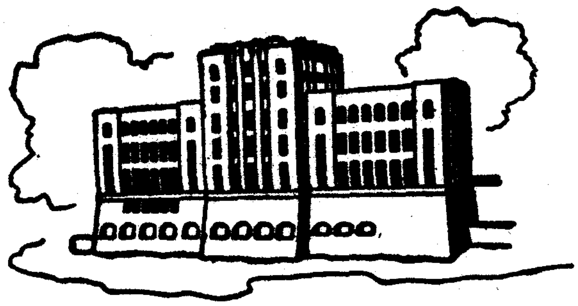
#194

FLOOD DAMAGES ON THE IOWA RIVER

by

Thomas E. Croley II
Fazle Karim
Rosa Chen

Sponsored by
Office of Water Research and Technology
Iowa State Water Resources Research Institute
(Title I Annual Allotment Project No. A-054-IA)



IIHR Report No. 194

Iowa Institute of Hydraulic Research
The University of Iowa
Iowa City, Iowa

October 1976

FLOOD DAMAGES ON THE IOWA RIVER

by

Thomas E. Croley II
Fazle Karim
Rosa Chen

Sponsored by
Office of Water Research and Technology
Iowa State Water Resources Research Institute
(Title I Annual Allotment Project No. A-054-IA)

IIHR Report No. 194

Iowa Institute of Hydraulic Research
The University of Iowa
Iowa City, Iowa

October 1976

PREFACE

This study was performed to construct a value function representing flood control use of the Coralville reservoir near Iowa City, Iowa under research entitled: "Flood Control Management in Sedimenting Reservoirs Subject to Recreation Demands". A companion study, previously completed as IIHR report no. 185, did the same for recreational values on the reservoir. These value functions are being used in an objective trade-off and optimization study to determine best operation plans for each level of trade-off between the operation objectives of flood control and recreation. The value function developments were plagued with a paucity of data and hence, conventional rigorous estimation of mathematical relations were impracticable. These developments made the maximum use of available data, existing relations observed elsewhere, physical insights, and intuitive reasoning. The results presented herein represent an estimate of flood damages on the Iowa river below the Coralville dam as affected by reservoir operations and time of the year. The flood damage model may then be used to construct estimates of flood control benefits in preliminary operation studies.

ACKNOWLEDGMENTS

The authors appreciate the cooperation of Mr. Doyle W. McCully, Chief, Engineering Division, Mr. Paul A. Soyke, and Mr. George E. Johnson of the Waters Resources Management Section, U.S. Army Corps of Engineers, Rock Island District, Illinois, for making available much relevant data for the Iowa river. The cooperation of the personnel of the Iowa City office of the U.S. Geological Survey is also appreciated.

This work was supported in part through the Title-I Annual Allotment Program, project number A-054-IA of the Iowa State Water Resources Research Institute under Annual Allotment Agreement No. 14-34-0001-6016 with the United States Department of the Interior, Office of Water Research and Technology.

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	Categories of Flood Damages	2
III.	Factors Affecting Flood Damages	4
IV.	Damage Estimation: Data Base and Purpose	6
V.	Current Practices of Estimating Damages	8
	A. Property Damages	8
	1. Aggregate formula approach	8
	2. Historical damage curve method	8
	3. Depth-damage curve method	9
	B. Crop Damages	11
	1. Aggregate formula approach	11
	2. Simulation approach	13
VI.	Flood Damages Downstream of the Coralville Dam	15
	A. Data Availability	15
	B. Model Building	17
	1. Crop damages	25
	2. Property damages	29
	3. Total flood damages	29
VII.	Flood Damages Upstream of the Coralville Dam	36
VIII.	Summary and Conclusions	38
IX.	References	42
X.	Appendix - Tables	43

