE SUBWATERSHED UNDER CONSIDERATION BASED ON THE EXISTING CHANNEL CAPACITY
F	3 R	28	CF	INTERMEDIATE VALUES IN SOLVING CUBIC ENERGY EQUATION AS APPLIED TO EMERGENCY SPILLWAY FLOW
FA	B R	1	\$/YR	DAMAGE EXPECTED PER ACRE FROM WEIGHTED AVERAGE SOIL IN A YEAR WHEN THE CROPLAND IS FLOODED
FALL	3 R	1	FT	THE APPROXIMATE FALL OF THE EMERGENCY SPILLWAY CHUTE BOTTOM TO POINT WHERE D2 IS BEING ESTIMATED
FD	B R	1	FT	FALL IN HYDRAULIC GRADIENT AT DESIGN DROP STRUCTURE
FD8	3 R	15	FT	TOTAL FALL AT DROP STRUCTURES IN SUBSCRIBED SUBWATERSHED ASSOCIATED WITH LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES TRIED THUS FAR
FD9	3 R	15	FT	TOTAL FALL OF OPTIMUM DROP STRUCTURES IN SUBSCRIBED SUBWATERSHED DOWNSTREAM FROM RESERVOIR STORAGE CURRENTLY BEING EVALUATED
FDA	B R	V	FT	VALUES OF FD FOR DROP STRUCTURES IN SUBSCRIBED SUBWATERSHED
FDTEMP	B R	1	FT	VALUE OF FD FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR
FIA*	B R	1	\$/AC/YR	EXPECTED FARM INCOME FROM MOST PRODUCTIVE SOIL IF FLOODING DOES NOT OCCUR
FIB*	B R	1	\$/AC/YR	EXPECTED FARM INCOME FROM INTERMEDIATE SOIL IF FLOODING DOES NOT OCCUR

FIC*	B R	1	\$/AC/YR EXPECTED FARM INCOME FROM LEAST PRODUCTIVE SOIL IF FLOODING DOES NOT OCCUR
FIF	B R	V	\$/AC/YR WEIGHTED AVERAGE FARM INCOME FROM THE SOIL TYPES IN SUBSCRIBED SUBWATERSHED
FJ	3 R	1	- NUMBER OF SIX-HOUR PERIODS OR DAYS UNTIL MAXIMUM FLDSTR IS REACHED IN RESERVOIR AS ESTIMATED FROM CUMULATIVE RUNOFF DATA
FLDSTR	3 R	1	AF RESERVOIR FLOOD STORAGE (FIG. 8)
FLDTRY	3 R	1	AF TRIAL VALUE OF FLDSTR WHILE SEEKING THE LARGEST TO ESTIMATE FLDSTR FROM CUMULATIVE RUNOFF DATA
FLPL1	3	1	- COMMON STATEMENT CONTAINING ALL ARRAYS DEALING WITH THE FLOOD PLAIN
FLPL2	3	1	- COMMON STATEMENT CONTAINING ALL SINGLE VALUE VARIABLES DEALING WITH THE FLOOD PLAIN
FM*	B R	1	- FACTOR MULTIPLIED BY CHANNEL EXCAVATION COST TO ACCOUNT FOR RIPRAP AND SEEDING
FMAX	B R	1	- FRACTION OF STRUCTURAL MARKET VALUE DESTROYED BY FLOODING TO A DEPTH DMAX
FP*	B R	1	\$/FT/\$ COST OF FLOOD PROOFING PER FOOT OF DESIGN FLOOD DEPTH PER DOLLAR OF BUILDING MARKET VALUE
FPCOST	3	SUBROUTINE	DETERMINES THE OPTIMUM COMBINATION OF FLOOD DAMAGE REDUCTION MEASURES FOR A GIVEN SUBWATERSHED-STAGE
FPIPE*	3 R	1	- DARCY FRICTION FACTOR FOR PRINCIPAL SPILLWAY PIPE
FQ*	2 R	25	- SUBSCRIBED SUBWATERSHED AVERAGE DESIGN FLOW FOR CHANNEL IMPROVEMENTS AS A FRACTION OF THE FLOW AT THE MOUTH OF THE CHANNEL
FRES	3 R	1	YR RETURN PERIOD OF RESERVOIR DESIGN FLOOD
FRNUM	3 R	1	- FROUDE NUMBER FOR FLOW IN EMERGENCY SPILLWAY
FRU*	B R	11	- FACTORS RELATING THE FRACTION OF THE OPEN LAND BEING FARMED TO THE FRACTION OF THE TOTAL LAND IN THE VICINITY IN URBAN DEVELOPMENT
FT	B R	1	FT TOTAL FALL PROVIDED BY ALL DROP STRUCTURES WITHIN THE SUBWATERSHED
FTOP	B R	1	- REDUCED VARIATE IN GUMBEL ANALYSIS OF THE RAREST OF THE ITOP FLOODS SPECIFIED IN DQCK(16)
FUQ	B R	1	- FACTOR INTERPOLATED FROM ARRAY FRU RELATING THE FRACTION OF THE OPEN LAND BEING FARMED TO THE DEGREE OF URBANIZATION IN THE AREA WHERE THE FARM LAND IS LOCATED
GA	B R	1	\$/FT/YR INCREASED FLOOD DAMAGE EXPECTED PER ACRE FROM WEIGHTED AVERAGE SOIL WHEN THE CROP IS FLOODED TO AN ADDITIONAL FOOT OF DEPTH
GBNF	3 R	1	\$/YR STORED VALUE OF BNFDST FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED
GCSTDM	3 R	1	\$/YR STORED VALUE OF COSTDM FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED
GDELAY*	3 R	1	HR TIME AFTER BEGINNING OF STORM BEFORE FLOOD GATES ARE OPENED TO RELEASE FLOOD FLOWS
GDRQ	3 R	1	CFS STORED VALUE OF DRQ FOR CURRENTLY JUSTIFIED

RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GELF05 3 R 1 FT STORED VALUE OF ELFB05 FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GELF43 3 R 1 FT STORED VALUE OF ELFB43 FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GELFDB 3 R 1 FT STORED VALUE OF ELFDBG FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GELPRF 3 R 1 FT STORED VALUE OF ELPRFL FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GELSPF 3 R 1 FT STORED VALUE OF ELSPFL FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GFLDST 3 R 1 AF STORED VALUE OF FLDSTR FOR CURRENTLY JUSTIFIED RESERVOIR SIZE WHILE A LARGER RESERVOIR IS BEING CONSIDERED

GOBIG 3 L 1 - TRUE IF EMERGENCY SPILLWAY TRIAL WIDTHS ARE INCREASING

GOUTF 3 R 25 CFS TOTAL OUTFLOW (PRINCIPAL AND EMERGENCY SPILLWAYS) UNDER HEAD INDICATED BY CORRESPONDING POINT IN ELEVATION WHEN PRINCIPAL SPILLWAY GATE IS BEING USED

GRADSP 3 R 1 - AVERAGE SLOPE OF THE EMERGENCY SPILLWAY (HORIZONTAL/VERTICAL)

GSF B R 1 - GRADIENT SERIES FACTOR FOR CONVERTING UNIFORMLY INCREASING GRADIENT SERIES TO EQUIVALENT UNIFORM ANNUAL SERIES FOR A DURATION TIME AND A DISCOUNT RATE R

GSTOR 3 R 25 SFH S/T+0/2 TERM AS A FUNCTION OF WATER SURFACE ELEVATION FOR RESERVOIR ROUTING WITH GATE BEING USED

H B R 1 FT DEPTH OF FLOW IN DESIGN CHANNEL

HO B R 1 FT DEPTH OF FLOW IN EXISTING CHANNEL

H1 B R 1 FT CHANNEL IS DESIGNED BY INCREASING FLOW DEPTH IN INCREMENTS AND DETERMINING CAPACITY. H1 IS THE VALUE OF H AT THE UPPER BOUND OF THE INCREMENT

HA B R 1 - NUMBER OF HIGHWAY BRIDGES HAVING ADEQUATE CAPACITY FOR THE DESIGN FLOW

HBRLM\* 3 R 1 FT ELEVATION OF LOWER BREAKPOINT GOVERNING CHOICE OF EMERGENCY SPILLWAY SITE

HBRMH\* 3 R 1 FT ELEVATION OF HIGHER BREAKPOINT GOVERNING CHOICE OF EMERGENCY SPILLWAY SITE

H DPRSP 3 R 1 FT DESIGN PRINCIPAL SPILLWAY HEAD

HE B R 1 - NUMBER OF HIGHWAY BRIDGES THAT MUST BE MODIFIED TO ACCOMMODATE CHANNEL DESIGN FLOW

HETEMP B R 1 - VALUE OF HE FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR

HL11 3 R 1 FT REFERENCE HORIZONTAL DISTANCE TO THE UPHILL CATCH POINT OF THE EMERGENCY SPILLWAY SIDE SLOPE (FIG. C)



HL13	3	R	1	FT REFERENCE HORIZONTAL DISTANCE TO THE UPHILL CATCH POINT OF THE EMERGENCY SPILLWAY APPROACH CHANNEL SIDE SLOPE (FIG. C)
HL4	3	R	1	FT REFERENCE HORIZONTAL DISTANCE TO THE DOWNHILL CATCH POINT OF THE EMERGENCY SPILLWAY APPROACH CHANNEL SIDE SLOPE (FIG. C)
HLH	3	R	1	FT REFERENCE HORIZONTAL DISTANCE TO THE SIDE OF THE EMERGENCY SPILLWAY AND APPROACH CHANNEL BOTTOM TOWARD THE UPHILL SLOPE (FIG. C)
HLL	3	R	1	FT REFERENCE HORIZONTAL DISTANCE TO THE SIDE OF THE EMERGENCY SPILLWAY AND APPROACH CHANNEL BOTTOM TOWARD THE DOWNHILL SLOPE (FIG. C)
HLRG	2	R	1	FT DEPTH OF FLOW IN CHANNEL ENLARGED TO HANDLE INCREASE IN FLOW CAUSED BY UPSTREAM CHANNELIZATION
HLSIDE	3	R	25	FT HORIZONTAL DISTANCE FROM THE STREAM CENTERLINE TO THE GROUND SURFACE ON THE BANK FOR AN EMERGENCY SPILLWAY ON A HILLSIDE, SADDLE WIDTH FOR AN EMERGENCY SPILLWAY SITE ON A SADDLE, REFERENCED TO ELEVATION BY ELEVA
HLSIDL*	3	R	25	FT VALUE OF HLSIDE FOR A SMALLER DAM REQUIRING A LOWER ELEVATION EMERGENCY SPILLWAY
HLSIDM*	3	R	25	FT VALUE OF HLSIDE FOR AN INTERMEDIATE SIZED DAM REQUIRING AN INTERMEDIATE ELEVATION FOR THE EMERGENCY SPILLWAY
HLSIDH*	3	R	25	FT VALUE OF HLSIDE FOR A LARGER DAM REQUIRING A HIGHER ELEVATION EMERGENCY SPILLWAY
HMAX*	B	R	1	FT MAXIMUM CHANNEL DESIGN DEPTH
HMAX	3	R	1	FT DAM HEIGHT AT CROSS SECTION AMAX
HMEAN	3	R	1	FT DAM HEIGHT AT CROSS SECTION AMEAN
HMIN	3	R	1	FT DAM HEIGHT AT CROSS SECTION AMIN
HN	B	R	1	- NUMBER OF NEW HIGHWAY BRIDGES REQUIRED BY THE CHANNEL DESIGN FLOW
HOLDNG	B	L	1	- READ TRUE TO CONSIDER HOLDING OF RIGHT-OF-WAY FOR FUTURE CHANNELS
HSML	2	R	1	FT DEPTH OF FLOW IN CHANNEL NOT ENLARGED TO HANDLE INCREASED FLOW CAUSED BY UPSTREAM CHANNELIZATION
HT	B	R	1	FT VALUE OF H AT LOWER BOUND OF INCREMENT, SEE H1
HTEMP	B	R	1	FT VALUE OF HN FOR MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR
HU	B	R	1	FT DEPTH OF FLOW IN UNLINED CHANNEL
HWAL*	3	R	24	FT RETAINING WALL HEIGHT HAVING CONCRETE VOLUMES PER LINEAR FOOT SPECIFIED BY CORRESPONDING SUBSCRIPT IN CONWAL
HYD05	3	R	50	CFS HYDROGRAPH OF THE 200-YEAR FLOOD FLOW, IF IMPROVED CHANNEL (UNIFORM TIME BASE)
HYD05N	3	R	50	CFS HYDROGRAPH OF THE 200-YEAR FLOOD FLOW, IF UNIMPROVED CHANNEL (UNIFORM TIME BASE)
HYD43	3	R	50	CFS HYDROGRAPH OF THE MEAN ANNUAL FLOOD FLOW, IF IMPROVED CHANNEL (UNIFORM TIME BASE)
HYD43N	3	R	50	CFS HYDROGRAPH OF THE MEAN ANNUAL FLOOD FLOW, IF UNIMPROVED CHANNEL (UNIFORM TIME BASE)

HYDBAS\* 3 R 5,21 - ARRAY INTO WHICH IS READ FIVE, 20 ELEMENT HYDROGRAPHS (EXPRESSED AS FRACTIONS OF PEAK FLOW) ONE HYDROGRAPH FOR EACH OF THE FOLLOWING CHARACTERISTIC SHAPES: SHARPER (COLUMN 1), SHARP (COLUMN 2), AVERAGE (COLUMN 3), FLAT (COLUMN 4), AND FLATTER (COLUMN 5)

HYDCOM 3 SUBROUTINE CONVERTS SUBWATERSHED TIME BASE HYDROGRAPH TO UNIFORM TIME BASE HYDROGRAPH AND COMBINES WITH MAIN LINE HYDROGRAPH ROUTED FROM UPSTREAM

HYDDS 3 R 50 CFS HYDROGRAPH OF THE DESIGN FLOOD FLOW, IF IMPROVED CHANNEL (UNIFORM TIME BASE)

HYDDSN 3 R 50 CFS HYDROGRAPH OF THE DESIGN FLOOD FLOW, IF UNIMPROVED CHANNEL (UNIFORM TIME BASE)

HYDEM 3 R 50 CFS EMERGENCY SPILLWAY FLOOD HYDROGRAPH (UNIFORM TIME BASE)

HYDIN 3 R 20 CFS LOCAL INFLOW HYDROGRAPH (SUBWATERSHED TIME BASE)

HYDINT\* 3 R 1 HR TIME BETWEEN ELEMENTS IN UNIFORM TIME BASE STREAMFLOW HYDROGRAPHS

HYDLOC 3 R 1 CFS HYDROGRAPH FLOW ELEMENT ON RECESSION CURVE AFTER BASIC CURVE HAS ENDED

HYDMLT\* 3 R 1 - RATIO OF EMERGENCY SPILLWAY FLOW TO 200-YEAR FLOW

HYDOUT 3 R 50 CFS COMBINED (MAIN STREAM + LOCAL INFLOW) HYDROGRAPH (UNIFORM TIME BASE)

HYDTLS 3 L 1 - SET TRUE TO HAVE HYDROLOGIC DETAILS PRINTED OUT

HYDTM 3 R 20 HR TIME TO POINTS ON LOCAL INFLOW HYDROGRAPH (SUBWATERSHED TIME BASE)

HYDTP 3 R 20 CFS FLOW ELEMENTS FOR LOCAL INFLOW HYDROGRAPH (SUBWATERSHED TIME BASE)

HYGRAF 3 R 50 CFS UNIFORM BASE TIME HYDROGRAPH ROUTED THROUGH A REACH OF CHANNEL BY THE MUSKINGUM METHOD

HYIN 3 R 50 CFS UNIFORM TIME BASE HYDROGRAPH ENTERING CHANNEL REACH AS USED IN MUSKINGUM ROUTING

I B I 1 - LOOP COUNTER INDEX IN DO STATEMENTS

I4 3 I 1 - STORED VALUE OF I, HOLDING THE SUBSCRIPT OF THE ELEVATION ELEMENT JUST BELOW THE DOWNHILL EDGE OF THE EMERGENCY SPILLWAY APPROACH CHANNEL

IA B R 1 \$/AC/YR EXPECTED ANNUAL FARM INCOME FROM WEIGHTED AVERAGE SOIL IN A YEAR WHEN FLOODING DOES NOT OCCUR

IB\* 3 I 1 - INTEGER READ TO SET BLDNOW (1=TRUE, 0=FALSE)

IC B I 1 - LOOP COUNTER INDEX IN DO STATEMENTS

IC 3 I 1 - LOWER END OF BRACKET IN TP FOR INTERPOLATION

ICAP9 B I 1 - NUMBER OF HIGHWAY BRIDGES BUILT OR ENLARGED SINCE INITIAL INPUT DATA

ICDIF B I 1 - TOTAL NUMBER OF HIGHWAY BRIDGES ENLARGED OR BUILT DURING THE CURRENT STAGE

ID\* 2 I 100 - FOR EVERY SUBWATERSHED, THE IDENTIFYING NUMBERS OF ALL DOWNSTREAM SUBWATERSHEDS

ID 3 I 1 - NUMBER OF ELEMENT IN CUMVOL CONTAINING VALUE AT TIME IMPT

IHE B I V - NUMBER OF HIGHWAY BRIDGES EXTENDED IN SUBSCRIBED SUBWATERSHED DURING A STAGE

IHLD7	3	I	1	- STORED VALUE OF IHLD9 USED IN PRINTING RIGHT-OF-WAY HOLDING FOR CHANNEL IMPROVEMENT OUTPUT
IHLD8	3	I	15	- VALUE OF IHOLD FOR THE SUBSCRIBED SUBWATERSHED FOR THE MOST ECONOMICAL COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR
IHLD9	3	I	15	- VALUE OF IHOLD FOR THE SUBSCRIBED SUBWATERSHED FOR THE COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT CURRENTLY UNDER ANALYSIS
IHN	B	I	V	- NUMBER OF NEW HIGHWAY BRIDGES BUILT IN SUBSCRIBED SUBWATERSHED DURING A STAGE
IHOLD	B	I	V	- FOR THE SUBSCRIBED SUBWATERSHED, THE NUMBER OF THE STAGE AT THE BEGINNING OF WHICH RIGHT-OF-WAY BEGAN TO BE HELD FOR FUTURE CHANNEL IMPROVEMENT
II	B	I	1	- INDEX SET EQUAL TO 1 IF THE CHANNEL IN A GIVEN SUBWATERSHED IS NOT COMPLETELY IMPROVED AND SET EQUAL TO 2 IN CASE OF FULL IMPROVEMENT FOR DETERMINING WHICH ROW OF ARRAY QQ TO USE
III	B	I	1	- CURRENT VALUE OF LINING FOR USE IN A COMPUTED GO TO STATEMENT
IIS	B	I	1	- SUBSCRIPT OF NEXT FREQUENCY IN ARRAY DF(NDF) RARER THAN ONE FOR WHICH CHANNEL IMPROVEMENT IS CURRENTLY BEING ATTEMPTED, USED AS BEGINNING POINT FOR ANALYSIS OF FLOOD PROOFING AND LOCATION ALTERNATIVE
IL	B	I	1	- SUBSCRIPT OF FREQUENCY IN ARRAY DF(NDF) FOR WHICH A LAND USE RESTRICTION IS CURRENTLY BEING ATTEMPTED
IMAX*	3	I	1	- NUMBER OF ELEVATIONS USED IN INPUT DATA
IMPROV	B	I	V	- INDEX SET EQUAL TO 1, 2, OR 3 FOR THE SUBSCRIBED SUBWATERSHED IF THE CHANNEL BEING CONSIDERED WAS UNCHANGED, INITIALLY IMPROVED, OR ENLARGED RESPECTIVELY IN THE CURRENT STAGE
IMPTY*	3	I	1	DY NUMBER OF DAYS FLOOD STORAGE IS DETAINED IN THE RESERVOIR DURING THE DESIGN FLOOD
INDEX*	2	I	25,2	- THE FIRST AND LAST ELEMENTS IN ARRAY ID PERTAINING TO THE SUBWATERSHED INDICATED BY THE FIRST SUBSCRIPT
IP	B	I	1	- SUBSCRIPT OF FREQUENCY IN ARRAY DF(NDF) FOR WHICH A FLOOD PROOFING DESIGN IS CURRENTLY BEING ATTEMPTED
IPP*	B	R	1	\$/AC ANNUAL VALUE RECEIVED FROM THE AMENITIES OF OPEN SPACE EXPRESSED AS A MULTIPLE OF THE FRACTION OF ADJACENT LAND BEING URBAN
IRE	B	I	V	- NUMBER OF RAILROAD BRIDGES EXTENDED IN SUBSCRIBED SUBWATERSHED DURING A STAGE
IRN	B	I	V	- NUMBER OF NEW RAILROAD BRIDGES BUILT IN SUBSCRIBED SUBWATERSHED DURING A STAGE
IS	B	I	1	- SUBSCRIPT OF FREQUENCY IN ARRAY DF(NDF) FOR WHICH A CHANNEL IMPROVEMENT DESIGN IS CURRENTLY BEING ATTEMPTED
IS	3	I	1	- NUMBER OF SELECTED EMERGENCY SPILLWAY SITE
ISD	3	I	1	- NUMBER OF BEST EMERGENCY SPILLWAY SITE FOUND

THUS FAR

ISG 3 I	1	- NUMBER OF TRIAL EMERGENCY SPILLWAY SITE
ISTAGE 3 I	1	- STAGE IN WHICH RESERVOIR WAS JUSTIFIED
ISX B I	1	- INDEX USED TO ADD 2 TO IS (FIRST DEFINITION)
ITEMP B I	1	- VARIABLE ENTERING THE SUBWATERSHED-STAGE WITH THE PERTAINING ELEMENT OF ARRAY IHOLD BUT SET TO 0 IF HOLDING NOT FOUND ADVANTAGEOUS
ITOP B I	1	- NUMBER OF STORMS FOR WHICH FLOOD DAMAGES ARE ESTIMATED TO ESTABLISH AVERAGE ANNUAL FLOOD DAMAGES
IUH B I	1	- NUMBER OF HIGHWAY BRIDGES REMAINING UNCHANGED THROUGH THE CURRENT STAGE
IUR B I	1	- NUMBER OF RAILROAD BRIDGES REMAINING UNCHANGED THROUGH THE CURRENT STAGE
J B I	1	- LOOP COUNTER INDEX IN DO STATEMENTS
J1 3 I	1	- SUBSCRIPT FOR QQ ARRAY TO DETERMINE WHICH ROW SHOULD BE USED - 1 FOR UNIMPROVED AND 2 FOR IMPROVED CHANNELS
JC 3 I	1	- VALUE OF IC+1 (OR IC IF IC=11) USED IN INTERPOLATING RELATIVE TIME-TO-PEAK FOR A SUBWATERSHED FROM TP ARRAY
JH 2 I	1	- POINT IN ARRAY ID WHERE NUMBER OF MOST DOWNSTREAM ON LINE SUBWATERSHED OCCURS
JL 2 I	1	- POINT IN ARRAY ID WHERE NUMBER OF MOST UPSTREAM ON LINE SUBWATERSHED OCCURS
JU B I	1	- LOOP COUNTER INDEX IN DO STATEMENT
K B I	1	- LOOP COUNTER INDEX IN DO STATEMENT
K1 B R	V	- ARRAY CONTAINING FOR THE SUBSCRIBED SUBWATERSHED THE RATIO OF MAXIMUM DEPTH OF FLOODING ANYWHERE IN THE FLOOD PLAIN TO THE CORRESPONDING FLOOD FLOW (IN EXCESS OF THE CHANNEL CAPACITY) TO THE 0.375 POWER
K1 3 I	1	- LOOP COUNTER FOR DEVELOPING VERY SHARP MEAN ANNUAL HYDROGRAPH
K2 B R	V AC/FT	ARRAY CONTAINING FOR THE SUBSCRIBED SUBWATERSHED THE RATIO OF ACRES FLOODED TO THE CORRESPONDING MAXIMUM FLOODING DEPTH
K2 3 I	1	- LOOP COUNTER FOR BRACKETING SHARPNESS OF SYNTHESIZED MEAN ANNUAL HYDROGRAPH IN HYDBAS
K3 3 I	1	- LOOP COUNTER FOR DEVELOPING BRACKETED MEAN ANNUAL HYDROGRAPH
K4 3 I	1	- LOOP COUNTER FOR DEVELOPING VERY FLAT MEAN ANNUAL HYDROGRAPH
K5 3 I	1	- LOOP COUNTER FOR SETTING TIME TO EACH POINT ON SYNTHESIZED MEAN ANNUAL HYDROGRAPH
KDF B I	1	- LOOP COUNTER FOR GOING THROUGH ARRAY DF
KDFG 3 I	1	- VALUE OF KDF ASSOCIATED WITH OPTIMUM RESERVOIR FLOOD STORAGE CAPACITY
KNBOT 3 L	1	- SET TRUE TO INDICATE THAT THE VALUE FOR BOTTOM HAS BEEN ESTABLISHED
L B R	1	- THE DESIGN FREQUENCY REPRESENTING THE LEVEL OF PROTECTION TO BE PROVIDED BY THE DEGREE OF LAND

				USE RESTRICTION UNDER ANALYSIS
L1*	B I	1		- INTEGER READ TO SET UMC (1=TRUE, 0=FALSE)
L1	3 I	1		- LOOP COUNTER FOR DEVELOPING VERY SHARP 200-YEAR HYDROGRAPH
L2*	B I	1		- INTEGER READ TO SET PTF (1=FALSE, 0=TRUE)
L2	3 I	1		- LOOP COUNTER FOR BRACKETING SHARPNESS OF SYNTHESIZED 200-YEAR HYDROGRAPH IN HYDBAS
L3*	B I	1		- INTEGER READ TO SET LTF (1=FALSE, 0=TRUE)
L3	3 I	1		- LOOP COUNTER FOR DEVELOPING BRACKETED 200-YEAR HYDROGRAPH
L4*	B I	1		- INTEGER READ TO SET STF (1=FALSE, 0=TRUE)
L4	3 I	1		- LOOP COUNTER FOR DEVELOPING VERY FLAT 200-YEAR HYDROGRAPH
L5*	B I	1		- INTEGER READ TO SET TRACE (1=TRUE, 0=FALSE)
L6*	B I	1		- INTEGER READ TO SET CHECK (1=TRUE, 0=FALSE)
L7*	B I	1		- INTEGER READ TO SET HOLDNG (1=TRUE, 0=FALSE)
L8*	3 I	1		- INTEGER READ TO SET DMDTLS (1=TRUE, 0=FALSE)
L9*	3 I	1		- INTEGER READ TO SET HYDTLS (1=TRUE, 0=FALSE)
L10*	3 I	1		- INTEGER READ TO SET LOOPTR (1=TRUE, 0=FALSE)
L11*	3 I	1		- INTEGER READ TO SET NODAM (1=FALSE, 0=TRUE)
LA	B R	1		- FACTOR FOR ESTIMATING COST OF LOCATION RESTRICTION BY MULTIPLYING BY Q**0.375
LACRE	2 R	1	AC	THE AREA OF RESTRICTED LAND USE
LC*	B R	V	MI	CHANNEL LENGTH WITHIN SUBSCRIBED SUBWATERSHED
LC8	3 I	15		- VALUE OF LOC FOR THE LEAST COST COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR
LC9	3 I	15		- VALUE OF LOC FOR THE COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT CURRENTLY UNDER ANALYSIS
LDF	3 I	1		- SUBSCRIPT USED AS A DO STATEMENT LOOP CONTROL INDEX (1 TO NDF) INDICATING WHICH VALUE OF DF IS TO BE PRINTED BY STRUT
LF*	2 R	1		- MULTIPLE OF LAND USE ADJUSTMENT COST TO BE USED FOR SENSITIVITY STUDIES
LG	B L	1		- SET TRUE IF LOCATION RESTRICTION MEASURES HAVE PROVED ECONOMICAL DURING THE CURRENT SUBWATERSHED STAGE
LGAPCH*	3 I	25	FT	LENGTH OF EMERGENCY SPILLWAY APPROACH CHANNEL REQUIRED FOR THE CORRESPONDING SUBSCRIBED VALUE OF ELEVA
LGDAM*	3 I	25	FT	LENGTH OF DAM REQUIRED FOR THE CORRESPONDING SUBSCRIBED VALUE OF ELEVA
LGEMSP*	3 I	25	FT	LENGTH OF EMERGENCY SPILLWAY REQUIRED FOR THE CORRESPONDING SUBSCRIBED VALUE OF ELEVA
LGTEMP	B I	1		- VALUE OF LINING FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR
LINED	B L	1		- SET TRUE IF THE CAPACITY OF THE CHANNEL IN THE SUBWATERSHED BEING CONSIDERED CAN BE MORE ECONOMICALLY INCREASED BY LINING THAN BY ENLARGING
LINEX	B L	1		- SET TRUE IF LINED IS TRUE BUT MAY BE SET BACK TO

FALSE IF INCREASING THE CAPACITY BY LINING DOES NOT PROVIDE THE OPTIMUM LEVEL OF PROTECTION FOR A STILL LARGER DESIGN FLOOD

LINING\* B I V - FOR THE SUBSCRIBED SUBWATERSHED, A VALUE INDICATING THE CHANNEL TYPES TO BE CONSIDERED FOR CHANNEL IMPROVEMENT AS FOLLOWS: 0 - CONSIDER ALL CHANNEL TYPES, 1 - CONSIDER ONLY UNLINED CHANNELS, 2 - CONSIDER ONLY UNLINED CHANNELS WITH DROP STRUCTURES, 3 - CONSIDER ONLY TRAPEZOIDAL PNEUMATICALLY LINED CHANNELS, 4 - CONSIDER ONLY REINFORCED CONCRETE RECTANGULAR CHANNELS. ONCE A CHANNEL IS CONSTRUCTED, THAT TYPE IS FIXED FOR ALL LATER ANALYSES EXCEPT FOR POSSIBLE ADDITION OF DROP STRUCTURES

LL B L 1 - SET TRUE TO ELIMINATE LAND USE MEASURES FROM FURTHER CONSIDERATION IN A SUBWATERSHED-STAGE WHERE IT HAS NO HOPE OF PROVING ECONOMICAL

LLL 2 L 1 - SET TRUE WHEN CHANNEL IS BEING DESIGNED FOR THE LARGER OF THE TWO FLOWS USED TO ESTIMATE DOWNSTREAM COSTS

LN7 3 I 1 - STORED VALUE OF LN9 USED IN PRINTING CHANNEL IMPROVEMENT OUTPUT

LN8 3 I 15 - TYPE OF CHANNEL LINING FOR THE SUBSCRIBED SUBWATERSHED FOR THE LEAST COST COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR

LN9 3 I 15 - TYPE OF CHANNEL LINING FOR THE SUBSCRIBED SUBWATERSHED FOR THE COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT CURRENTLY UNDER ANALYSIS

LOC B I V - THE NUMBER OF THE STAGE SINCE THE BEGINNING OF WHICH LAND USE ADJUSTMENT HAS BEEN CONTINUOUSLY IMPLEMENTED IN THE SUBSCRIBED SUBWATERSHED. EQUAL TO -1 IF IT IS NOT CURRENTLY BEING IMPLEMENTED

LOOPTR 3 L 1 - SET TRUE TO HAVE THE PROGRAM PRINT ITS ENTRY INTO AND EXIT FROM EACH SUBROUTINE

LTA B I 1 - USED IN CALCULATING RIGHT-OF-WAY COST AND SET EQUAL TO THE STAGE AT THE BEGINNING OF WHICH THE LAND FOR RIGHT-OF-WAY WAS OBTAINED, EITHER THE CURRENT STAGE OR THE STAGE IN WHICH HOLDING BEGAN

LTB B I 1 - USED IN CALCULATING RIGHT-OF-WAY COST AND SET EQUAL TO THE STAGE AT THE BEGINNING OF WHICH THE URBAN BUILDINGS WOULD BE LOCATED ON THE RIGHT-OF-WAY, THE NUMBER OF THE STAGE IN WHICH HOLDING BEGAN, LAND USE ADJUSTMENT WAS IMPLEMENTED, OR THE PRESENT STAGE, WHICHEVER CAME FIRST

LTF B L 1 - SET TRUE TO ELIMINATE LAND USE RESTRICTION FROM CONSIDERATION IN PLANNING

M B I 1 - LOOP COUNTER INDEX IN DO STATEMENTS

M1 3 I 1 - LOOP COUNTER FOR DEVELOPING VERY SHARP RESERVOIR

Code	Type	Unit	Value	Description
				DESIGN HYDROGRAPH
M2	3 I	1	1	- LOOP COUNTER FOR BRACKETING SHARPNESS OF SYNTHESIZED 200-YEAR RESERVOIR DESIGN HYDROGRAPH
M3	3 I	1	1	- LOOP COUNTER FOR DEVELOPING BRACKETED RESERVOIR DESIGN HYDROGRAPH
M4	3 I	1	1	- LOOP COUNTER FOR DEVELOPING VERY FLAT RESERVOIR DESIGN HYDROGRAPH
M5	3 I	1	1	- LOOP COUNTER FOR ZEROING VESTIGIAL RESERVOIR DESIGN HYDROGRAPH
MANNR*	B R	1	1	- VALUE OF MANNINGS "N" FOR RECTANGULAR LINED CHANNELS
MANNT*	B R	1	1	- VALUE OF MANNINGS "N" FOR FOR TRAPEZOIDAL PNEUMATICALLY LINED CHANNELS
MANNU*	B R	1	1	- VALUE OF MANNINGS "N" FOR PRISMATIC UNLINED CHANNELS
MCH*	B R	1	1	- ANNUAL MAINTENANCE COST OF EARTH CHANNELS AS A FRACTION OF FIRST COST
MDAM*	3 R	1	1	- ANNUAL MAINTENANCE COST FOR THE DAM AND RESERVOIR AS A FRACTION OF CONSTRUCTION COST
MFP*	B R	1	1	- ANNUAL MAINTENANCE COST OF FLOOD PROOFING MEASURES AS A FRACTION OF FIRST COST
MIN*	B R	1	1	- ANNUAL MAINTENANCE COST OF CONCRETE STRUCTURES AS A FRACTION OF FIRST COST
MN	B I	1	1	- INTERMEDIATE VARIABLE EXPRESSING THE CURRENT VALUE OF LOC
MR	3 I	1	1	- NUMBER OF ELEMENT IN DF CONTAINING SECOND RESERVOIR DESIGN FLOOD FREQUENCY
MRDF*	3 I	1	1	- NUMBER OF THE ELEMENT IN ARRAY DF CONTAINING MINIMUM RESERVOIR DESIGN FLOOD FREQUENCY
MTLCH*	B R	1	1	- ANNUAL MAINTENANCE COST OF TRAPEZOIDAL LINED CHANNELS AS A FRACTION OF FIRST COST
MW*	B I	1	1	- NUMBER OF SUBWATERSHEDS TO BE ANALYZED
N	2 I	1	1	- CURRENT VALUE OF INDEX
N1	3 I	1	1	- LOOP COUNTER FOR FINDING PEAK ELEMENT IN BASIC HYDROGRAPH
NBR	B I	1	1	- NUMBER OF HIGHWAY BRIDGES WITHIN A SUBWATERSHED
ND	B I&R	1	1	- NUMBER OF DROP STRUCTURES WITHIN A SUBWATERSHED DESIGN CHANNEL
ND8	3 I	15	15	- NUMBER OF DROP STRUCTURES IN THE SUBSCRIBED SUBWATERSHED FOR THE MOST ECONOMICAL COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR
ND9	3 I	15	15	- NUMBER OF DROP STRUCTURES IN THE SUBSCRIBED SUBWATERSHED FOR THE COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT CURRENTLY UNDER ANALYSIS
NDF*	B I	1	1	- NUMBER OF DESIGN FLOOD FREQUENCIES TO BE CONSIDERED
NDF	B I	1	1	- CURRENT VALUE OF NSTEMX + 1
NCT	B I	V	V	- NUMBER OF DROP STRUCTURES WITHIN THE SUBSCRIBED SUBWATERSHED

NDTEMP	B I	1	- VALUE OF ND FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND SO FAR
NHILSD*	3 I	1	- NUMBER OF ALTERNATIVE EMERGENCY SPILLWAY LOCATIONS
NID*	2 I	1	- NUMBER OF ITEMS TO BE READ INTO ID
NIN*	B R	1	- NUMBER OF INLETS REQUIRED PER MILE OF CHANNEL
NN	B I	1	- CALLING ARGUMENT FOR CD1 AND CD2. NN = 1 INDICATES THE CHANNEL IS NOT IMPROVED WHILE NN = 2 INDICATES THE CHANNEL IS IMPROVED
NODAM	3 L	1	- LOGICAL VARIABLE SET TRUE TO ELIMINATE CONSIDERATION OF DAM CONSTRUCTION
NRS	B I	1	- INTERMEDIATE LOOP COUNTER USED TO CALCULATE NRT
NRT	B I	1	- LOOP COUNTER INDICATING STAGES IN REVERSE ORDER USED IN VERIFYING THAT LOCATION COST INCREASES WITH URBANIZATION
NSTAGE	B I	1	- NUMBER OF CURRENT PLANNING STAGE
NSTEMX*	B I	1	- NUMBER OF STAGES TO BE ANALYZED
NSTG	3 I	1	- COUNTER USED TO COUNT THE STAGES THUS FAR INCLUDED IN CALCULATING THE AVERAGE ANNUAL URBANIZATION AND CHANNELIZATION VALUES OVER THE DESIGN LIFE OF THE DAM AND RESERVOIR
NW	B I	1	- NUMBER OF CURRENT SUBWATERSHED
NWD	2 I	1	- NUMBER OF THE DOWNSTREAM SUBWATERSHED WITHIN WHICH THE DOWNSTREAM COST IS CURRENTLY BEING CONSIDERED
NWH*	3 I	1	- NUMBER OF WALL HEIGHTS AND CORRESPONDING CONCRETE VOLUMES USED IN ARRAYS HWAL AND CONWAL RESPECTIVELY
OUTFLO	3 R	25	CFS TOTAL OUTFLOW (PRINCIPAL AND EMERGENCY SPILLWAYS) UNDER HEAD INDICATED BY CORRESPONDING POINT IN ELEVA FOR USE IN ROUTING A HYDROGRAPH THROUGH THE RESERVOIR
OUTPUT	2 R	25,13	- ARRAY USED TO CONTAIN THE 13 VALUES DESCRIBING THE OPTIMUM MEASURES FOUND THUS FAR IN THE SUBWATERSHED OF THE FIRST SUBSCRIPT. AFTER ALL MEASURES AND COMBINATIONS ARE CONSIDERED, OUTPUT IS PRINTED AS A SUMMARY OF THE OPTIMUM MEASURES
OUTPUT	3 R	13	- OUTPUT ARRAY OF 13 VALUES FOR CURRENT SUBWATERSHED
P	B R	1	- THE DESIGN FREQUENCY REPRESENTING THE LEVEL OF PROTECTION TO BE PROVIDED BY THE DEGREE OF FLOOD PROOFING UNDER ANALYSIS
P	3 R	1	FT INTERMEDIATE FALL FACTOR USED IN SOLVING CUBIC ENERGY EQUATION
PO	B R	1	FT PERIMETER OF THE CHANNEL LINING IF CHANNEL NOT ENLARGED
PI	3 R	1	- LOCATION OF MAXIMUM ELEMENT IN HYDBAS
PA	B R	1	- FACTOR USED IN COMPUTING COST OF FLOOD PROOFING BUILDINGS WHEN LOCATION ALTERNATIVE IS NOT INVOLVED
PA	3 R	1	FT INTERMEDIATE FALL FACTOR USED IN SOLVING CUBIC ENERGY EQUATION