LIST OF TABLES

Table No.	Title	Page
1	Flood Damages Prevented By Coralville Reservoir Since 1959	44
2	Iowa River Floods of 1969 and 1973	45
3	Flood Water Damage Factors for Corn as a Percentage of Flood Free Gross Return	46
4	Percent of Total Crop Value Destroyed by Flooding	47
5	Average Yields of 1966 Corn-Flooding Experiment	48
6	Average Yields of 1967 Corn-Flooding Experiment	49
7	Average Yields of 1968 Corn-Flooding Experiment	50
8	Estimated Unit Crop Damage Factor (K) in Dollars per Cultivated Acre	51
9	Acreage of Crops in Iowa River Basin Downstream of the Coralville Dam	52
10	Observed Peak Discharges at Iowa City, Lone Tree and Wapello (1958-74)	53
11	Computation of Average Relative Error for Peak Discharge Relation: Iowa City vs. Lone Tree	54
12	Computation of Average Relative Error for Peak Discharge Relation: Lone Tree vs. Wapello	55
13	Comparison of the Discharges of Iowa River, English River and Cedar River	56
14	Computation of Weights for Reaches 1 and 2A	57
15a	Computation of Total Flood Damages for May-June-July Flood	58
15b	Computation of Total Flood Damages for August Flood	59
15c	Computation of Total Flood Damages for September Flood	60

LIST OF TABLES (cont'd)

Table No.	Title	Page
15d	Computation of Total Flood Damages for October Flood	61
15e	Computation of Total Flood Damages for November-April Flood	62
15f	Computation of Total Flood Damages for Dec.-Jan.-Feb.-March Flood	63
16	Summary of Total Flood Damages on the Iowa River Downstream of the Coralville Dam	64

LIST OF FIGURES

Figure No.	Title	Page
1	Typical Stage-Damage Curve	8
2	Typical Depth-Damage Curves	10
3	Variation of Crop Damage with Depth of Flooding	12
4	Location Map	16
5	Stage-Area Flooded, Stage-Crop Damage and Stage-Property Damage Curves for Reach 2A	18
6	Stage-Area Flooded, Stage-Crop Damage and Stage-Property Damage Curves for Reach 2B	19
7	Discharge-Cultivated Area Flooded Curve for Reach 1	20
8	Discharge-Property Damage Curve for Reach 1	21
9	Flood Hydrograph (1969) at Iowa City	23
10	Flood Hydrograph (1973) at Iowa City	24
11	Discharge-Cultivated Area Flooded Curve for Reach 2A	27
12	Discharge-Cultivated Area Flooded Curve for Reach 2B	28
13	Discharge-Property Damage Curve for Reach 2A	30
14	Discharge-Property Damage Curve for Reach 2B	31
15	Peak Discharge at Iowa City vs. Peak Discharge at Lone Tree	33
16	Peak Discharge at Lone Tree vs. Peak Discharge at Wapello	34
17	Total Flood Damage Downstream of Coralville Dam vs. Discharge at Iowa City	37
18	"Easement Area" vs. Reservoir Pool Elevation	39
19	Upstream Flood Damage vs. Reservoir Pool Elevation	40

ABSTRACT

Total flood damages associated with the different discharges of the Iowa river, as determined by Coralville Reservoir operation are estimated herein. Recognizing the limitations imposed by the inadequacy of the available data, a simple physical model has been developed. Total flood damages on the Iowa river downstream of the Coralville dam have been divided into two categories - crop damages and property damages. Crop damages are heavily dependent upon the time of occurrence of the flood, while property damages can be considered as independent of the time of the year for all practical purposes. Because of the time-independence characteristics, property damages are estimated by using historical stage-damage relationships directly. The crop damages, which are dependent upon the time of the year, are estimated by multiplying cultivated area flooded by a unit crop damage value, K ($/cultivated acre). The factor K may be considered, in general, as a function of depth, duration, time of the year of flood, etc. In the present study, only the variation of K with the time of the year has been considered; other factors influencing K are ignored because of insufficient data. In estimating variation of K with the time of the year, relevant data from other areas of the United States have been used to supplement the available Iowa river data. Estimates of total flood damages downstream of the Coralville dam for different discharges of the Iowa river at the dam are presented for six different periods of the year. Certain assumptions and interpretations made in this study restrict the applicability of the results; however, flood damage values downstream of the Coralville dam as presented herein may be considered sufficient for preliminary planning purposes. Flood damages upstream of the Coralville dam are not considered effective damages by the managing agency of the reservoir since all adjoining lands subject to damage are owned by the Federal Government; however, a rough estimate of the upstream flood damages is also included herein separately.

FLOOD DAMAGES ON THE IOWA RIVER

I. INTRODUCTION

The United States suffers an average of about one billion dollars in flood damages every year. More than 10 billion dollars have been spent on structural measures alone to mitigate flood damages since passage of the Flood Control Act of 1936 (Cline, 1968). This enormous amount spent on flood control projects has certainly reduced flood damages below what they would have been otherwise. Flood control projects of the U.S. Army Corps of Engineers prevented flood damages estimated at 38 billion dollars - a return of $3 for every dollar spent (Corps of Engineers, 1974). However, the expected annual flood damages are still increasing every year. Thus, more flood-mitigating measures, both structural and non-structural, need to be considered in years to come. The importance of reasonably accurate quantifications of flood damages, which are necessary to justify the costs of such measures, therefore can be hardly overestimated. This assumes even more importance in the case of planning and operating multipurpose projects, wherein trade-off studies between flood control and other objectives must be executed.

The major objective of this report is to review the methods for quantitative estimation of flood damages and to formulate a model for estimating flood damages on the Iowa river in relation to different operations of Coralville Reservoir. The Coralville dam, located on the Iowa river about 5 miles upstream from Iowa City, was completed in 1958 and was primarily designed for flood control purposes. Recreation use of the reservoir has increased at such a fast rate as to result in great public demand for revision of the reservoir operation plan in order to provide more recreation opportunities. Thus, a potential conflict between flood control use and recreation use of the reservoir exists and warrants a trade-off study between these two uses to arrive at an optimal operation plan.

This report attempts to examine the residual flood damages associated with different levels of operation of the reservoir. With due consideration to the limitation of data available and the scope of this study, a simple physical model is developed. It is based on historical data and physically based arguments. The limitation of available data is recognized and methods are developed herein for application to limited data situations, but provisions are incorporated for improving the estimates as more detailed data becomes available. The flood damage values obtained herein and recreation values obtained from a companion report are to be used in a separate study of trade-offs between flood control and recreation for the Coralville Reservoir.

II. CATEGORIES OF FLOOD DAMAGE

Flood damages are generally classified into five categories: direct damages, indirect damages, secondary damages, intangible damages, and uncertainty damages.

Direct damages result from direct physical contact of damageable property with floodwater. If the property (buildings, crops, roads, etc.) fulfilled a function worth restoring, the damage may be taken as the cost of restoring the property to a state adequately performing its preflood function. If restoration cannot be justified or is physically impossible, the damage may be taken as the present worth of the expected future productivity if the flood had not occurred. The loss in income from crops destroyed in the field is a special case of this. Direct urban damages are taken as the cost of restoring damaged property to its preflood condition or its loss in market value if restoration is not worthwhile. The damage to totally destroyed urban property is its market value at the time of the loss. If some other kind of property can be used to fulfill the same function, the damages may be taken as the cost of substitute measures. Since direct damages are the only kind of flood damages which can be expressed in monetary terms in a straightforward way, in most cases it is the only damage considered for project evaluation.

Indirect damages result from physical or technological linkages with flood waters, other than direct physical contact. It includes the value of lost business and services, the costs of alleviating hardships, safeguarding health, constructing temporary barriers, removing goods from the flood area, rerouting highway and railroad traffic and delaying the delivery of goods and services, etc. Since these damages are difficult to quantify individually, indirect damages as a group are usually taken as a fixed percentage of the direct damages, and appropriate percentages are determined from pilot studies. The percentages adopted by the Corps of Engineers are as follows: residential 15%, commercial 35%, industrial 45%, utilities 10%, public facilities 34%, agriculture 10%, highway 25%, and railroads 23% (Kates, 1965).

Secondary damages result from economic rather than physical or technological linkages. Economic losses caused by flooding may extend further than losses to those whose property is damaged or whose activities are hindered. Other people depending on output produced by damaged property or hindered services may feel adverse effects. Adverse effects also accrue to those who supply goods and services to the flooded area. For example, damages inflicted by a flood may prevent a family from being financially able to purchase a new automobile. An automobile dealer then loses a potential sale and thus suffers a secondary damage. An auto-manufacturer then also loses a sale with more secondary damages. Such damages are difficult to quantify and are at least partially offset by pecuniary gains in areas not affected by the flood. While users of goods and services and suppliers of inputs in flood-affected areas suffer secondary damages, suppliers of materials and labor for rehabilitation and suppliers of goods and services from areas not affected by the flood receive extra pecuniary gains. From the national economic viewpoint, this may be considered as a shift of pecuniary gains from one group of people (affected by flood) to another (not affected by flood). Secondary damages in the floodplain thus tend to be offset by economic gains in other areas, and hence under normal economic conditions are considered to be zero from the national viewpoint (Cline, 1968; Breaden, 1973) even if unfair from the local viewpoint.