PB	B	R	1	- FACTOR USED IN COMPUTING COST OF FLOOD PROOFING BUILDINGS RESIDUAL TO LOCATION ALTERNATIVE
PC	B	R	1	- FACTOR USED IN COMPUTING COST OF FLOOD PROOFING BUILDINGS OUTSIDE THE RESTRICTED AREA
PCAREA	3	R	1	SF AREA OF CONCRETE IN THE PRINCIPAL SPILLWAY PIPE CROSS SECTION
PCT	B	R	1	MI DISCOUNTED AVERAGE ANNUAL LENGTH OVER PROJECT LIFE OF TRIBUTARY IMPROVED CHANNELS
PD	3	R	1	FT INSIDE DIAMETER OF PRINCIPAL SPILLWAY PIPE
PEAK	3	R	1	CFS THE PEAK OUTFLOW FROM THE RESERVOIR
PERFER	3	R	1	% RESERVOIR DESIGN FLOOD FREQUENCY
PF*	2	R	1	- MULTIPLE OF FLOOD PROOFING COST TO BE USED FOR SENSITIVITY STUDIES
PG	B	L	1	- SET TRUE IF FLOOD PROOFING MEASURES HAVE BEEN PROVED ECONOMICAL DURING THE CURRENT SUBWATERSHED-STAGE
PHT	3	R	1	- INTERMEDIATE VARIABLE FOR ESTIMATING VRAT
PKTIME	3	R	1	HR TIME FROM BEGINNING OF STORM TO PEAK OUTFLOW FROM THE RESERVOIR
PLACEA	B	SUBROUTINE		ARITHMETIC INTERPOLATION SUBROUTINE
PLNGH	3	R	1	FT LENGTH OF HORIZONTAL PRINCIPAL SPILLWAY PIPE
PLNGT	3	R	1	FT TOTAL LENGTH OF PRINCIPAL SPILLWAY PIPE (PLNGH + PLNGV)
PLNGV	3	R	1	FT LENGTH OF VERTICAL SHAFT LEADING TO PRINCIPAL SPILLWAY PIPE
PLRG	2	R	1	FT LINED PERIMETER OF CHANNEL SUFFICIENTLY LARGE TO HANDLE FLOW INCREASED BY UPSTREAM CHANNELIZATION
PN	B	R	1	- PROBABILITY THAT A GIVEN FLOW WILL NOT BE EQUALLED OR EXCEEDED IN A GIVEN YEAR
PP	B	L	1	- SET TRUE TO PREVENT FURTHER CONSIDERATION OF FLOOD PROOFING IN A SUBWATERSHED-STAGE WHERE IT HAS NO HOPE OF PROVING ECONOMICAL
PR	B	R	1	FT PERIMETER OF THE CHANNEL LINING
PRCON	3	R	1	CY VOLUME OF CONCRETE IN PRINCIPAL SPILLWAY
PRM	3	R	1	FT LENGTH OF PRINCIPAL SPILLWAY WEIR CREST
PSML	2	R	1	FT LINED PERIMETER OF CHANNEL JUST LARGE ENOUGH TO HANDLE FLOW WITHOUT UPSTREAM CHANNELIZATION
PRNSP	3	SUBROUTINE		DESIGNS AND DETERMINES QUANTITIES FOR THE PRINCIPAL SPILLWAY
PSUM	2	R	1	- FACTOR FOR CONVERTING ANNUAL COST OF MEASURES OVER THE STAGE BEING STUDIED TO ANNUAL COST OVER THE TIMST-YEAR PLANNING PERIOD
PT	B	R	1	- COUNTER FOR THE NUMBER OF DESIGN FREQUENCIES FOR WHICH FLOOD PROOFING HAS BEEN CONSIDERED
PTF	B	L	1	- SET TRUE TO ELIMINATE FLOOD PROOFING FROM CONSIDERATION
PTH	3	R	1	FT THICKNESS OF PRINCIPAL SPILLWAY PIPE
PU	B	R	1	FT PERIMETER OF UNLINED CHANNEL INCLUDING FREEBOARD
PUL	B	R	1	FT TOTAL LENGTH OF THE TWO SIDES OF AN UNLINED PRISMATIC CHANNEL WITHOUT FREEBOARD
PURELV	3	R	1	FT ELEVATION UP TO WHICH RIGHT-OF-WAY FOR THE RESERVOIR IS PURCHASED

PUT	B	R	1	- DISCOUNTED AVERAGE ANNUAL TRIBUTARY URBANIZATION OVER PROJECT LIFE
PWF	B	R	1	- SINGLE PAYMENT PRESENT WORTH FACTOR FOR DURATION TIME AND DISCOUNT RATE RPI
PWFAC	2	R	1	- SINGLE PAYMENT PRESENT WORTH FACTOR FOR DURATION XTIME*TIME AND DISCOUNT RATE R
PWFR	3	R	1	- SINGLE PAYMENT PRESENT WORTH FACTOR FOR A DURATION TIME AND DISCOUNT RATE R
Q	B	R	1	CFS WEIGHTED AVERAGE DESIGN FLOW FOR THE SUBWATERSHED
Q	3	R	1	CFS PRINCIPAL SPILLWAY DESIGN FLOWRATE
Q0*	B	R	V	CFS EXISTING CHANNEL CAPACITY FOR SUBSCRIBTED SUBWATERSHED
Q05*	B	R	11,11	- ARRAY INTO WHICH IS READ THE RELATIONSHIP EXPRESSING THE MAGNITUDE OF THE 200-YEAR FLOOD OVER ONE SQUARE MILE AS A FUNCTION OF TRIBUTARY CHANNELIZATION AND URBANIZATION
Q05N	3	R	1	CFS 200-YEAR FLOOD PEAK IF LOCAL CHANNEL IS NOT IMPROVED
Q05Y	3	R	1	CFS 200-YEAR FLOOD PEAK IF LOCAL CHANNEL IS IMPROVED
Q1	B	R	1	CFS EXPECTED FLOW OF GIVEN FREQUENCY FOR THE VALUES OF U AND C AT THE BEGINNING OF A PLANNING STAGE, FOR IMPROVED CHANNELS WITHIN THE SUBWATERSHED
Q2	B	R	1	CFS EXPECTED FLOW OF A GIVEN FREQUENCY FOR THE VALUES OF U AND C AT THE END OF A PLANNING STAGE, FOR IMPROVED CHANNELS WITHIN THE SUBWATERSHED
Q3	B	R	1	CFS EXPECTED FLOW OF A GIVEN FREQUENCY FOR THE VALUES OF U AND C AT THE BEGINNING OF A PLANNING STAGE, FOR UNIMPROVED CHANNELS WITHIN THE SUBWATERSHED
Q4	B	R	1	CFS EXPECTED FLOW OF A GIVEN FREQUENCY FOR THE VALUES OF U AND C AT THE END OF A PLANNING STAGE, FOR UNIMPROVED CHANNELS WITHIN THE SUBWATERSHED
Q43*	B	R	11,11	- ARRAY INTO WHICH IS READ THE RELATIONSHIP EXPRESSING THE MAGNITUDE OF THE MEAN ANNUAL FLOOD OVER ONE SQUARE MILE AS A FUNCTION OF TRIBUTARY CHANNELIZATION AND URBANIZATION
Q43N	3	R	1	CFS MEAN ANNUAL FLOOD PEAK IF LOCAL CHANNEL IS NOT IMPROVED
Q43Y	3	R	1	CFS MEAN ANNUAL FLOOD PEAK IF LOCAL CHANNEL IS IMPROVED
Q5	B	R	1	CFS SMALLER DESIGN FLOW USED TO BOUND INCREMENT BY WHICH LINED CHANNELS ARE SIZED
Q6	B	R	1	CFS LARGER DESIGN FLOW USED TO BOUND INCREMENT BY WHICH LINED CHANNELS ARE SIZED
Q7	3	R	1	CFS STORED VALUE OF Q9 USED IN PRINTING CHANNEL IMPROVEMENT OUTPUT
Q8	3	R	15	CFS CHANNEL CAPACITY FOR THE SUBSCRIBTED SUBWATERSHED FOR THE MOST ECONOMICAL COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR
Q9	3	R	15	CFS CHANNEL CAPACITY FOR THE SUBSCRIBTED SUBWATERSHED

FOR THE COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT CURRENTLY UNDER ANALYSIS

QA	B R	1	-	A VALUE OF Q43 OR Q05 INTERPOLATED FOR A GIVEN DEGREE OF URBANIZATION BETWEEN TWO VALUES OF THE DEGREE OF CHANNELIZATION. QR IS INTERPOLATED BETWEEN QA AND QB
QB	B R	1	-	A VALUE OF Q43 OR Q05 INTERPOLATED FOR A GIVEN DEGREE OF URBANIZATION BETWEEN TWO VALUES OF THE DEGREE OF CHANNELIZATION. QR IS INTERPOLATED BETWEEN AQ AND QB
QB05*	B R	1	CFS	THE 200-YEAR FLOOD PEAK FROM A DRAINAGE AREA OF ONE SQUARE MILE
QB43*	B R	1	CFS	MEAN ANNUAL FLOOD PEAK FROM A DRAINAGE AREA OF ONE SQUARE MILE
QCAP	3 R	1	CFS	EXISTING CHANNEL CAPACITY
QCST	2		SUBROUTINE	ESTIMATES INCREASE IN FLOOD DAMAGE IN DOWNSTREAM SUBWATERSHED NWD WHICH WOULD RESULT IF THE CHANNEL IN UPSTREAM SUBWATERSHED NW WERE IMPROVED ASSUMING NO DAMAGE REDUCTION MEASURES WERE TAKEN. RESULT IS COMPARED WITH COST OF DOWNSTREAM CHANNEL IMPROVEMENT IN SUBROUTINE COST, THE SMALLER OF THE TWO COSTS BEING USED
QDIS	B R	1	CFS	DISCOUNTED AVERAGE VALUE OVER A PLANNING STAGE OF A FLOOD PEAK OF GIVEN FREQUENCY
QDSN	3 R	1	CFS	FLOOD PEAK FOR RESERVOIR DESIGN FLOOD FREQUENCY IF LOCAL CHANNEL IS NOT IMPROVED
QDSY	3 R	1	CFS	FLOOD PEAK FOR RESERVOIR DESIGN FLOOD FREQUENCY IF LOCAL CHANNEL IS IMPROVED
QEMSP	3 R	1	CFS	EMERGENCY SPILLWAY DESIGN FLOW
QF05	3 R	1	CFS	PEAK FLOW OF THE 200-YEAR LOCAL HYDROGRAPH
QF43	3 R	1	CFS	PEAK FLOW OF THE MEAN ANNUAL LOCAL HYDROGRAPH
QFDS	3 R	1	CFS	PEAK FLOW OF THE RESERVOIR DESIGN FREQUENCY LOCAL HYDROGRAPH
QK12*	B R	V	CFS	THE FLOOD PEAK WITHIN THE SUBSCRIBED SUBWATERSHED FOR WHICH THE VALUES OF DK12 AND AK12 ARE ALSO KNOWN - ALL THREE ARRAYS ARE FILLED WITH DATA COLLECTED FROM HISTORICAL FLOODS
QL	B R	1	CFS	DESIGN FLOW FOR LAND USE RESTRICTION MEASURES
QLINED	B R	1	CFS	CAPACITY OF CHANNEL IMPROVED BY LINING
QLL	B R	1	CFS	THE EXCESS OF THE DESIGN FLOW FOR LAND USE ADJUSTMENT OVER THE EXISTING CHANNEL CAPACITY
QLRG	2 R	1	CFS	THE VALUE TO WHICH CHANNEL DISCHARGE IS INCREASED BY UPSTREAM CHANNELIZATION
QN	3 R	1	CFS	STORAGE LOCATION FOR VALUE OF Q05N, Q43N, OR QDSN, WHICHEVER IS BEING USED AS A BASIS FOR CALCULATING THE QX AND QG FLOODS FOR UNIMPROVED CHANNELS
QP	B R	1	CFS	DESIGN FLOW FOR FLOOD PROOFING
QPP	B R	1	CFS	THE EXCESS OF THE DESIGN FLOW FOR FLOOD PROOFING OVER THE EXISTING CHANNEL CAPACITY
QC	B R	2,10	CFS	FOR EACH POTENTIAL DESIGN FREQUENCY, THE DISCOUNTED AVERAGE EXPECTED FLOW FOR UNIMPROVED

			(ROW 1) AND IMPROVED (ROW 2) CHANNEL CONDITIONS
QR	B R	1	- THE VALUE INTERPOLATED BETWEEN QA AND QB ACCORDING TO THE CURRENT VALUE OF URBANIZATION
QRATIO*	3 R	1	- RATIO OF THE PEAK TO THE AVERAGE PRINCIPAL SPILLWAY DISCHARGE
QS	B R	1	CFS DESIGN FLOW FOR CHANNEL IMPROVEMENT
QSML	2 R	1	CFS THE VALUE OF CHANNEL DISCHARGE WITHOUT CHANNELIZATION IN THE SUBWATERSHED BEING EVALUATED
QSPILL	3 R	1	CFS CURRENT PRINCIPAL SPILLWAY DISCHARGE
QSPLWR	3 R	1	CFS CURRENT FLOW THROUGH PRINCIPAL SPILLWAY IF WEIR CONTROL
QSS	B R	1	CFS THE EXCESS OF DESIGN CHANNEL FLOW OVER THE EXISTING CHANNEL CAPACITY
QT05	3 R	1	- MULTIPLIER INTERPOLATED FROM Q05 ACCORDING TO EXISTING CHANNELIZATION AND URBANIZATION TO DETERMINE QF05
QT43	3 R	1	- MULTIPLIER INTERPOLATED FROM Q43 ACCORDING TO EXISTING CHANNELIZATION AND URBANIZATION TO DETERMINE QF43
QWEIR	3 R	1	CFS EMERGENCY SPILLWAY DISCHARGE BASED ON A WEIR COEFFICIENT AND EQUATION
QX	B R	2,16	CFS DISCOUNTED AVERAGE FLOWS IN EXCESS OF CHANNEL CAPACITY FOR EACH OF THE ITOP FLOODS USED IN ESTIMATING ANNUAL FLOOD DAMAGES FOR BOTH UNIMPROVED (ROW 1) AND IMPROVED (ROW 2) CHANNELS
QX1	B R	1	- THE VALUE INTERPOLATED FROM ARRAY Q43 ACCORDING TO THE DEGREE OF URBANIZATION AND CHANNELIZATION
QXC	B R	1	CFS THE AMOUNT BY WHICH THE FLOOD FLOW EXCEEDS THE PROPOSED CHANNEL DESIGN FLOW
QXCS	B R	1	CFS MAXIMUM FLOW IN EXCESS OF CHANNEL CAPACITY THAT WILL NOT LEAVE THE AREA OF LAND USE RESTRICTION
QXX	B R	1	CFS MEAN ANNUAL FLOOD PEAK FOR THE SUBWATERSHED
QY	B R	1	CFS 200-YEAR FLOOD PEAK FOR THE SUBWATERSHED
QY	3 R	1	CFS SAME AS QN BUT FOR IMPROVED CHANNELS
QY1	B R	1	- THE VALUE INTERPOLATED FROM Q05 ACCORDING TO THE DEGREE OF URBANIZATION AND CHANNELIZATION
QYC	2 R	1	CFS 200-YEAR FLOOD PEAK CALCULATED FROM GUMBEL PARAMETERS AT THE END OF THE PREVIOUS STAGE IN ORDER TO TEST WHETHER UPSTREAM CHANNELS HAVE BEEN IMPROVED IN CURRENT STAGE
R*	B R	1	- DISCOUNT RATE FOR USE IN PROJECT PLANNING
RBEG	B R	1	\$/AC VALUE OF URBAN LAND AND BUILDINGS AT THE BEGINNING OF A PLANNING STAGE
RBIG	3 L	1	- SET TRUE IF SIZING RESERVOIR BASED ON DAMAGE REDUCTION OVER PROJECT LIFE, FALSE IF JUSTIFYING RESERVOIR BASED ON DAMAGE REDUCTION IN CURRENT STAGE
RC	B R	V	\$/AC RIGHT-OF-WAY COST OF LANDS AND BUILDINGS WITHIN THE SUBSCRIBED SUBWATERSHED - IT DEPENDS ON WHEN RIGHT-OF-WAY WAS PURCHASED AND SINCE WHEN LAND USE HAS BEEN CONTINUOUSLY RESTRICTED - SET

-1.0 IF NOT YET CALCULATED

RD	3	R	1	DY	IMPTY AS A REAL NUMBER
RDDATA	3			SUBROUTINE	READS INPUT DATA AND COMBINES SELECTED TERMS FOR LATER USE
RE	B	R	1		- NUMBER OF RAILWAY BRIDGES THAT MUST BE MODIFIED TO ACCOMMODATE CHANNEL DESIGN FLOW
READ	B			SUBROUTINE	USED TO READ INPUT DATA. ALLOWS FORMAT FREEDOM AND PLACING OF COMMENTS ON DATA CARDS
REND	B	R	1	\$/AC	TOTAL VALUE OF URBAN LAND AND BUILDINGS AT THE END OF A PLANNING STAGE
RESACR*	3	R	25	AC	SURFACE AREA OF RESERVOIR HAVING THE CORRESPONDINGLY SUBSCRIPTED VALUE OF ELEVA AS ITS SURFACE ELEVATION
RESEL	3	R	25	FT	RESERVOIR SURFACE ELEVATIONS FOR WHICH OUTFLOW AND STORAGE VALUES ARE COMPUTED FOR RESERVOIR ROUTING
RESIN	3	L	1		- SET TRUE IF HYDROGRAPH TO BE DEVELOPED REPRESENTS INFLOW TO A RESERVOIR
RESINF	3	R	50	CFS	UNIFORM TIME BASE HYDROGRAPH FLOWING INTO RESERVOIR
RESOUT	3	R	50	CFS	UNIFORM TIME BASE HYDROGRAPH FLOWING OUT OF RESERVOIR
RESRTE	3			SUBROUTINE	ROUTES THE INFLOW HYDROGRAPH THROUGH THE RESERVOIR
RESVOL	3	R	25	AF	VOLUME OF WATER STORED IN RESERVOIR WHEN THE SURFACE ELEVATION IS THE CORRESPONDINGLY SUBSCRIPTED VALUE OF ELEVA
RETEMP	B	R	1		- VALUE OF RE FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND THUS FAR
RETWAL	3			SUBROUTINE	CALCULATES RETAINING WALL VOLUME
RK24	3	R	1		- DAILY TOTAL FLOW RECESSION CONSTANT IMPTY DAYS AFTER STORM
RN	B	R	1		- NUMBER OF NEW RAILWAY BRIDGES REQUIRED BY THE CHANNEL DESIGN FLOW
RONE	3	L	1		- SET TRUE AS SOON AS THE DECISION TO BUILD A RESERVOIR HAS BEEN MADE
ROWACR	3	R	1	AC	AREA OF RIGHT-OF-WAY TO BE PURCHASED
RPI*	B	R	1		- RATE OF RETURN REQUIRED BY PRIVATE INVESTORS IN LAND
RS1	3		1		- COMMON STATEMENT CONTAINING ALL ARRAYS DEALING WITH THE DAM AND RESERVOIR
RS2	3		1		- COMMON STATEMENT CONTAINING ALL SINGLE VALUE VARIABLES DEALING WITH THE DAM AND RESERVOIR
RSBLT	3	L	1		- SET TRUE IF A RESERVOIR CAN BE CONSIDERED IN ANALYSIS AS HAVING BEEN BUILT
RSFLD	3	L	1		- SET TRUE IF RESERVOIR CAN BE CONSIDERED IN IN ANALYSIS AS HAVING BEEN BUILT TO CONTAIN FLOOD CONTROL STORAGE
RSHYDR	3			SUBROUTINE	DEVELOPS LOCAL INFLOW HYDROGRAPHS AND COMBINES INTO TOTAL HYDROGRAPHS
RTEMP	B	R	1		- VALUE OF RN FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND THUS FAR