In recent times, intangible damages and benefits have received greater attention. Some examples of intangible damages are: environmental quality, social well-being, loss of life and health, and aesthetic degradation. The economic and aesthetic value of property in urban floodplains tends to be depressed by flood events. This has a definite impact on the social well-being of the affected community. Perpetual threat of flood damages to rural areas also has a definite impact on the local or regional economy. It is currently not possible to estimate monetary values of intangible damages. There are several research projects underway to investigate methodogies for estimating intangible damages (Grigg & Helweg, 1975; Breaden, 1973), but no quantitative information is available currently.

Recent research has indicated uncertainty damage as the fifth category of flood damage. The occupants of a floodplain suffer from an ever present uncertainty with respect to when the next flood will occur and how serious it will be. This imparts a burden of insecurity which may be considered as a damage in its own right. Uncertainty damages may be calculated as amounts in excess of the expected values of damages that people are willing to pay to avoid financial disaster or even the financial inconvenience of irregular budgeting (Breaden, 1973). Methods of calculating uncertainty damages are not straightforward and hence usually are not included in the estimation of total flood damages.

In the case of the Iowa river flood damages, only direct damages are considered. Other types of damages are excluded because their inclusion could not be justified due to lack of adequate data or to their insignificance in the present context. Direct damages may be divided into several sub-groups, e.g.: residential, commercial, industrial, utilities, public facilities, crops, highways, railroads, etc. Considering limitations of available data, direct damages are divided herein into two broad groups - crop damages and property damages. Property damages include damages to rural farm structures and buildings, urban structures and buildings, roads, utilities, etc. Considering these two types of damages separately is intuitively appealing since they are affected by floods in distinctly different manners. This will be discussed later. Since concern is with direct damages only, the word "damage" in the rest of the report will refer to direct damages unless otherwise stated.

III. FACTORS AFFECTING FLOOD DAMAGE

Flood damages relate to a combination of factors including depth of water, velocity of flow, duration of inundation, the lapse of time since the last flood, the rate of rise and fall of the flood hydrograph, time of the year, and climate (Breaden, 1973). In addition to the above factors, crop damages also depend on the productivity and distribution of various soil types within the floodplain, the value of the crops grown and their susceptibility to flood damages at various times of the year. On the other hand, property damges depend on the depth and duration of inundation, the velocity of flow, the lapse of time since the last flood, and the type and value of property. The important difference between crop and property damages is that the latter is almost independent of the time of the year while the former is dependent heavily on the time of the year.

The velocity of flow determines the amount of sediment carried onto the floodplain and deposited in the relatively still water there. Sediment destroys the usefulness of household materials. High velocity flows may erode highway fills, scour gullies in fields, wash away fertilizers and soil nutrients from crops or push buildings off their foundations. Data scarcity makes it difficult to evaluate the effect of flow velocity. Fortunately, for a given spot on the floodplain and for a given stage, velocity seldom varies significantly from one flood to another. Consequently, the differences in damages associated with differences in velocity can be considered to be reflected in the variation of damage with stage (Breaden, 1973).

The degree to which crops or properties are damaged increases with both depth and duration of flooding. However, maximum damages are reached at some point when crops are totally destroyed or the value of capital goods is reduced to the minimum salvage value so that no further damage can occur. Crops are more susceptible to damage in some seasons than in others depending on the stage of growth of crops. Also, stage of growth or height of crops interacts differently with different combinations of depth and duration. For example, a shallow depth of flooding will cause much greater damage to crops in early stages of growth than to crops in later stages of growth. Again, this depends on the duration of inundation and the type of crops affected. Levels of nitrogen fertility in fields affect the degree of crop damages. Plots with high levels of nitrogen fertility are affected much less than those with low nitrogen fertility when shallow flooding occurs (Beer, 1968). If the flood occurs early enough in the growing season and temperature is favorable for quick drying of the land, the crop can be replanted with minor losses. If the temperature is not favorable, so that it takes too long for drying, replanting will be delayed or may not be practical at all, thus causing larger damages.

The time lapse between two consecutive flood events is another major factor affecting damages. If two floods of equal depth occur in rapid succession, the second flood will not add a great deal to the damages which resulted from the first flood. Alternatively, if the second flood occurred after the damages caused by the first flood have been repaired, the second flood may nearly double the damages.