RTEST	3	L	1	- SET TRUE IF ANALYSIS CURRENTLY EVALUATING CONSTRUCTION OF A RESERVOIR
RTRYD	3	L	1	- SET TRUE IF SEPARATE HYDROGRAPHS (BESIDES MEAN ANNUAL AND 200-YEAR) ARE REQUIRED FOR RESERVOIR DESIGN
RWF*	2	R	1	- MULTIPLE OF RIGHT-OF-WAY COST TO BE USED FOR SENSITIVITY STUDIES
S*	B	R	V	- THE AVERAGE LONGITUDINAL CHANNEL SLOPE FOR THE SUBSCRIBED SUBWATERSHED
SAFC*	B	R	1	- RATIO OF RIGHT-OF-WAY WIDTH TO BE HELD TO RIGHT-OF-WAY WIDTH PREDICTED TO BE REQUIRED
SBCONC	3	R	1	CY TOTAL VOLUME OF CONCRETE IN STILLING BASIN
SBEX	3	R	1	CY EXCAVATION REQUIRED FOR STILLING BASIN INSTALLATION
SBLNG	3	R	1	FT LENGTH OF EMERGENCY SPILLWAY STILLING BASIN (FIG. A)
SECCND	3	L	1	- SET TRUE IF HYDROGRAPHS BEING DEVELOPED ARE THOSE FOR AN IMPROVED MAINLINE CHANNEL IN THE REACH
SEDIN*	3	R	1	AF/SM ANNUAL SEDIMENT INFLOW INTO RESERVOIR
SEDSTR	3	R	1	AF RESERVOIR SEDIMENT STORAGE RESERVATION (FIG. B)
SF*	2	R	1	- MULTIPLE OF CHANNEL CONSTRUCTION COST TO BE USED FOR SENSITIVITY STUDIES
SG	B	L	1	- SET TRUE IF STRUCTURAL MEASURES HAVE BEEN PROVED ECONOMICAL DURING THE CURRENT SUBWATERSHED-STAGE
SI7	3	R	1	MI TEMPORARY LOCATION FOR VALUE OF SI9 USED IN PRINTING OUTPUT
SI8	3	R	15	MI LENGTH OF MAIN CHANNEL IMPROVED IN SUBSCRIBED SUBWATERSHED FOR THE LEAST COST COMBINATION OF RESERVOIR STORAGE AND CHANNEL IMPROVEMENT FOUND THUS FAR
SI9	3	R	15	MI LENGTH OF MAIN CHANNEL IMPROVED IN SUBSCRIBED SUBWATERSHED FOR RESERVOIR STORAGE BEING TRIED CURRENTLY
SIC*	2	R	V	MI CHANNEL LENGTH WITHIN THE SUBSCRIBED SUBWATERSHED WHICH WAS IMPROVED PRIOR TO THE BEGINNING OF THE PLANNING STAGE
SIC*	3	R	15	MI MAIN LINE CHANNEL LENGTH WITHIN SUBSCRIBED SUBWATERSHED WHICH WAS IMPROVED PRIOR TO THE BEGINNING OF THE PLANNING STAGE
SIGMA	B	R	1	\$/YR STANDARD DEVIATION OF EXPECTED FLOOD DAMAGES USED IN CALCULATING UNCERTAINTY COST
SK1	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF CHANNEL EARTHWORK
SK2	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF DRAINAGE INLETS
SK3	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF RIGHT-OF-WAY
SK4	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF HIGHWAY BRIDGES
SK5	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF RAILWAY BRIDGES
SK6	B	R	1	- FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL

				COST OF DROP STRUCTURES
SK7	B R	1	-	FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF TRAPEZOIDAL LINING
SK8	B R	1	-	FACTOR COMBINING TERMS USED IN COMPUTING ANNUAL COST OF RECTANGULAR LINING
SL	3 R	1	-	SLOPE OF HILLSIDE ABOVE EMERGENCY SPILLWAY BETWEEN TWO BOUNDING ELEVATIONS
SLC	3 R	1	MI	CHANNEL LENGTH ALONG WHICH RIGHT-OF-WAY IS ALREADY HELD
SLG	3 R	1	FT	AVERAGE LENGTH OF THE SECTION OF THE UPSTREAM DAM FACE FOR WHICH RIPRAP QUANTITIES ARE BEING DETERMINED
SLGTH	3 R	1	FT	INCREMENTAL LENGTH ADDED IN GOING TO CURRENT VERTICAL DAM SECTION IN CALCULATING THE VOLUME OF THE EMBANKMENT
SLOPE	B R	1	-	THE AVERAGE LONGITUDINAL CHANNEL SLOPE FOR THE SUBWATERSHED AFTER BEING REDUCED BY ADDING DROP STRUCTURES
SLOPE	3 R	1	-	AVERAGE SLOPE OF EMERGENCY SPILLWAY (VERTICAL/HORIZONTAL)
SPCONC	3 R	1	CY	VOLUME OF CONCRETE IN EMERGENCY SPILLWAY CHUTE
SPCRAR	3 R	1	SF	AREA OF THE EMERGENCY SPILLWAY EXCAVATION SECTION AT THE SPILLWAY CREST
SPEX	3 R	1	CY	TOTAL VOLUME OF EMERGENCY SPILLWAY EXCAVATION
SPLNG	3 R	1	FT	DISTANCE FROM EMERGENCY SPILLWAY CREST TO BEGINNING OF STILLING BASIN WALL (FIG. A)
SPLSIZ	3		SUBROUTINE	SELECTS THE OPTIMUM EMERGENCY SPILLWAY WIDTH
SPRKEX	3 R	1	CY	VOLUME OF ROCK EXCAVATION REQUIRED FOR EMERGENCY SPILLWAY CONSTRUCTION
SPWF	B R	1	-	UNIFORM SERIES PRESENT WORTH FACTOR FOR DURATION TIME AND DISCOUNT RATE RPI
SPWFAC	B R	1	-	UNIFORM SERIES PRESENT WORTH FACTOR FOR DURATION TIME AND DISCOUNT RATE R
SS	B L	1	-	SET TRUE TO ELIMINATE CHANNEL IMPROVEMENT FROM FURTHER CONSIDERATION IN A SUBWATERSHED-STAGE WHERE IT HAS NO HOPE OF PROVING ECONOMICAL
ST	B R	1	-	FREQUENCY OF CHANNEL DESIGN FLOOD
STEMP	B R	1	-	VALUE OF ST FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND THUS FAR
STF	B L	1	-	SET TRUE TO ELIMINATE CHANNEL IMPROVEMENT FROM CONSIDERATION IN PLANNING
STFLOW	3 R	1	CFS	FLOW THROUGH PRINCIPAL SPILLWAY IF PIPE CONTROL AT STORM BEGINNING
STLBAS	3		SUBROUTINE	DESIGNS AND DETERMINES QUANTITIES FOR THE EMERGENCY SPILLWAY STILLING BASIN
STLBT*	3 R	1	FT	THICKNESS OF CONCRETE IN STILLING BASIN BOTTOM (FIG. A)
STOR	3 R	25	SFH	S/T+O/2 TERM AS A FUNCTION OF WATER SURFACE ELEVATION FOR RESERVOIR ROUTING WITH UNGATED SPILLWAYS
STOUT	3 R	50	SFH	CURRENT VALUE OF S/T+O/2 IN RESERVOIR ROUTING
STR	B		SUBROUTINE	SELECTS THE LEAST COSTLY TYPE OF CHANNEL

IMPROVEMENT AND DETERMINES THE RESULTING DESIGN DIMENSIONS AND COSTS

STROUT B SUBROUTINE PRINTS OUT SUMMARY OF CHANNEL IMPROVEMENTS

STWEIR 3 R - CFS FLOW THROUGH PRINCIPAL SPILLWAY IF WEIR CONTROL AT STORM BEGINNING

T B R 1 FT WIDTH OF DESIGN CHANNEL WATER SURFACE

TO B R V FT TOP WIDTH OF EXISTING CHANNEL IN SUBSCRIBED SUBWATERSHED

T7 3 R 1 FT TEMPORARY LOCATION FOR VALUE OF CHANNEL TOP WIDTH USED IN PRINTING OUTPUT

T8 3 R 15 FT IMPROVED CHANNEL TOP WIDTH IN SUBSCRIBED SUBWATERSHED FOR LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES FOUND THUS FAR

T9 3 R 15 FT IMPROVED CHANNEL TOP WIDTH IN SUBSCRIBED SUBWATERSHED FOR RESERVOIR STORAGE BEING TRIED CURRENTLY

TBW 3 R 1 HR LENGTH OF LOCAL HYDROGRAPH BASE

TCL\* B R V MI TOTAL LENGTH OF CHANNEL TRIBUTARY TO THE DOWNSTREAM END OF SUBSCRIBED SUBWATERSHED

TEMP B R 1 - INTERMEDIATE VARIABLE USED IN GUMBEL ANALYSIS IN CALCULATING THE REDUCED VARIATE FROM THE PROBABILITY OF NON-OCCURRENCE

TF\* B R V PSF THE MAXIMUM ALLOWABLE TRACTIVE FORCE FOR SUBSCRIBED SUBWATERSHED AS DETERMINED FROM SOIL ANALYSIS

TFF B R 1 PSF THE TRACTIVE FORCE ACTUALLY DEVELOPED BY A GIVEN FLOW

TI8 3 R 15 MI TOTAL LENGTH OF IMPROVED CHANNEL IN SUBSCRIBED SUBWATERSHED ASSOCIATED WITH LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES FOUND THUS FAR

TI9 3 R 15 MI TOTAL LENGTH OF IMPROVED CHANNEL IN SUBSCRIBED SUBWATERSHED ASSOCIATED WITH RESERVOIR STORAGE BEING TRIED CURRENTLY

TIA 3 R 1 MI TRIBUTARY LENGTH OF IMPROVED CHANNEL NOT ON MAIN LINE STREAM AS APPLIES TO HYDROGRAPH BEING DEVELOPED

TIC\* 2 R 25 MI THE TOTAL LENGTH OF IMPROVED CHANNEL TRIBUTARY TO THE DOWNSTREAM END OF THE SUBSCRIBED SUBWATERSHED

TIC 3 R 1 MI TRIBUTARY LENGTH OF IMPROVED CHANNEL NOT ON MAIN LINE STREAM DURING CURRENT STAGE

TIM 3 R 1 HR TIME FROM BEGINNING OF STORM TO END TO CURRENT RESERVOIR ROUTING PERIOD

TIME\* B R 1 YR DURATION OF ONE PLANNING STAGE

TIMEP 3 R 1 HR TIME FROM BEGINNING OF STORM TO BEGINNING OF CURRENT RESERVOIR ROUTING PERIOD

TIMST\* B R 1 YR THE PLANNING PERIOD AMOUNTING TO NSTEMX\*TIME YEARS, ALSO USED AS DESIGN LIFE OF CHANNEL AND RESERVOIR MEASURES

TLRG 2 R 1 FT TOP WIDTH OF CHANNEL REQUIRED TO HANDLE FLOW INCREASED BY UPSTREAM CHANNELIZATION



TOPACR	3 R	1	AC	RESERVOIR SURFACE AREA AT EMERGENCY SPILLWAY CREST ELEVATION (TOP OF RESERVOIR CLEARING)
TOTHOD	2 R	1	\$/YR	TOTAL ANNUAL COST FOR ALL SUBWATERSHEDS OF HOLDING RIGHT-OF-WAY DURING STAGE
TP*	3 R	11	-	MULTIPLIERS TO REDUCE TIME TO PEAK WITH TRIBUTARY CHANNELIZATION
TP	3 R	1	FT	ELEVATION OF GROUND SURFACE AT POINT WHERE BEDROCK REACHES ELEVATION OF DAM TOP (FIG. C)
TPB*	3 R	1	HR	TIME TO PEAK FOR ONE SQUARE MILE WATERSHED WITH NO TRIBUTARY CHANNELIZATION
TPELEV	3 R	1	FT	ELEVATION OF DAM TOP (FIGS. A, B, C)
TPW	3 R	1	HR	TIME TO PEAK FOR LOCAL HYDROGRAPH
TRACE	B L	1	-	READ TRUE TO HAVE EACH COMBINATION OF MEASURES THAT IS CONSIDERED, PRINTED
TRAREA	3 R	1	SF	REQUIRED AREA OF PRINCIPAL SPILLWAY OPENING
TRIP	3 I	1	-	COUNTER FOR NUMBER OF EMERGENCY SPILLWAY TRIAL WIDTHS
TRV*	3 R	1	FPS	DESIGN FLOW VELOCITY THROUGH PRINCIPAL SPILLWAY TRASHRACK
TSML	2 R	1	FT	TOP WIDTH OF CHANNEL REQUIRED TO HANDLE FLOW WITH NO CHANNELIZATION IN UPSTREAM SUBWATERSHED UNDER ANALYSIS
TSWCD	2 R	1	\$/YR	TOTAL ANNUAL COST OF FLOOD DAMAGES OVER THE ENTIRE WATERSHED DURING A PLANNING STAGE
TSWCF	2 R	1	\$/YR	TOTAL ANNUAL VALUE OF ALL FLOOD CONTROL MEASURES AND ALL RESIDUAL FLOOD DAMAGES DURING A PLANNING STAGE
TSWCL	2 R	1	\$/YR	TOTAL ANNUAL COST OF LAND USE RESTRICTION OVER THE ENTIRE WATERSHED DURING A PLANNING STAGE
TSWCP	2 R	1	\$/YR	TOTAL ANNUAL COST OF FLOOD PROOFING MEASURES OVER THE ENTIRE WATERSHED DURING A PLANNING STAGE
TSWCS	2 R	1	\$/YR	TOTAL ANNUAL COST OF CHANNEL IMPROVEMENT OVER THE ENTIRE WATERSHED DURING A PLANNING STAGE
TSWCU	2 R	1	\$/YR	TOTAL ANNUAL COST OF UNCERTAINTY AS CALCULATED BY A THOMAS UNCERTAINTY FUND OVER THE ENTIRE WATERSHED DURING A PLANNING STAGE
TT	B R	1	FT	STORED VALUE OF T WHILE OTHER SECTION TYPES ARE BEING TRIED TO SEE IF THEY COST LESS
TTEMP	B R	1	FT	VALUE OF T FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND THUS FAR
TWELEV*	3 R	1	FT	WATER SURFACE ELEVATION DOWNSTREAM FROM RESERVOIR DURING DESIGN FLOOD
U	B R	1	-	FRACTION OF THE TOTAL AREA TRIBUTARY TO A SUBWATERSHED IN URBAN LAND USE
UCCLR*	3 R	1	\$/AC	AVERAGE UNIT COST OF CLEARING RESERVOIR SITE
UCCNID*	3 R	1	\$/CY	UNIT COST OF IN PLACE IMPACT ENERGY DISSIPATOR
UCCT*	3 R	1	\$/CY	UNIT COST OF EXCAVATING CUTOFF TRENCH AND BACK-FILLING WITH IMPERVIOUS MATERIAL (VOLCT)
UCDAM*	3 R	1	\$/CY	UNIT COST OF IN PLACE DAM EMBANKMENT (VOLDAM)
UCFIX	3 SUBROUTINE			DETERMINES AVERAGE ANNUAL URBANIZATION AND CHANNELIZATION OVER THE LIFE OF THE RESERVOIR
UCPRCN*	3 R	1	\$/CY	UNIT COST OF IN PLACE PRINCIPAL SPILLWAY CONDUIT

				PER CUBIC YARD OF PIPE CONCRETE (PRCON)
UCRKEX*	3 R	1	\$/CY	UNIT COST OF ROCK EXCAVATION FOR EMERGENCY SPILLWAY (RKEX)
UCROW	3 R	1	\$/AC	AVERAGE UNIT COST PAID FOR REAL PROPERTY
UCRP*	3 R	1	\$/CY	UNIT COST OF PROTECTIVE COVERING ON UPSTREAM FACE OF DAM
UCSPCN*	3 R	1	\$/CY	UNIT COST OF IN PLACE STRUCTURAL CONCRETE IN EMERGENCY SPILLWAY (SPCN, SBCNC)
UCSPEX*	3 R	1	\$/CY	UNIT COST OF EARTH EXCAVATION FOR EMERGENCY SPILLWAY (SPEX, SBEX)
UCTRK*	3 R	1	\$/SF	UNIT COST OF PRINCIPAL SPILLWAY ENTRANCE (INCLUDING TOWER) PER SQUARE FOOT OF OPENING (TRAREA)
UJ	B R	1	-	VALUE OF U ROUNDED TO THE NEXT LOWER DECILE FOR THE PURPOSE OF INTERPOLATION
UN	B R	1	-	DISCOUNTED AVERAGE ANNUAL SUBWATERSHED URBANIZATION OVER THE PLANNING STAGE EXPRESSED AS A FRACTION OF TOTAL LAND AREA
UNC	B L	1	-	SET TRUE TO CALCULATE FLOOD DAMAGE AS INCLUDING DAMAGE BASED ON THOMAS UNCERTAINTY FUND
UQ	B R	1	-	THE URBANIZATION TO THE NEAREST ROUNDED TENTH BELOW THE VALUE OF UN+1.0 USED TO INTERPOLATE A VALUE OF FUQ FROM FRU
UR	B R	1	-	THE URBANIZATION UN+0.1 EXPRESSED IN TENTHS USED IN INTERPOLATING FUQ VALUES FROM FRU
USUBW*	B R	V,6	-	THE FRACTION OF THE SUBSCRIBED SUBWATERSHED FLOOD PLAIN IN URBAN LAND USE AT THE BEGINNING AND END OF EACH STAGE
UT2	3 R	1	-	DISCOUNTED AVERAGE ANNUAL URBAN FRACTION OVER STAGE
UTOTR*	B R	V,6	-	THE FRACTION OF THE TOTAL AREA TRIBUTARY TO THE SUBSCRIBED SUBWATERSHED IN URBAN LAND USE AT THE BEGINNING AND END OF EACH STAGE
UU	B R	1	-	VALUE OF U USED IN INTERPOLATION
UZ	B R	1	-	FLOOD PLAIN URBAN FRACTION PRESENT AT THE TIME LAND USE RESTRICTION WAS INITIATED
V05*	3 R	11,11	-	MULTIPLIERS TO CONVERT 200-YEAR FLOOD VOLUME WITH NO TRIBUTARY URBANIZATION OR CHANNELIZATION TO VOLUME FOR KNOWN URBANIZATION AND CHANNELIZATION
V43*	3 R	11,11	-	MULTIPLIERS TO CONVERT MEAN ANNUAL FLOOD VOLUME WITH NO TRIBUTARY URBANIZATION OR CHANNELIZATION TO VOLUME FOR KNOWN URBANIZATION AND CHANNELIZATION
VA*	B R	1	-	THE NORMAL DEVIATE READ FOR USE IN CALCULATING UNCERTAINTY COSTS
VALUE*	B R	V,6	\$/AC	MARKET VALUE OF LAND WITHIN THE SUBSCRIBED SUBWATERSHED AT THE BEGINNING AND END OF EACH STAGE
VB05*	3 R	1	CFS	MEAN FLOW DURING 200-YEAR FLOOD FROM ONE SQUARE MILE
VB43*	3 R	1	CFS	MEAN FLOW DURING MEAN ANNUAL FLOOD FROM ONE SQUARE MILE
VEL	3 R	1	FPS	FLOW VELOCITY THROUGH PRINCIPAL SPILLWAY

VF*	B R	1	- RATIO OF AREA REQUIRING FLOOD PROOFING TO THAT INUNDATED BY THE DESIGN FLOOD
VF05	3 R	1	CFS MEAN FLOW DURING 200-YEAR LOCAL HYDROGRAPH
VF43	3 R	1	CFS MEAN FLOW DURING MEAN ANNUAL LOCAL HYDROGRAPH
VFDS	3 R	1	CFS MEAN FLOW DURING RESERVOIR DESIGN FREQUENCY LOCAL HYDROGRAPH
VHEAD	3 R	1	FT VELOCITY HEAD OF FLOW THROUGH PRINCIPAL SPILLWAY
VK	3 R	1	FT VELOCITY HEAD OF FLOW AT BASE OF EMERGENCY SPILLWAY
VLAGST*	B R	1	\$/AC VALUE OF BUILDINGS IN RURAL AREAS
VLURST*	B R	1	\$/AC VALUE OF BUILDINGS IN URBANIZED AREAS
VGL	3 R	1	AF VOLUME OF RESERVOIR STORAGE AT GIVEN ELEVATION
VOLCT	3 R	1	CY VOLUME OF CUTOFF TRENCH UNDER DAM
VOLDAM	3 R	1	CY VOLUME OF DAM EMBANKMENT
VOLRP	3 R	1	CY VOLUME OF RIPRAP ON DAM FACE
VRAT	3 R	1	- RATIO OF MEAN FLOW TO PEAK FLOW DURING HYDROGRAPH
VT05	3 R	1	- MULTIPLIER INTERPOLATED FROM V05 ACCORDING TO EXISTING CHANNELIZATION AND URBANIZATION TO DETERMINE VF05
VT43	3 R	1	- MULTIPLIER INTERPOLATED FROM V43 ACCORDING TO EXISTING CHANNELIZATION AND URBANIZATION TO DETERMINE VF43
W	B R	1	FT CHANNEL RIGHT-OF-WAY WIDTH
W0	B R	V	FT CHANNEL RIGHT-OF-WAY WIDTH IN SUBSCRIBED SUBWATERSHED
W7	3 R	1	FT TEMPORARY LOCATION FOR VALUE OF CHANNEL RIGHT-OF-WAY WIDTH USED IN PRINTING OUTPUT
W8	3 R	15	FT CHANNEL RIGHT-OF-WAY WIDTH IN SUBSCRIBED SUBWATERSHED FOR LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES FOUND THUS FAR
W9	3 R	15	FT CHANNEL RIGHT-OF-WAY WIDTH IN SUBSCRIBED SUBWATERSHED FOR RESERVOIR STORAGE BEING TRIED CURRENTLY
WD	3 R	1	FT MAXIMUM WIDTH OF EARTH EXCAVATION ABOVE EMERGENCY SPILLWAY (FIG. C)
WDEMSP*	3 R	1	FT EMERGENCY SPILLWAY WIDTH (FIG. C)
WEXTRA	B R	1	FT EXTRA RIGHT-OF-WAY WIDTH REQUIRED WHEN A TRAPEZOIDAL CHANNEL IS ENLARGED
WFIX	3 L	5	- TRUE IF EMERGENCY SPILLWAY WIDTH HAS BEEN OPTIMIZED FOR SUBWATERSHED STAGE
WFX	3 L	1	- TRUE IF EMERGENCY SPILLWAY WIDTH HAS BEEN OPTIMIZED FOR CURRENT STAGE
WLHT1	3 R	1	FT EMERGENCY SPILLWAY WALL HEIGHT NEAR UPSTREAM END (FIG. A)
WLHT2	3 R	1	FT EMERGENCY SPILLWAY WALL HEIGHT NEAR CREST (FIG. A)
WLHTB	3 R	1	FT STILLING BASIN WALL HEIGHT (FIG. A)
WLHTCH	3 R	1	FT MEAN EMERGENCY SPILLWAY WALL HEIGHT
WLHTD1	3 R	1	FT EMERGENCY SPILLWAY WALL HEIGHT NEAR DOWNSTREAM END (FIG. A)
WLHTM	3 R	1	FT SECTION MEAN WALL HEIGHT USED IN ESTIMATING VOLUME

WLRG	2 R	1	FT RIGHT-OF-WAY WIDTH REQUIRED BY CHANNEL ENLARGED TO HANDLE FLOW AS INCREASED BY UPSTREAM CHANNELIZATION
WLVOL	3 R	1	CY VOLUME OF CONCRETE IN STILLING BASIN WALLS
WSML	2 R	1	FT RIGHT-OF-WAY WIDTH REQUIRED BY A CHANNEL DESIGNED TO HANDLE THE FLOW WITHOUT CHANNELIZATION IN THE SUBWATERSHED UNDER STUDY
WT	B R	V	FT EXTRA RIGHT-OF-WAY WIDTH HELD FOR FUTURE CHANNEL IMPROVEMENT IN SUBSCRIBED SUBWATERSHED
WT7	3 R	1	FT TEMPORARY LOCATION FOR VALUE OF CHANNEL RIGHT-OF-WAY HOLDING WIDTH USED IN PRINTING OUTPUT
WT8	3 R	15	FT CHANNEL RIGHT-OF-WAY HOLDING WIDTH IN SUBSCRIBED SUBWATERSHED FOR LEAST COST COMBINATION OF RESERVOIR STORAGE AND DOWNSTREAM MEASURES FOUND THUS FAR
WT9	3 R	15	FT CHANNEL RIGHT-OF-WAY HOLDING WIDTH IN SUBSCRIBED SUBWATERSHED FOR RESERVOIR STORAGE BEING TRIED CURRENTLY
WTEMP	B R	1	FT VALUE OF W FOR THE MOST ECONOMICAL CHANNEL IMPROVEMENT FOUND THUS FAR
WU	3 R	1	FT MAXIMUM WIDTH OF EARTH EXCAVATION ABOVE EMERGENCY SPILLWAY APPROACH CHANNEL (FIG. C)
WW	B R	1	FT STORED VALUE OF W WHILE OTHER SECTION TYPES ARE BEING TRIED TO SEE IF THEY COST LESS
X	B R	11,11	- TWO DIMENSIONAL ARRAY BROUGHT INTO PLACE FOR DOUBLE INTERPOLATION
X	B R	1	- RATIO OF CHANNEL BOTTOM WIDTH TO DEPTH OF FLOW
XF	B R	1	CFS MODE OF DISTRIBUTION OF FLOWS USED IN THE GUMBEL ANALYSIS TO DETERMINE THE FREQUENCY AT WHICH FLOODING BEGINS
XF1	2 R	25	CFS SUBSCRIBED SUBWATERSHED MODE OF THE DISTRIBUTION OF FLOWS USED IN THE GUMBEL ANALYSIS TO DETERMINE FLOW-FREQUENCY RELATIONSHIPS - "1" DENOTES BEGINNING OF STAGE FLOWS FOR IMPROVED CHANNELS
XF2	2 R	25	CFS SEE XF - "2" DENOTES END OF STAGE FLOWS FOR IMPROVED CHANNELS
XF3	2 R	25	CFS SEE XF1 - "3" DENOTES BEGINNING OF STAGE FLOWS FOR UNIMPROVED CHANNELS
XF4	2 R	25	CFS SEE XF1 - "4" DENOTES END OF STAGE FLOWS FOR UNIMPROVED CHANNELS
XFL	2 R	1	CFS MODE OF THE ANNUAL SERIES OF EXPECTED FLOWS WITHOUT CHANNELIZATION IN UPSTREAM SUBWATERSHED UNDER ANALYSIS
XHN	3 R	1	CFS MODE OF FLOWS IN FLOOD FREQUENCY RELATIONSHIP WITH NO MAIN LINE CHANNEL IMPROVEMENT IN SUBWATERSHED FOR FLOODS RARER THAN RESERVOIR DESIGN FREQUENCY
XHY	3 R	1	CFS MODE OF FLOWS IN FLOOD FREQUENCY RELATIONSHIP WITH MAIN LINE CHANNEL IMPROVEMENT IN SUBWATERSHED FOR FLOODS RARER THAN RESERVOIR DESIGN FREQUENCY
XLN	3 R	1	CFS MODE OF FLOWS IN FLOOD FREQUENCY RELATIONSHIP

WITH NO MAIN LINE CHANNEL IMPROVEMENT IN SUB-  
WATERSHED FOR FLOODS LESS RARE THAN RESERVOIR  
DESIGN FREQUENCY

XLY	3 R	1	CFS	MODE OF FLOWS IN FLOOD FREQUENCY RELATIONSHIP WITH MAIN LINE CHANNEL IMPROVEMENT IN SUBWATERSHED FOR FLOODS LESS RARE THAN RESERVOIR DESIGN FREQUENCY
XTIME	2 R	1	-	NUMBER OF PLANNING STAGES WHICH HAVE ALREADY ELAPSED
XTRSTR*	3 R	1	AF	DESIGN RESERVOIR STORAGE FOR PURPOSES OTHER THAN FLOOD CONTROL (FIG. B)
Y	B R	16	-	REDUCED VARIATE IN GUMBEL ANALYSIS CORRESPONDING TO THE FREQUENCY OF OCCURRENCE OF FLOODS OF THE ITOP FREQUENCIES SPECIFIED IN DQCK FOR ESTIMATING AVERAGE ANNUAL FLOOD DAMAGE
Y	3 R	1	-	INTERMEDIATE FACTOR IN APPLYING ENERGY EQUATION TO EMERGENCY SPILLWAY FLOW
YCOMP	2 R	1	-	REDUCED VARIATE IN GUMBEL ANALYSIS FOR THE 200-YEAR FLOOD
YDIF	B R	1	-	DIFFERENCE IN THE REDUCED VARIATE FOR THE MEAN ANNUAL FLOOD AND THAT FOR THE 200-YEAR FLOOD
YDS	3 R	1	-	REDUCED VARIATE OF RESERVOIR DESIGN FLOOD FREQUENCY
YF	B R	1	-	REDUCED VARIATE IN GUMBEL ANALYSIS OF FLOOD OF THE FREQUENCY AT WHICH FLOODING BEGINS
YPRIME	3 R	1	-	FIRST DIFFERENTIAL OF Y IN ENERGY EQUATION
YY	B R	10	-	REDUCED VARIATE IN GUMBEL ANALYSIS CORRESPONDING TO EACH OF THE NDF DESIGN FREQUENCIES SPECIFIED IN DF
YYTEST	3 R	1	-	REDUCED VARIATE OF RESERVOIR DESIGN FLOOD FREQUENCY
ZCT*	3 R	1	-	HORIZONTAL TO VERTICAL SIDE SLOPE OF CUTOFF TRENCH (FIG. B)
ZDN*	3 R	1	-	HORIZONTAL TO VERTICAL SLOPE OF DOWNSTREAM DAM FACE (FIG. B)
ZES*	3 R	1	-	HORIZONTAL TO VERTICAL SLOPE OF CUT ABOVE EMERGENCY SPILLWAY (FIG. C)
ZM	3 R	1	-	MEAN OF SLOPE ON UPSTREAM AND DOWNSTREAM FACES OF DAM
ZT*	B R	1	-	DESIGN SIDE SLOPE OF TRAPEZOIDAL LINED CHANNELS
ZU*	B R	1	-	DESIGN SIDE SLOPE OF UNLINED PRISMATIC CHANNELS
ZUP*	3 R	1	-	HORIZONTAL TO VERTICAL SLOPE OF UPSTREAM DAM FACE (FIG. B)

APPENDIX C

INPUT DATA

FOR

THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II

\* DATA INPUT TO UNIV. OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM II  
 \* NORTH FORK OF THE KENTUCKY RIVER - CARR FORK

\* PROGRAM CONTROL PARAMETERS

0 \* L1 - "0" EXCLUDES UNCERTAINTY FROM DAMAGES  
 1 \* L2 - "0" EXCLUDES CONSIDERATION OF FLOOD PROOFING  
 0 \* L3 - "0" EXCLUDES CONSIDERATION OF LAND USE MEASURES  
 1 \* L4 - "0" EXCLUDES CONSIDERATION OF CHANNEL IMPROVEMENT  
 1 \* L5 - "0" EXCLUDES PRINTING OF ALL COMBINATIONS TRIED  
 1 \* L6 - "0" EXCLUDES PRINTING OF EACH NEW OPTIMUM  
 \* COMBINATION  
 0 \* L7 - "0" EXCLUDES CONSIDERATION OF HOLDING EXTRA  
 \* RIGHT-OF-WAY  
 5 \* NSTEMX - NUMBER OF PLANNING STAGES  
 9 \* MW - NUMBER OF SUBWATERSHEDS

\* SIZE AND ARRANGEMENT OF WATERSHED

\* AW() - AREA TRIBUTARY TO DOWNSTREAM END OF EACH SUBWATERSHED  
 \* IN SQ. MILES  
 58.18 78.38 85.98 464.01 469.39 511.27 582.69 616.38 639.91

\* INDEX() - INDEX TO ARRAY 'ID'

*SUBWATERSHED NO.	1	2	3	4	5	6	7	8	9	
	1	9	16	22	27	31	34	36	0	* FIRST VALUE
	8	15	21	26	30	33	35	36	0	* LAST VALUE

36 \* NID - NO. OF ITEMS IN DOWNSTREAM SUBWATERSHED ARRAY "ID"

\* ID() - IDENTIFYING NUMBERS OF DOWNSTREAM SUBWATERSHEDS

2	3	4	5	6	7	8	9	*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 1
3	4	5	6	7	8	9		*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 2
4	5	6	7	8	9			*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 3
5	6	7	8	9				*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 4
6	7	8	9					*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 5
7	8	9						*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 6
8	9							*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 7
9								*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 8
								*SUBWATERSHEDS DOWNSTREAM FROM SUBWATERSHED 9

\* LC() - LENGTH OF CHANNEL WITHIN EACH SUBWATERSHED IN MILES  
 17.90 3.84 4.97 4.78 3.74 7.53 17.28 9.66 12.31

\* SIC() - LENGTH OF IMPROVED CHANNEL IN SUBWATERSHED BEFORE

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*          PLANNING BEGAN
  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
* TCL() - LENGTH OF CHANNEL TRIBUTARY TO DOWNSTREAM END OF EACH
*          SUBWATERSHED
  50.2    66.2    73.6    407.4   412.3   452.5   525.2   557.1   581.6
* TIC() - LENGTH OF IMPROVED CHANNEL TRIBUTARY TO DOWNSTREAM END
*          OF EACH SUBWATERSHED BEFORE PLANNING BEGAN
  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
* HYDROLOGY
  177.    * QB43 - MEAN ANNUAL FLOOD PEAK FROM ONE SQUARE MILE
  550.    * QB05 - 200-YEAR FLOOD PEAK FROM ONE SQUARE MILE
* Q43() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND MEAN
*          ANNUAL FLOOD PEAK FROM ONE SQUARE MILE, EXPRESSED AS
*          MULTIPLES OF THE PEAK WITH U=0.0 AND C=0.0
*0.00   0.10   0.20   0.30   0.40   0.50   0.60   0.70   0.80   0.90   1.00 = U
1.000   1.005   1.029   1.068   1.108   1.156   1.196   1.236   1.276   1.320   1.365 *C=.0
1.156   1.179   1.304   1.337   1.367   1.403   1.434   1.460   1.489   1.494   1.499 *C=.1
1.491   1.544   1.578   1.614   1.655   1.703   1.750   1.789   1.838   1.848   1.858 *C=.2
1.978   2.029   2.069   2.113   2.153   2.195   2.237   2.276   2.324   2.361   2.384 *C=.3
2.496   2.507   2.545   2.587   2.606   2.677   2.731   2.791   2.856   2.927   3.006 *C=.4
2.990   3.026   3.063   3.099   3.124   3.152   3.218   3.300   3.442   3.531   3.620 *C=.5
3.262   3.353   3.444   3.536   3.627   3.718   3.810   3.901   3.991   4.053   4.131 *C=.6
3.429   3.518   3.520   3.628   3.735   3.844   3.955   4.073   4.184   4.289   4.474 *C=.7
3.533   3.560   3.596   3.722   3.844   3.970   4.110   4.247   4.378   4.525   4.705 *C=.8
3.588   3.602   3.672   3.815   3.952   4.109   4.268   4.420   4.571   4.761   4.912 *C=.9
3.627   3.644   3.748   3.907   4.075   4.250   4.426   4.593   4.765   4.936   5.112 *C=1.
* Q05() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND 200-
*          YEAR FLOOD PEAK FROM ONE SQUARE MILE, EXPRESSED AS
*          MULTIPLES OF THE PEAK WITH U=0.0 AND C=0.0
*0.00   0.10   0.20   0.30   0.40   0.50   0.60   0.70   0.80   0.90   1.00 = U
1.000   1.004   1.013   1.029   1.045   1.062   1.079   1.096   1.113   1.130   1.147 *C=.0
1.059   1.143   1.154   1.165   1.177   1.190   1.204   1.213   1.227   1.230   1.245 *C=.1
1.308   1.441   1.455   1.470   1.486   1.502   1.519   1.532   1.548   1.556   1.578 *C=.2
1.614   1.739   1.757   1.775   1.795   1.814   1.834   1.851   1.870   1.882   1.910 *C=.3
1.919   2.037   2.059   2.081   2.103   2.126   2.149   2.169   2.192   2.208   2.242 *C=.4
2.227   2.336   2.361   2.386   2.412   2.438   2.464   2.488   2.513   2.534   2.575 *C=.5
2.533   2.634   2.663   2.692   2.721   2.750   2.779   2.807   2.834   2.861   2.907 *C=.6
2.835   2.932   2.965   2.997   3.030   3.062   3.094   3.126   3.156   3.187   3.240 *C=.7
3.146   3.230   3.267   3.302   3.338   3.374   3.409   3.444   3.478   3.513   3.572 *C=.8
3.455   3.528   3.568   3.608   3.647   3.686   3.724   3.763   3.799   3.839   3.904 *C=.9
3.757   3.827   3.870   3.913   3.956   3.998   4.039   4.081   4.120   4.165   4.237 *C=1.
* AFCTR() - RATIOS OF CSM FOR FLOOD PEAKS FROM STATED DRAINAGE AREA
*          TO CSM FOR FLOOD PEAKS FROM ONE SQ. MI. FOR TWO FLOOD
*          FREQUENCIES
*          DRAINAGE AREA IN SQ. MI.
  1.0    400.0  700.0  700.0  700.0  700.0  700.0  700.0  700.0  700.0  700.0
*          MEAN ANNUAL FLOOD
  1.000  0.223  0.152  0.152  0.152  0.152  0.152  0.152  0.152  0.152  0.152
*          200-YEAR FLOOD
  1.000  0.220  0.148  0.148  0.148  0.148  0.148  0.148  0.148  0.148  0.148
* FLOOD DAMAGES - GENERAL
* Q0() - EXISTING SUBWATERSHED CHANNEL CAPACITY IN CFS

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1300. 3710. 2230. 14010. 15380. 18930. 20050. 17890. 16360.

\* QK(),AK(),DK() - MAGNITUDE OF ANY KNOWN FLOOD PEAK AND ASSOCIATED  
 \* MAXIMUM DEPTH OF FLOODING AND AREA FLOODED

* FLOOD PEAK	AREA FLOODED	MAXIMUM DEPTH	SUBWATERSHED
* CFS	ACRES	FEET	
5400.	152.	5.0	* 1
11600.	89.	3.0	* 2
13700.	154.	10.2	* 3
47800.	174.	23.3	* 4
47900.	307.	22.7	* 5
49300.	586.	22.8	* 6
50000.	953.	22.2	* 7
50400.	829.	24.6	* 8
50800.	946.	27.4	* 9

\* FLOOD DAMAGES - UNCERTAINTY

2.575 \* VA - NORMAL DEVIATE USED IN EVALUATING UNCERTAINTY

\* FLOOD DAMAGES - URBAN

37000. \* VLURST - MEAN VALUE OF URBAN STRUCTURES, IN \$/ACRE

0.052 \* COEFD - FLOOD DAMAGE PER FOOT OF FLOOD DEPTH PER DOLLAR  
 \* OF BUILDING MARKET VALUE

\* FLOOD DAMAGES - AGRICULTURAL

\* D() - FRACTION OF SUBWATERSHED FLOOD PLAIN LAND WITHIN EACH OF  
 \* THREE SOIL CLASSES

* BEST SOIL	MED. SOIL	WORST SOIL	SUBWATERSHED
0.86	0.01	0.13	* 1
0.55	0.40	0.05	* 2
0.70	0.04	0.26	* 3
1.00	0.00	0.00	* 4
0.92	0.00	0.08	* 5
0.82	0.00	0.18	* 6
0.72	0.03	0.25	* 7
1.00	0.00	0.00	* 8
0.93	0.07	0.00	* 9

1.02 \* CDA - CROP DAMAGE PER ACRE OF MOST PRODUCTIVE SOIL WHEN  
 \* FLOODED TO A MINIMAL DEPTH

1.24 \* CDB - CROP DAMAGE PER ACRE OF INTERMEDIATE SOIL WHEN  
 \* FLOODED TO A MINIMAL DEPTH

0.01 \* CDC - CROP DAMAGE PER ACRE OF LEAST PRODUCTIVE SOIL WHEN  
 \* FLOODED TO A MINIMAL DEPTH

0.368 \* CDAV - INCREMENTAL DAMAGE PER ACRE OF MOST PRODUCTIVE  
 \* SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH

0.149 \* CDBV - INCREMENTAL DAMAGE PER ACRE OF INTERMEDIATE  
 \* SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH

0.009 \* CDCV - INCREMENTAL DAMAGE PER ACRE OF LEAST PRODUCTIVE  
 \* SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH

\* FRU() - RELATIONSHIP BETWEEN AGRICULTURAL PRODUCTIVITY AND  
 \* URBANIZATION EXPRESSED AS A MULTIPLE OF FULL RURAL VALUE

\* U=0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00  
 1.00 0.97 0.91 0.82 0.71 0.58 0.44 0.37 0.30 0.23 0.16

0.0 \* VLAGST - MEAN VALUE OF AGRICULTURAL STRUCTURES,  
 \* IN \$/ACRE

\* GENERAL DESIGN VARIABLES



0.03125 \* R - DISCOUNT RATE USED IN PLANNING  
 50.0 \* TIMST - DESIGN LIFE OF CHANNEL IMPROVEMENTS IN YEARS  
 10.0 \* TIME - DURATION OF ONE PLANNING STAGE  
 10 \* NDF - NUMBER OF DESIGN FLOOD FREQUENCIES CONSIDERED  
 \* DF(I) - DESIGN FLOOD FREQUENCIES TO BE CONSIDERED IN ANALYSIS  
 0.43 0.30 0.20 0.15 0.10 0.07 0.04 0.02 0.01 0.005  
 \* CHANNEL IMPROVEMENT - PHYSICAL FACTORS  
 \* AO(I) - INITIAL SUBWATERSHED CHANNEL CROSS SECTIONAL AREA IN SQ.FT.  
 940. 940. 940. 3700. 3700. 3700. 3700. 3700. 3700.  
 \* LINING(I) - DESIGNATION OF CHANNEL TYPES TO BE CONSIDERED IN  
 \* SUBWATERSHED  
 \* \*0\* ALL TYPES OF CHANNEL IMPROVEMENT TO BE CONSIDERED  
 \* \*1\* CONSIDERS ONLY UNLINED CHANNELS, NO EXISTING DROP  
 \* STRUCTURES  
 \* \*2\* CONSIDERS ONLY UNLINED CHANNELS, EXISTING DROP  
 \* STRUCTURES  
 \* \*3\* CONSIDERS ONLY TRAPEZOIDAL LINED CHANNELS  
 \* \*4\* CONSIDERS ONLY RECTANGULAR LINED CHANNELS  
 0 0 0 0 0 0 0 0  
 \* FQ(I) - AVERAGE DESIGN FLOW FOR SUBWATERSHED CHANNELS AS A FRACTION  
 \* OF DESIGN FLOOD FLOW AT LOWER END OF SUBWATERSHED  
 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
 0.025 \* MANNU - MANNINGS 'N' FOR UNLINED PRISMATIC CHANNELS  
 0.016 \* MANNT - MANNINGS 'N' FOR LINED TRAPEZOIDAL CHANNELS  
 0.012 \* MANNR - MANNINGS 'N' FOR LINED RECTANGULAR CHANNELS  
 1.5 \* ZU - SIDE SLOPE OF UNLINED PRISMATIC CHANNELS  
 1.0 \* ZT - SIDE SLOPE OF LINED TRAPEZOIDAL CHANNELS  
 \* S(I) - AVERAGE LONGITUDINAL SUBWATERSHED CHANNEL SLOPE  
 .001820 .001712 .001916 .000710 .000798 .000521 .000571 .000413 .000505  
 \* TF(I) - MAXIMUM ALLOWABLE TRACTIVE FORCE FOR SUBWATERSHED CHANNELS  
 \* IN POUNDS PER SQ.FT.  
 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5  
 10.0 \* BDMAX - MAXIMUM ALLOWABLE RATIO OF CHANNEL BOTTOM  
 \* WIDTH TO DEPTH  
 4.0 \* BDMIN - MINIMUM ALLOWABLE RATIO OF CHANNEL BOTTOM  
 \* WIDTH TO DEPTH  
 25. \* HMAX - MAXIMUM CHANNEL DESIGN DEPTH, IN FEET  
 6.0 \* NIN - NO. DRAINAGE INLETS REQUIRED PER MILE OF CHANNEL  
 \* CAP(I) - NUMBER AND CAPACITY IN CFS OF EXISTING BRIDGES  
 \* HIGHWAY BRIDGES RAILWAY BRIDGES  

* 1	2	3	4	5	6	1	2	SUBW
30000.	30000.	22000.	-1.	-1.	-1.	-1.	-1.	* 1
32300.	30930.	25920.	23500.	-1.	-1.	21200.	-1.	* 2
21200.	-1.	-1.	-1.	-1.	-1.	15900.	15900.	* 3
126500.	126500.	-1.	-1.	-1.	-1.	126500.	-1.	* 4
185000.	177000.	110480.	-1.	-1.	-1.	140000.	127000.	* 5
397000.	241000.	209650.	192000.	-1.	-1.	233000.	192000.	* 6
250000.	-1.	-1.	-1.	-1.	-1.	155000.	-1.	* 7
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	* 8
-1.	-1.	-1.	-1.	-1.	-1.	284000.	185000.	* 9

 30.0 \* BW - REQUIRED WIDTH OF HIGHWAY BRIDGES IN FEET  
 \* CHANNEL IMPROVEMENT - COST FACTORS

0.45	* CX - UNIT COST OF CHANNEL EXCAVATION IN \$/C.Y.
1.10	* FM - MULTIPLIER FOR CHANNEL EXCAVATION COST TO ACCOUNT FOR RIPRAP AND SEEDING
900.0	* CIN - COST PER DRAINAGE INLET IN DOLLARS
0.70	* CLSF - UNIT COST OF TRAPEZOIDAL LINING IN \$/SQ.FT.
60.0	* CCY - COST OF IN PLACE STRUCTURAL CONCRETE FOR RECTANGULAR CHANNELS IN \$/SQ.FT.
15.0	* CBR - UNIT COST OF HIGHWAY BRIDGES IN \$/SQ.FT.
300.0	* CRR - UNIT COST OF RAILROAD BRIDGES IN \$/LINEAR FT.
3.584	* AQR - MULTIPLE OF RIGHT-OF-WAY COST USED TO INCLUDE COSTS OTHER THAN FOR LAND AND IMPROVEMENTS
1.00	* SAFC - RATIO OF RIGHT-OF-WAY WIDTH TO BE HELD TO RIGHT-OF-WAY WIDTH EXPECTED TO BE REQUIRED
1.0	* RWF - MULTIPLE OF RIGHT-OF-WAY COST TO BE USED IN PLANNING
1.15	* CSM - MULTIPLE OF CHANNEL CONSTRUCTION COST TO ACCOUNT FOR CONTINGENCIES
1.45	* ESM - MULTIPLE OF CHANNEL CONSTRUCTION COST TO ACCOUNT FOR DESIGN, ADMINISTRATION, AND SUPERVISION OF CONSTRUCTION
0.005	* MIN - ANNUAL MAINTENANCE COST OF CONCRETE STRUCTURES AS FRACTION OF FIRST COST
0.015	* MCH - ANNUAL MAINTENANCE COST OF EARTH CHANNELS AS A FRACTION OF FIRST COST
0.01	* MTLCH - ANNUAL MAINTENANCE COST OF TRAPEZOIDAL LINED CHANNELS AS A FRACTION OF FIRST COST
1.0	* SF - MULTIPLE OF CHANNELIZATION COST TO BE USED IN PLANNING
* FLOOD PROOFING - COST FACTORS	
0.035	* FP - COST OF FLOOD PROOFING PER FOOT OF DESIGN FLOOD DEPTH PER DOLLAR OF BUILDING MARKET VALUE
1.00	* VF - RATIO OF AREA REQUIRING FLOOD PROOFING TO THAT INUNDATED BY THE DESIGN FLOOD
1.30	* DD - MULTIPLIER FOR FLOOD PROOFING INSTALLATION COST TO ACCOUNT FOR DESIGN AND CONTINGENCIES
0.05	* MFP - ANNUAL MAINTENANCE COST OF FLOOD PROOFING MEASURES AS A FRACTION OF FIRST COST
1.00	* PF - MULTIPLE OF FLOOD PROOFING COST TO BE USED IN PLANNING
* LOCATION ADJUSTMENT - COST FACTORS	
1.00	* CLEN - ANNUAL COST OF ENFORCING LAND USE RESTRICTIONS IN DOLLARS PER ACRE
0.08	* RPI - RETURN RATE REQUIRED BY PRIVATE INVESTORS IN LAND
14.45	* FIA - EXPECTED ANNUAL FARM INCOME FROM MOST PRODUCTIVE SOIL IF FLOODING DOES NOT OCCUR
6.70	* FIB - EXPECTED ANNUAL FARM INCOME FROM INTERMEDIATE SOIL IF FLOODING DOES NOT OCCUR
0.28	* FIG - EXPECTED ANNUAL FARM INCOME FROM LEAST PRODUCTIVE SOIL IF FLOODING DOES NOT OCCUR
0.00	* IPP - ANNUAL OPEN SPACE AMENITIES AS A MULTIPLE OF THE FRACTION OF SURROUNDING LAND BEING URBAN
1.00	* LF - MULTIPLE OF LAND USE COST TO BE USED IN PLANNING

\* DEGREE OF URBANIZATION

\* USUBW() - FRACTION OF SUBWATERSHED FLOOD PLAIN IN URBAN USE

* NOW	AFTER TIME	AFTER 2TIME	AFTER 3TIME	AFTER 4TIME	AFTER 5TIME	SUBWATERSHED
	YEARS	YEARS	YEARS	YEARS	YEARS	
0.0335	0.0335	0.0335	0.0335	0.0335	0.0335	* 1
0.1350	0.1350	0.1350	0.1350	0.1350	0.1350	* 2
0.0611	0.0611	0.0611	0.0611	0.0611	0.0611	* 3
0.0917	0.0917	0.0917	0.0917	0.0917	0.0917	* 4
0.4839	0.4839	0.4839	0.4839	0.4839	0.4839	* 5
0.1039	0.1039	0.1039	0.1039	0.1039	0.1039	* 6
0.0241	0.0241	0.0241	0.0241	0.0241	0.0241	* 7
0.0128	0.0128	0.0128	0.0128	0.0128	0.0128	* 8
0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	* 9

\* UTOTR() - FRACTION OF TRIBUTARY AREA ADDED IN URBAN DEVELOPMENT

* NOW	AFTER TIME	AFTER 2TIME	AFTER 3TIME	AFTER 4TIME	AFTER 5TIME	SUBWATERSHED
	YEARS	YEARS	YEARS	YEARS	YEARS	
0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	* 1
0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	* 2
0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	* 3
0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	* 4
0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	* 5
0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	* 6
0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	* 7
0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	* 8
0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	* 9

\* LAND VALUE

\* VALUE() - VALUE OF LAND IN SUBWATERSHED FLOOD PLAIN, IN \$/ACRE

* NOW	AFTER TIME	AFTER 2TIME	AFTER 3TIME	AFTER 4TIME	AFTER 5TIME	SUBWATERSHED
	YEARS	YEARS	YEARS	YEARS	YEARS	
130.	130.	130.	130.	130.	130.	* 1
133.	133.	133.	133.	133.	133.	* 2
131.	131.	131.	131.	131.	131.	* 3
231.	231.	231.	231.	231.	231.	* 4
50000.	50000.	50000.	50000.	50000.	50000.	* 5
380.	380.	380.	380.	380.	380.	* 6
133.	133.	133.	133.	133.	133.	* 7
181.	181.	181.	181.	181.	181.	* 8
174.	174.	174.	174.	174.	174.	* 9

APPENDIX D

INPUT DATA

FOR

THE UNIVERSITY OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM III

\* DATA INPUT TO UNIV. OF KENTUCKY FLOOD CONTROL PLANNING PROGRAM III  
 \* NORTH FORK OF THE KENTUCKY RIVER - CARR FORK RESERVOIR SITE

\* PROGRAM CONTROL PARAMETERS

1 \* L1 - "0" EXCLUDES UNCERTAINTY FROM DAMAGES  
 1 \* L2 - "0" EXCLUDES CONSIDERATION OF FLOOD PROOFING  
 0 \* L3 - "0" EXCLUDES CONSIDERATION OF LAND USE MEASURES  
 1 \* L4 - "0" EXCLUDES CONSIDERATION OF CHANNEL IMPROVEMENT  
 1 \* L5 - "0" EXCLUDES PRINTING OF ALL COMBINATIONS TRIED  
 1 \* L6 - "0" EXCLUDES PRINTING OF EACH NEW OPTIMUM  
 \* COMBINATION  
 0 \* L7 - "0" EXCLUDES CONSIDERATION OF HOLDING EXTRA  
 \* RIGHT-OF-WAY  
 1 \* L8 - "0" EXCLUDES PRINTING OF DAM DETAILS  
 1 \* L9 - "0" EXCLUDES PRINTING OF HYDROLOGIC DETAILS  
 1 \* L10 - "0" EXCLUDES PRINTING OF SUBROUTINE ENTRY AND EXIT  
 1 \* L11 - "0" EXCLUDES CONSIDERATION OF DAM  
 5 \* NSTEMX - NUMBER OF PLANNING STAGES  
 9 \* MW - NUMBER OF SUBWATERSHEDS

\* AW() - ADDITIONAL DRAINAGE AREA ADDED BY CHANNEL REACH IN SQ.MI.  
 58.18 20.20 7.60 378.03 5.38 41.88 71.42 33.69 23.53

\* MAIN LINE, TRIBUTARY, AND IMPROVED CHANNEL LENGTHS

\* LC() - LENGTH OF MAIN LINE CHANNEL WITHIN SUBWATERSHED, IN MILES  
 17.90 3.84 4.97 4.78 3.74 7.53 17.28 9.66 12.31  
 \* TCL() - TOTAL LENGTH OF CHANNEL IN TRIBUTARY AREA ADDED, IN MILES  
 50.19 15.96 7.48 333.81 4.83 40.20 72.73 31.91 24.53  
 \* SIC() - INITIAL IMPROVED CHANNEL LENGTH IN SUBWATERSHED, IN MILES  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 \* CTOTR() - IMPROVED CHANNEL LENGTH WITHIN TRIBUTARY AREA ADDED BUT  
 \* NOT ON MAIN LINE STREAM, IN MILES

* STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	SUBWATERSHED
0.0	0.0	0.0	0.0	0.0	* 2
0.0	0.0	0.0	0.0	0.0	* 3
0.0	0.0	0.0	0.0	0.0	* 4
0.0	0.0	0.0	0.0	0.0	* 5
0.0	0.0	0.0	0.0	0.0	* 6
0.0	0.0	0.0	0.0	0.0	* 7

0.0 0.0 0.0 0.0 0.0 \* 8  
 0.0 0.0 0.0 0.0 0.0 \* 9

\* FLOOD PEAK HYDROLOGY

177. \* QB43 - MEAN ANNUAL FLOOD PEAK FROM ONE SQUARE MILE  
 550. \* QB05 - 200-YEAR FLOOD PEAK FROM ONE SQUARE MILE  
 \* Q43() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND MEAN  
 \* ANNUAL FLOOD PEAK FROM ONE SQUARE MILE, EXPRESSED AS  
 \* MULTIPLES OF THE PEAK WITH U=0.0 AND C=0.0

*0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	= U
1.000	1.005	1.029	1.068	1.108	1.156	1.196	1.236	1.276	1.320	1.365	*C=.0
1.156	1.179	1.304	1.337	1.367	1.403	1.434	1.460	1.489	1.494	1.499	*C=.1
1.491	1.544	1.578	1.614	1.655	1.703	1.750	1.789	1.838	1.848	1.858	*C=.2
1.978	2.029	2.069	2.113	2.153	2.195	2.237	2.276	2.324	2.361	2.384	*C=.3
2.496	2.507	2.545	2.587	2.606	2.677	2.731	2.791	2.856	2.927	3.006	*C=.4
2.990	3.026	3.063	3.099	3.124	3.152	3.218	3.300	3.442	3.531	3.620	*C=.5
3.262	3.353	3.444	3.536	3.627	3.718	3.810	3.901	3.991	4.053	4.131	*C=.6
3.429	3.518	3.520	3.628	3.735	3.844	3.955	4.073	4.184	4.289	4.474	*C=.7
3.533	3.560	3.596	3.722	3.844	3.970	4.110	4.247	4.378	4.525	4.705	*C=.8
3.588	3.602	3.672	3.815	3.952	4.109	4.268	4.420	4.571	4.761	4.912	*C=.9
3.627	3.644	3.748	3.907	4.075	4.250	4.426	4.593	4.765	4.936	5.112	*C=1.

\* Q05() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND 200-  
 \* YEAR FLOOD PEAK FROM ONE SQUARE MILE, EXPRESSED AS  
 \* MULTIPLES OF THE PEAK WITH U=0.0 AND C=0.0

*0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	= U
1.000	1.004	1.013	1.029	1.045	1.062	1.079	1.096	1.113	1.130	1.147	*C=.0
1.059	1.143	1.154	1.165	1.177	1.190	1.204	1.213	1.227	1.230	1.245	*C=.1
1.308	1.441	1.455	1.470	1.486	1.502	1.519	1.532	1.548	1.556	1.578	*C=.2
1.614	1.739	1.757	1.775	1.795	1.814	1.834	1.851	1.870	1.882	1.910	*C=.3
1.919	2.037	2.059	2.081	2.103	2.126	2.149	2.169	2.192	2.208	2.242	*C=.4
2.227	2.336	2.361	2.386	2.412	2.438	2.464	2.488	2.513	2.534	2.575	*C=.5
2.533	2.634	2.663	2.692	2.721	2.750	2.779	2.807	2.834	2.861	2.907	*C=.6
2.835	2.932	2.965	2.997	3.030	3.062	3.094	3.126	3.156	3.187	3.240	*C=.7
3.146	3.230	3.267	3.302	3.338	3.374	3.409	3.444	3.478	3.513	3.572	*C=.8
3.455	3.528	3.568	3.608	3.647	3.686	3.724	3.763	3.799	3.839	3.904	*C=.9
3.757	3.827	3.870	3.913	3.956	3.998	4.039	4.081	4.120	4.165	4.237	*C=1.

\* AFCTR() - RATIOS OF CSM FOR FLOOD PEAKS FROM STATED DRAINAGE AREA  
 \* TO CSM FOR FLOOD PEAKS FROM ONE SQ.MI. FOR TWO FLOOD  
 \* FREQUENCIES  
 \* DRAINAGE AREA IN SQ.MI.  
 1.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0  
 \* MEAN ANNUAL FLOOD  
 1.000 0.223 0.223 0.223 0.223 0.223 0.223 0.223 0.223 0.223 0.223  
 \* 200-YEAR FLOOD  
 1.000 0.220 0.220 0.220 0.220 0.220 0.220 0.220 0.220 0.220 0.220

\* FLOOD VOLUME HYDROLOGY

46.2 \* VB43 - SFD IN MEAN ANNUAL HYDROGRAPH FROM ONE SQ. MILE  
 131.5 \* VB05 - SFD IN 200-YEAR HYDROGRAPH FROM ONE SQ. MILE  
 \* V43() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND MEAN  
 \* ANNUAL FLOOD VOLUME FROM ONE SQUARE MILE, EXPRESSED AS  
 \* MULTIPLES OF THE VOLUME WITH U=0.0 AND C=0.0

*0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	= U
1.000	1.022	1.050	1.077	1.105	1.146	1.174	1.202	1.243	1.271	1.307	*C=.0

1.160	1.198	1.235	1.272	1.309	1.347	1.384	1.421	1.458	1.496	1.533	*C=.1
1.284	1.327	1.370	1.413	1.456	1.499	1.541	1.584	1.627	1.667	1.713	*C=.2
1.409	1.453	1.497	1.541	1.586	1.630	1.674	1.718	1.762	1.807	1.851	*C=.3
1.506	1.551	1.597	1.642	1.688	1.733	1.779	1.824	1.870	1.916	1.961	*C=.4
1.588	1.638	1.688	1.738	1.787	1.837	1.887	1.936	1.986	2.036	2.086	*C=.5
1.657	1.710	1.762	1.815	1.867	1.920	1.972	2.025	2.077	2.130	2.182	*C=.6
1.713	1.766	1.820	1.874	1.928	1.982	2.036	2.090	2.144	2.198	2.251	*C=.7
1.754	1.808	1.862	1.916	1.970	2.023	2.077	2.131	2.185	2.239	2.293	*C=.8
1.789	1.841	1.895	1.948	2.001	2.054	2.108	2.160	2.214	2.266	2.320	*C=.9
1.796	1.892	1.961	2.016	2.072	2.113	2.155	2.196	2.238	2.293	2.348	*C=1.

\* V05() - RELATIONSHIP AMONG URBANIZATION, CHANNELIZATION, AND 200-  
\* YEAR FLOOD VOLUME FROM ONE SQUARE MILE, EXPRESSED AS  
\* MULTIPLES OF THE VOLUME WITH U=0.0 AND C=0.0

*0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	= U
1.000	1.007	1.014	1.021	1.028	1.035	1.042	1.049	1.056	1.063	1.070	*C=.0
1.167	1.182	1.196	1.211	1.225	1.240	1.254	1.268	1.283	1.297	1.312	*C=.1
1.367	1.386	1.406	1.425	1.444	1.463	1.482	1.501	1.520	1.539	1.558	*C=.2
1.563	1.583	1.604	1.624	1.645	1.665	1.686	1.706	1.726	1.747	1.767	*C=.3
1.721	1.740	1.760	1.780	1.800	1.819	1.838	1.858	1.877	1.897	1.916	*C=.4
1.832	1.852	1.871	1.890	1.909	1.928	1.947	1.966	1.985	2.004	2.023	*C=.5
1.907	1.926	1.944	1.963	1.981	2.000	2.019	2.037	2.056	2.074	2.093	*C=.6
1.953	1.972	1.991	2.009	2.028	2.046	2.065	2.084	2.102	2.121	2.140	*C=.7
1.986	2.004	2.022	2.040	2.059	2.077	2.095	2.113	2.131	2.149	2.167	*C=.8
2.009	2.026	2.044	2.061	2.078	2.095	2.112	2.130	2.147	2.164	2.181	*C=.9
2.023	2.040	2.056	2.072	2.088	2.105	2.121	2.137	2.153	2.170	2.186	*C=1.

\* AFCTRV() - RATIOS OF CSM FOR FLOOD VOLUMES FROM STATED DRAINAGE  
\* AREA TO CSM FOR FLOOD VOLUMES FROM ONE SQ.MI. FOR TWO  
\* FLOOD FREQUENCIES  
\* DRAINAGE AREA IN SQUARE MILES  
\* 1.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0  
\* MEAN ANNUAL FLOOD  
1.000 0.345 0.345 0.345 0.345 0.345 0.345 0.345 0.345 0.345 0.345  
\* 200-YEAR FLOOD  
1.000 0.355 0.355 0.355 0.355 0.355 0.355 0.355 0.355 0.355 0.355

\* FLOOD PEAK TIMING DATA  
9.0 \* TPB - HOURS TO PEAK FOR HYDROGRAPH FROM ONE SQUARE MILE  
\* TP() - RELATIONSHIP BETWEEN TIME TO PEAK AND CHANNELIZATION  
\* EXPRESSED AS MULTIPLES OF TIME TO PEAK WITHOUT  
\* CHANNELIZATION

* C =	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
	1.000	0.892	0.786	0.682	0.587	0.521	0.500	0.500	0.500	0.500	0.500

\* AFCTRT() - RELATIONSHIP BETWEEN DRAINAGE AREA AND TIME TO PEAK  
\* DRAINAGE AREA IN SQUARE MILES  
\* 1.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0 400.0  
\* TIME TO PEAK RATIO  
1.00 2.92 2.92 2.92 2.92 2.92 2.92 2.92 2.92 2.92 2.92

\* FLOOD HYDROGRAPH SHAPE DATA  
2.0 \* HYDINT - HOURS BETWEEN POINTS ON COMBINED HYDROGRAPHS  
\* HYDBAS() - FIVE BASIC HYDROGRAPH SHAPES - ALL FLOWS EXPRESSED AS  
\* FRACTIONS OF FLOW AT PEAK  
\* SHARPER SHARP AVERAGE FLAT FLATTER  
0.002 0.008 0.024 0.265 0.613 \* ITPW/4

0.004	0.010	0.084	0.503	0.926	* 2TPW/4
0.472	0.488	0.470	0.777	0.994	* 3TPW/4
1.000	1.000	1.000	1.000	1.000	* PEAK
0.702	0.816	0.892	0.934	0.996	* 5TPW/4
0.466	0.567	0.654	0.787	0.986	* 6TPW/4
0.312	0.390	0.515	0.642	0.970	* 7TPW/4
0.208	0.267	0.411	0.552	0.951	* 8TPW/4
0.141	0.188	0.310	0.445	0.927	* 9TPW/4
0.096	0.135	0.240	0.367	0.902	* 10TPW/4
0.067	0.101	0.194	0.313	0.874	* 11TPW/4
0.048	0.078	0.163	0.274	0.844	* 12TPW/4
0.035	0.064	0.149	0.246	0.813	* 13TPW/4
0.026	0.055	0.142	0.224	0.781	* 14TPW/4
0.021	0.048	0.133	0.207	0.750	* 15TPW/4
0.017	0.043	0.125	0.193	0.718	* 16TPW/4
0.012	0.041	0.118	0.181	0.686	* 17TPW/4
0.008	0.039	0.112	0.171	0.654	* 18TPW/4
0.006	0.037	0.106	0.162	0.624	* 19TPW/4
0.004	0.036	0.101	0.153	0.594	* 20TPW/4
0.180	0.221	0.297	0.420	0.830	*AVG/PEAK

\* FLOOD DAMAGES - GENERAL

\* Q0() - EXISTING SUBWATERSHED CHANNEL CAPACITY IN CFS  
 3710. 2230. 14010. 15380. 18930. 20050. 17890. 16360.

\* QK(),AK(),DK() - MAGNITUDE OF ANY KNOWN FLOOD PEAK AND ASSOCIATED  
 \* MAXIMUM DEPTH OF FLOODING AND AREA FLOODED

* FLOOD PEAK	AREA FLOODED	MAXIMUM DEPTH	SUBWATERSHED
* CFS	ACRES	FEET	
11600.	89.	3.0	* 2
13700.	154.	10.2	* 3
47800.	174.	23.3	* 4
47900.	307.	22.7	* 5
49300.	586.	22.8	* 6
50000.	953.	22.2	* 7
50400.	829.	24.6	* 8
50800.	946.	27.4	* 9

\* FLOOD DAMAGES - URBAN

37000. \* VLURST - MEAN VALUE OF URBAN STRUCTURES, IN \$/ACRE  
 0.052 \* COEFD - FLOOD DAMAGE PER FOOT OF FLOOD DEPTH PER DOLLAR  
 \* OF BUILDING MARKET VALUE

\* FLOOD DAMAGES - AGRICULTURAL

\* D() - FRACTION OF SUBWATERSHED FLOOD PLAIN LAND WITHIN EACH OF  
 \* THREE SOIL CLASSES

* BEST SOIL	MED. SOIL	WORST SOIL	SUBWATERSHED
0.55	0.40	0.05	* 2
0.70	0.04	0.26	* 3
1.00	0.00	0.00	* 4
0.92	0.00	0.08	* 5
0.82	0.00	0.18	* 6
0.72	0.03	0.25	* 7
1.00	0.00	0.00	* 8
0.93	0.07	0.00	* 9

1.02 \* CDA - CROP DAMAGE PER ACRE OF MOST PRODUCTIVE SOIL WHEN

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*          FLOODED TO A MINIMAL DEPTH
1.24      * CDB - CROP DAMAGE PER ACRE OF INTERMEDIATE SOIL WHEN
*          FLOODED TO A MINIMAL DEPTH
0.01     * CDC - CROP DAMAGE PER ACRE OF LEAST PRODUCTIVE SOIL WHEN
*          FLOODED TO A MINIMAL DEPTH
0.368    * CDAV - INCREMENTAL DAMAGE PER ACRE OF MOST PRODUCTIVE
*          SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH
0.149    * CDBV - INCREMENTAL DAMAGE PER ACRE OF INTERMEDIATE
*          SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH
0.009    * CDCV - INCREMENTAL DAMAGE PER ACRE OF LEAST PRODUCTIVE
*          SOIL PER ADDITIONAL FOOT OF FLOOD DEPTH
* FRU() - RELATIONSHIP BETWEEN AGRICULTURAL PRODUCTIVITY AND
*          URBANIZATION EXPRESSED AS A MULTIPLE OF FULL RURAL VALUE
* U=0.00  0.10  0.20  0.30  0.40  0.50  0.60  0.70  0.80  0.90  1.00
      1.00  0.97  0.91  0.82  0.71  0.58  0.44  0.37  0.30  0.23  0.16
      0.0   * VLAGST - MEAN VALUE OF AGRICULTURAL STRUCTURES,
*          IN $/ACRE
* FLOOD DAMAGES - UNCERTAINTY
2.575    * VA - NORMAL DEVIATE USED IN EVALUATING UNCERTAINTY
* GENERAL DESIGN VARIABLES
0.03125 * R - DISCOUNT RATE USED IN PLANNING
50.0     * TIMST - DESIGN LIFE OF CHANNEL IMPROVEMENTS IN YEARS
10.0     * TIME - DURATION OF ONE PLANNING STAGE
1        * MRDF - LOCATION IN ARRAY OF OF MINIMUM RESERVOIR
*          DESIGN FLOOD
10       * NDF - NUMBER OF DESIGN FLOOD FREQUENCIES CONSIDERED
* DF() - DESIGN FLOOD FREQUENCIES TO BE CONSIDERED IN ANALYSIS
0.43    0.30  0.20  0.15  0.10  0.07  0.04  0.02  0.01  0.005
* CHANNEL IMPROVEMENT - PHYSICAL FACTORS
* AO() - INITIAL SUBWATERSHED CHANNEL CROSS SECTIONAL AREA IN SQ.FT.
940.    940.  3700.  3700.  3700.  3700.  3700.  3700.
* LINING() - DESIGNATION OF CHANNEL TYPES TO BE CONSIDERED IN
*          SUBWATERSHED
*          '0' ALL TYPES OF CHANNEL IMPROVEMENT TO BE CONSIDERED
*          '1' CONSIDERS ONLY UNLINED CHANNELS, NO EXISTING DROP
*          STRUCTURES
*          '2' CONSIDERS ONLY UNLINED CHANNELS, EXISTING DROP
*          STRUCTURES
*          '3' CONSIDERS ONLY TRAPEZOIDAL LINED CHANNELS
*          '4' CONSIDERS ONLY RECTANGULAR LINED CHANNELS
0        0        0        0        0        0
0.025    * MANNU - MANNINGS 'N' FOR UNLINED PRISMATIC CHANNELS
0.016    * MANNT - MANNINGS 'N' FOR LINED TRAPEZOIDAL CHANNELS
0.012    * MANNR - MANNINGS 'N' FOR LINED RECTANGULAR CHANNELS
1.5      * ZU - SIDE SLOPE OF UNLINED PRISMATIC CHANNELS
1.0      * ZT - SIDE SLOPE OF LINED TRAPEZOIDAL CHANNELS
* S() - AVERAGE LONGITUDINAL SUBWATERSHED CHANNEL SLOPE
.001712 .001916 .000710 .000798 .000521 .000571 .000413 .000505
* TF() - MAXIMUM ALLOWABLE TRACTIVE FORCE FOR SUBWATERSHED CHANNELS
*          IN POUNDS PER SQ.FT.
2.5      2.5      2.5      2.5      2.5      2.5      2.5
10.0     * BDMAX - MAXIMUM ALLOWABLE RATIO OF CHANNEL BOTTOM

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\* WIDTH TO DEPTH

4.0 \* BDMIN - MINIMUM ALLOWABLE RATIO OF CHANNEL BOTTOM WIDTH TO DEPTH

25. \* HMAX - MAXIMUM CHANNEL DESIGN DEPTH, IN FEET

6.0 \* NIN - NO. DRAINAGE INLETS REQUIRED PER MILE OF CHANNEL

\* CAP() - NUMBER AND CAPACITY IN CFS OF EXISTING BRIDGES

	HIGHWAY BRIDGES						RAILWAY BRIDGES		
* 1	2	3	4	5	6	1	2	SUBW	
32300.	30930.	25920.	23500.	-1.	-1.	21200.	-1.	* 2	
21200.	-1.	-1.	-1.	-1.	-1.	15900.	15900.	* 3	
126500.	126500.	-1.	-1.	-1.	-1.	126500.	-1.	* 4	
185000.	177000.	110480.	-1.	-1.	-1.	140000.	127000.	* 5	
397000.	241000.	209650.	192000.	-1.	-1.	233000.	192000.	* 6	
250000.	-1.	-1.	-1.	-1.	-1.	155000.	-1.	* 7	
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	* 8	
-1.	-1.	-1.	-1.	-1.	-1.	284000.	185000.	* 9	

30.0 \* BW - REQUIRED WIDTH OF HIGHWAY BRIDGES IN FEET

\* CHANNEL IMPROVEMENT - COST FACTORS

0.45 \* CX - UNIT COST OF CHANNEL EXCAVATION IN \$/C.Y.

1.10 \* FM - MULTIPLIER FOR CHANNEL EXCAVATION COST TO ACCOUNT FOR RIPRAP AND SEEDING

900.0 \* CIN - COST PER DRAINAGE INLET IN DOLLARS

0.70 \* CLSF - UNIT COST OF TRAPEZOIDAL LINING IN \$/SQ.FT.

60.0 \* CCY - COST OF IN PLACE STRUCTURAL CONCRETE FOR RECTANGULAR CHANNELS IN \$/SQ.FT.

15.0 \* CBR - UNIT COST OF HIGHWAY BRIDGES IN \$/SQ.FT.

300.0 \* CRR - UNIT COST OF RAILROAD BRIDGES IN \$/LINEAR FT.

3.584 \* AQR - MULTIPLE OF RIGHT-OF-WAY COST USED TO INCLUDE COSTS OTHER THAN FOR LAND AND IMPROVEMENTS

1.00 \* SAFC - RATIO OF RIGHT-OF-WAY WIDTH TO BE HELD TO RIGHT-OF-WAY WIDTH EXPECTED TO BE REQUIRED

1.15 \* CSM - MULTIPLE OF CHANNEL CONSTRUCTION COST TO ACCOUNT FOR CONTINGENCIES

1.45 \* ESM - MULTIPLE OF CHANNEL CONSTRUCTION COST TO ACCOUNT FOR DESIGN, ADMINISTRATION, AND SUPERVISION OF CONSTRUCTION

0.005 \* MIN - ANNUAL MAINTENANCE COST OF CONCRETE STRUCTURES AS FRACTION OF FIRST COST

0.015 \* MCH - ANNUAL MAINTENANCE COST OF EARTH CHANNELS AS A FRACTION OF FIRST COST

0.01 \* MTLCH - ANNUAL MAINTENANCE COST OF TRAPEZOIDAL LINED CHANNELS AS A FRACTION OF FIRST COST

\* FLOOD PROOFING - COST FACTORS

0.035 \* FP - COST OF FLOOD PROOFING PER FOOT OF DESIGN FLOOD DEPTH PER DOLLAR OF BUILDING MARKET VALUE

1.00 \* VF - RATIO OF AREA REQUIRING FLOOD PROOFING TO THAT INUNDATED BY THE DESIGN FLOOD

1.30 \* DD - MULTIPLIER FOR FLOOD PROOFING INSTALLATION COST TO ACCOUNT FOR DESIGN AND CONTINGENCIES

0.05 \* MFP - ANNUAL MAINTENANCE COST OF FLOOD PROOFING MEASURES AS A FRACTION OF FIRST COST

\* LOCATION ADJUSTMENT - COST FACTORS

1.00 \* CLEN - ANNUAL COST OF ENFORCING LAND USE RESTRICTIONS IN  
 \* DOLLARS PER ACRE  
 0.08 \* RPI - RETURN RATE REQUIRED BY PRIVATE INVESTORS IN LAND  
 14.45 \* FIA - EXPECTED ANNUAL FARM INCOME FROM MOST PRODUCTIVE  
 \* SOIL IF FLOODING DOES NOT OCCUR  
 6.70 \* FIB - EXPECTED ANNUAL FARM INCOME FROM INTERMEDIATE  
 \* SOIL IF FLOODING DOES NOT OCCUR  
 0.28 \* FIC - EXPECTED ANNUAL FARM INCOME FROM LEAST PRODUCTIVE  
 \* SOIL IF FLOODING DOES NOT OCCUR  
 0.00 \* IPP - ANNUAL OPEN SPACE AMENITIES AS A MULTIPLE OF THE  
 \* FRACTION OF SURROUNDING LAND BEING URBAN

\* DEGREE OF URBANIZATION

\* USUBW() - FRACTION OF SUBWATERSHED FLOOD PLAIN IN URBAN USE

* NOW	AFTER TIME YEARS	AFTER 2TIME YEARS	AFTER 3TIME YEARS	AFTER 4TIME YEARS	AFTER 5TIME YEARS	SUBWATERSHED
0.0335	0.0335	0.0335	0.0335	0.0335	0.0335	* 1
0.1350	0.1350	0.1350	0.1350	0.1350	0.1350	* 2
0.0611	0.0611	0.0611	0.0611	0.0611	0.0611	* 3
0.0917	0.0917	0.0917	0.0917	0.0917	0.0917	* 4
0.4839	0.4839	0.4839	0.4839	0.4839	0.4839	* 5
0.1039	0.1039	0.1039	0.1039	0.1039	0.1039	* 6
0.0241	0.0241	0.0241	0.0241	0.0241	0.0241	* 7
0.0128	0.0128	0.0128	0.0128	0.0128	0.0128	* 8
0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	* 9

\* UTOTR() - FRACTION OF TRIBUTARY AREA ADDED IN URBAN DEVELOPMENT

* NOW	AFTER TIME YEARS	AFTER 2TIME YEARS	AFTER 3TIME YEARS	AFTER 4TIME YEARS	AFTER 5TIME YEARS	SUBWATERSHED
0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	* 1
0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	* 2
0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	* 3
0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	* 4
0.0968	0.0968	0.0968	0.0968	0.0968	0.0968	* 5
0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	* 6
0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	* 7
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	* 8
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	* 9

\* LAND VALUE

\* VALUE() - VALUE OF LAND IN SUBWATERSHED FLOOD PLAIN, IN \$/ACRE

* NOW	AFTER TIME YEARS	AFTER 2TIME YEARS	AFTER 3TIME YEARS	AFTER 4TIME YEARS	AFTER 5TIME YEARS	SUBWATERSHED
130.	130.	130.	130.	130.	130.	* 1
133.	133.	133.	133.	133.	133.	* 2
131.	131.	131.	131.	131.	131.	* 3
231.	231.	231.	231.	231.	231.	* 4
50000.	50000.	50000.	50000.	50000.	50000.	* 5
380.	380.	380.	380.	380.	380.	* 6
133.	133.	133.	133.	133.	133.	* 7
181.	181.	181.	181.	181.	181.	* 8
174	174.	174.	174.	174.	174.	* 9

\* HYDROLOGIC DATA FOR RESERVOIR DESIGN

2.80 \* HYDMLT - RATIO OF EMERGENCY SPILLWAY DESIGN FLOOD PEAK  
\* TO THE 200-YEAR FLOOD PEAK

60.4 \* AWC - DRAINAGE AREA IN SQ. MI. USED TO DEVELOP  
\* CUMULATIVE RUNOFF CURVE

20 \* IMPTY - NUMBER OF DAYS THE DESIGN FLOOD IS DETAINED IN  
\* THE RESERVOIR

\* CUMVOL(I) - CUMULATIVE RUNOFF CURVE - AVERAGE FLOW IN CFS BY  
\* DURATION IN DAYS

* 0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	3.00
2523.	2205.	2030.	1905.	1816.	1727.	1639.	1567.	1168.

* 4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
919.	876.	778.	709.	646.	591.	540.	500.	475.

*13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
461.	444.	416.	398.	382.	366.	351.	340.

0 \* IB - WHETHER XTRSTR IS NEEDED NOW - "0" INDICATES NO DAM  
\* TO BE BUILT UNLESS JUSTIFIED BY FLOOD CONTROL

0.0 \* GDELAY - NUMBER OF HOURS HYDROGRAPH DELAYED BY  
\* CLOSING GATES

\* MUSKINGUM ROUTING PARAMETERS

* K(NAT)	K(IMP)	X(NAT)	X(IMP)	SUBWATERSHED
1.27	0.95	0.24	0.36	* 2
1.65	1.24	0.24	0.36	* 3
1.59	1.19	0.24	0.36	* 4
1.24	0.93	0.24	0.36	* 5
2.50	1.87	0.24	0.36	* 6
5.73	4.30	0.24	0.36	* 7
3.21	2.40	0.24	0.36	* 8
4.09	3.06	0.24	0.36	* 9

\* PROPERTIES OF THE DAM SITE BY ELEVATION CONTOURS

18 \* IMAX - NUMBER OF ELEVATIONS USED IN INPUT DATA

1 \* NHILSD - NUMBER OF ALTERNATIVE SPILLWAY LOCATIONS

* ELEVA	RESACR	LGDAM	LGEMSP	LGAPCH	CRELOC	HLSIDL
948.	0.	0.	300.	200.	0.	0.
950.	2.	70.	300.	200.	0.	35.
960.	23.	180.	300.	200.	0.	100.
970.	99.	260.	300.	200.	0.	140.
980.	188.	330.	300.	200.	0.	160.
990.	292.	390.	300.	200.	0.	180.
1000.	393.	430.	300.	200.	0.	210.
1010.	508.	510.	300.	200.	1160000.	250.
1020.	627.	560.	300.	200.	2211000.	300.
1030.	748.	610.	300.	200.	3070000.	350.
1040.	875.	670.	300.	200.	3830000.	420.
1050.	1032.	700.	300.	220.	4610000.	520.
1060.	1220.	730.	300.	240.	5555000.	680.
1070.	1428.	770.	300.	260.	6810000.	1080.
1080.	1640.	810.	300.	280.	8308000.	1250.
1120.	2490.	980.	350.	350.	12820000.	1530.
1160.	3340.	1200.	400.	420.	15850000.	1700.
1200.	4190.	1450.	450.	500.	18210000.	1850.

\* VOLUME OF RETAINING WALL CONCRETE AS A FUNCTION OF WALL HEIGHT

2 \* NWH - NUMBER OF WALL HEIGHTS USED

\* WALL HEIGHT CONCRETE

\* FEET CY/FT

0.0 0.0

50.0 0.0

\* PHYSICAL FACTORS USED IN DAM AND RESERVOIR DESIGN

5.0 \* BYVERT - VERTICAL DISTANCE IN FEET FROM DAM TOP TO  
\* RIGHT-OF-WAY PURCHASE LINE

0.0 \* CONBOT - THICKNESS IN FEET OF CONCRETE CHUTE BOTTOM

300.0 \* CTBW - WIDTH IN FEET OF CUTOFF TRENCH BOTTOM

2.6 \* CWEIR - EMERGENCY SPILLWAY WEIR COEFFICIENT

3.0 \* DMFRBD - DAM FREEBOARD IN FEET ABOVE PEAK OF EMERGENCY  
\* SPILLWAY FLOOD

44.0 \* DMPW - WIDTH IN FEET OF TOP OF DAM

1.0 \* DPRCKH - DEPTH IN FEET TO BEDROCK ON EMERGENCY SPILLWAY  
\* HILLSIDE

1.0 \* DPRCKV - DEPTH IN FEET TO BEDROCK UNDER DAM

3.0 \* DPRP - DEPTH IN FEET OF RIPRAP ON DAM FACE

0.0133 \* FPIPE - DARCY FRICTION FACTOR FOR PRINCIPAL SPILLWAY  
\* PIPE

1.25 \* QRATIO - RATIO OF PEAK TO AVERAGE PRINCIPAL SPILLWAY  
\* DISCHARGE

0.30 \* SEDIN - ANNUAL SEDIMENT INFLOW IN ACRE-Feet/SQUARE MILE

0.0 \* STLBOT - THICKNESS IN FEET OF STILLING BASIN BOTTOM

3.0 \* TRV - DESIGN FLOW VELOCITY THROUGH TRASHRACK IN FEET/SEC

955.2 \* TWELEV - DESIGN TAILWATER ELEVATION

700.0 \* WDEMSP - INITIAL VALUE OF EMERGENCY SPILLWAY DESIGN  
\* WIDTH IN FEET

15290. \* XTRSIR - CONSERVATION STORAGE IN ACRE-Feet

1.0 \* ZCT - CUTOFF TRENCH SIDE SLOPE

2.5 \* ZDN - SLOPE OF DOWNSTREAM FACE OF DAM

0.25 \* ZES - CUT SLOPE IN HILLSIDE ABOVE EMERGENCY SPILLWAY

3.0 \* ZUP - SLOPE OF UPSTREAM FACE OF DAM

\* UNIT COST FACTORS FOR ESTIMATING COST OF DAM AND RESERVOIR

1.50 \* UCDAM - COST OF DAM EMBANKMENT IN \$/CY

0.75 \* UCCT - COST OF CUTOFF TRENCH EXCAVATION AND BACKFILL  
\* IN \$/CY

4.00 \* UCRP - COST OF RIPRAP IN \$/CY

0.50 \* UCSPEX - COST OF SPILLWAY EARTH EXCAVATION IN \$/CY

1.50 \* UCRKEX - COST OF SPILLWAY ROCK EXCAVATION IN \$/CY

69.0 \* UCSPCN - COST OF EMERGENCY SPILLWAY CONCRETE IN \$/CY

160.0 \* UCPRCN - COST OF PRINCIPAL SPILLWAY CONCRETE IN \$/CY

75.0 \* UCCNID - COST OF IMPACT DISSIPATOR CONCRETE IN \$/CY

750.0 \* UCTRK - COST OF TRASH RACK AND INLET STRUCTURE IN  
\* \$/SQ.FT. OF OPENING

100.0 \* UCCLR - COST OF RESERVOIR SITE CLEARING IN \$/ACRE

1.15 \* CSMD - COST MULTIPLIER TO INCLUDE CONTINGENCIES

1.45 \* ESMD - COST MULTIPLIER TO INCLUDE ENGINEERING

0.008 \* MDAM - ANNUAL MAINTENANCE COST AS A FRACTION OF  
\* CONSTRUCTION COST

\* DMBN() - BENEFITS ACCRUING DOWNSTREAM FROM AREA OF PRIMARY  
\* ANALYSIS AS A FUNCTION OF RESERVOIR FLOOD CONTROL STORAGE

\* FLOOD STORAGE IN ACRE-FEET  
 0.0 0.0 31600. 316000. 316000. 316000. 316000. 316000. 316000. 316000.  
 \* BENEFITS IN DOLLARS  
 0.0 0.0 85600. 856000. 856000. 856000. 856000. 856000. 856000. 856000.  
 \* DMBNF() - STAGE MULTIPLIERS FOR DOWNSTREAM BENEFITS  
 \* STAGE           1           2           3           4           5  
                   0.8617    0.9522    1.0513    1.1616    1.2831

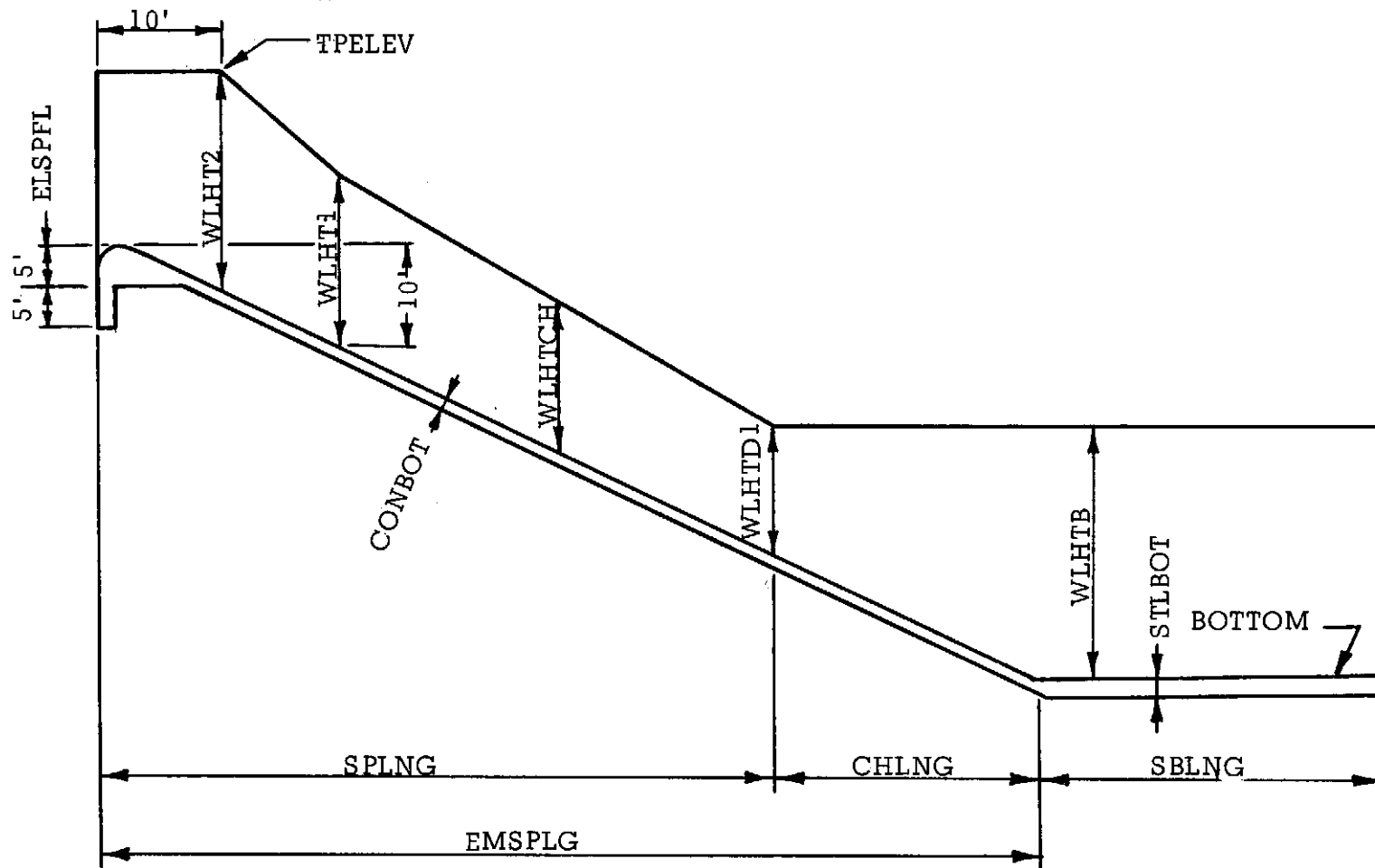


Figure A. Emergency Spillway Profile  
(Not to scale)

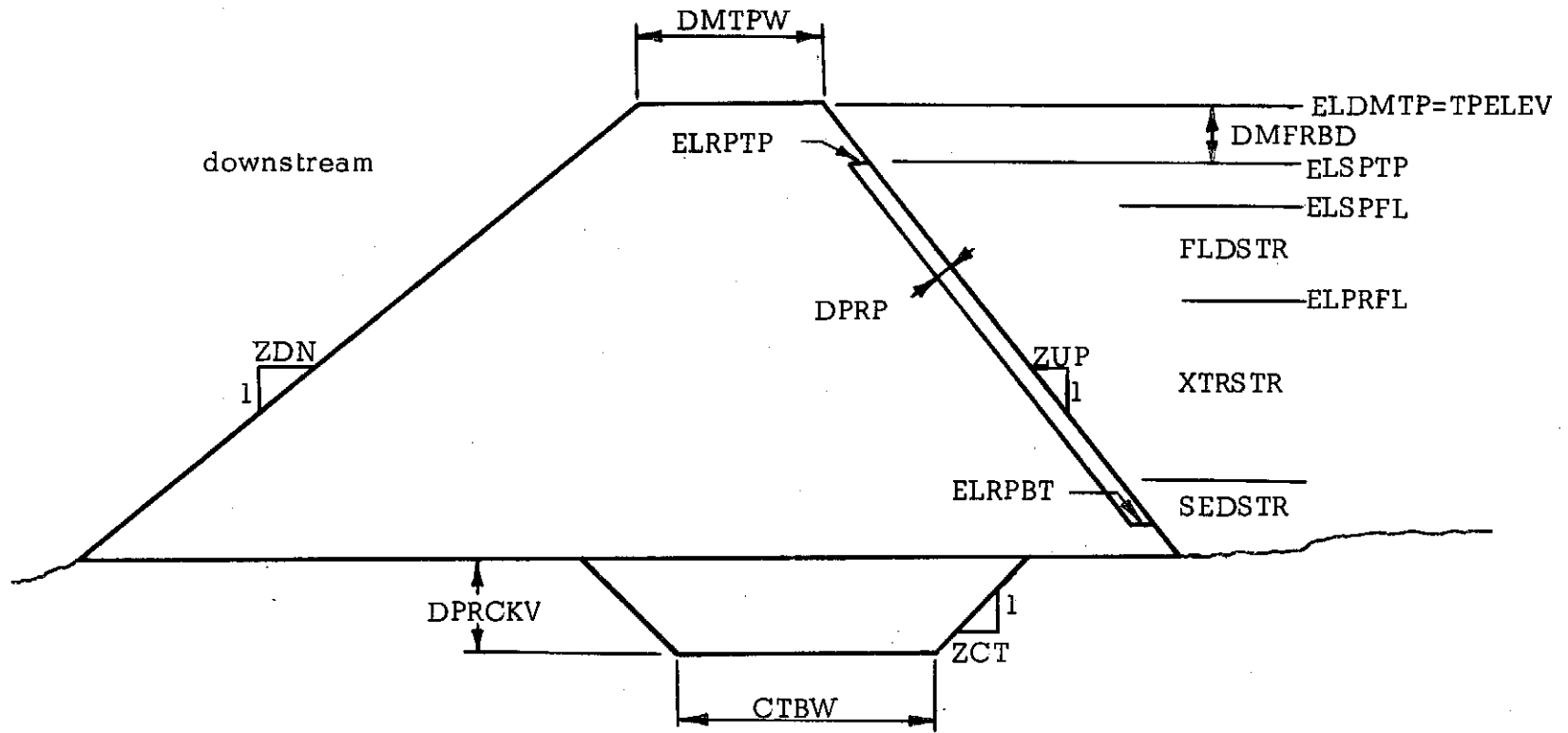


Figure B. Dam Cross Section  
(Not to scale)

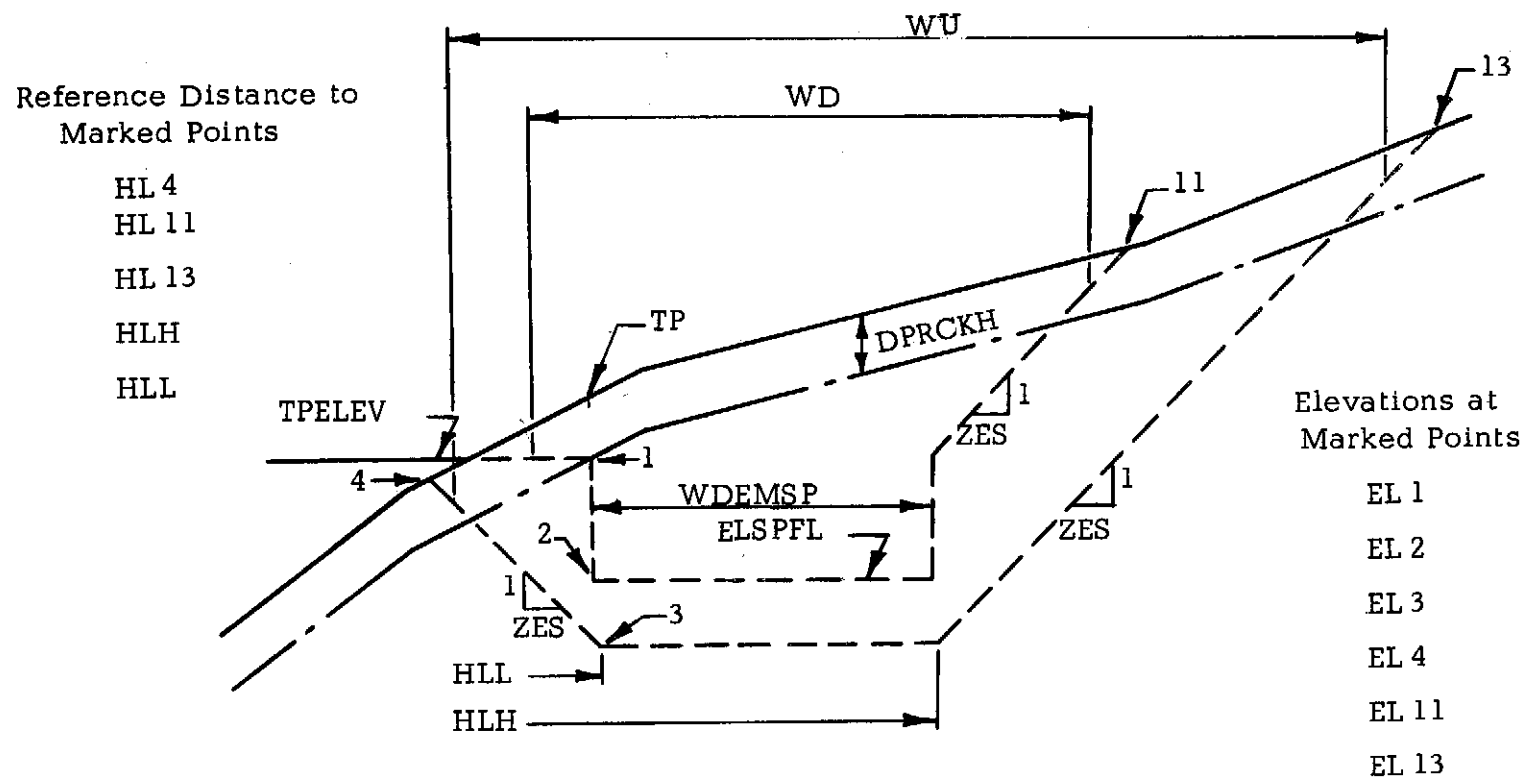


Figure C. Emergency Spillway Cross Section  
(Not to scale)



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