In this study, depth of flooding (in terms of stage) and seasonal effects are considered. Flood duration, which is a significant factor in determining flood damages (especially for crops), is neglected since no data is available for estimation of this effect.

IV. DAMAGE ESTIMATION: DATA BASE AND PURPOSE

Detailed documentation of damages associated with past floods is essential for estimating damages associated with future flood events. The variety of ways an individual flood will disrupt human activity is great and the number of individual interruptions is many. It is therefore impractical, if not impossible, from the point of view of the time and expenditures involved, to record each individual damage related to each individual property due to the occurrence of a flood. This fact is aptly described by Breaden (1973) as follows:

> "The ideal data base for flood damage estimation would be on-the-spot records of how each property item and each human activity was affected by a series of flood events representing a range of conditions with respect to such parameters as time of year, depth and duration, period since last flood, hydrograph shape, warning, etc. The ideal analysis would then assign each effect a fair economic value and sum the values to estimate total damage. Compilation of such a broad data base, however, is manifestly impractical as a routine step in planning. Such detailed information might possibly be collected in a research case study of a limited area, but even information of this type is unavailable."

Flood damage estimates usually available are the total annual damages which may result from a single flood or a series of small and large floods. It is not possible to isolate the damages which are attributable to different flood events of a year. Thus, it is not always possible to relate accurately such annual damage estimates to parameters of floods like depth, duration, time of the year, etc.

The manner in which flood damage data are collected has an important bearing on the quality and the extent of applicability of such data. Breaden (1973) describes this aspect of flood damage data as follows:

> "Flood damage estimates used for water resources planning are generally collected by survey teams who rely heavily on the memory of local residents with respect to what happened during major flood events. If the team can get into the field soon enough after a flood, high water marks and observed unrepaired damages also provide important information. Interviews and residual water marks are fairly good sources for providing an understanding of what went on in terms of areas and depths of inundation and the kinds of damages inflicted to estimate the economic losses from flooding. People vary drastically in the viewpoint they take of the damage, the effects they overlook, and the kinds of things they unintentionally or purposefully exaggerate."

The presence of such subjective elements in the damage estimates prepared on the basis of interviews of local residents further complicates the task of interpreting them in terms of flood parameters like depth, duration, time of the year, etc.

For single purpose flood control projects, it is adequate to determine the average annual flood damages which are required for justification of such projects. This can be accomplished by plotting total annual flood damages against the peak annual stage for each year, for which data are available, to obtain stage-damage curves. A single stage-damage curve may be developed for the entire affected reach of the river or the affected reach may be divided into several sub-reaches depending upon the data availability and the desired accuracy. Damage-frequency curves can be developed from stage-damage curves and flood-frequency curves. The area under a damage-frequency curve gives the average annual damages. This procedure is not adequate for reservoir operation determinations. In such cases a damage function is needed relating damages to the discharge from the reservoir. It is desired that such a damage function should take into account, if possible, depth and duration of inundation and the time of the year, which is of primary importance in determining crop damages. The limitation of available data is recognized and methods are developed herein to apply to cases where little data is available but provisions are incorporated for improving the estimates as more detailed data becomes available. Before damage estimation method developments are described, it is worthwhile to review current methods for flood damage estimates.

V. CURRENT PRACTICES OF ESTIMATING DAMAGES

A. Property Damages. Current techniques to estimate property damages can be divided into three categories: the aggregate formula approach, the historical damage curve method, and the empirical depth-damage curve method (Grigg and Helweg, 1975).

1. Aggregate formula approach. The aggregate formula, as suggested by James (1972) for estimating urban damages, is:

$$C_D = K_D \; U \; M_S \; h \; A \qquad (1)$$

where C_D = flood damage ($) for a particular flood event; K_D = flood damage per unit flood depth per dollar ($/ft/$) of market value of structure; U = fraction of flood plain in urban development; M_S = market value of structure inundated per unit developed area ($/acre); h = average flood depth over inundated area (ft); and A = area flooded (acres).

A representative value for K_D is 0.052 as determined by James (1964) for estimating total (direct and indirect) urban damages of the floodplain. This value of K_D assumes moderate to low velocities, flood durations, and flow sediment contents and should be raised for more adverse conditions (Cline, 1968).

2. Historical damage curve method. This method consists of preparing a stage-damage curve by plotting the estimated historical damages against the corresponding peak flood stages as shown in figure 1.

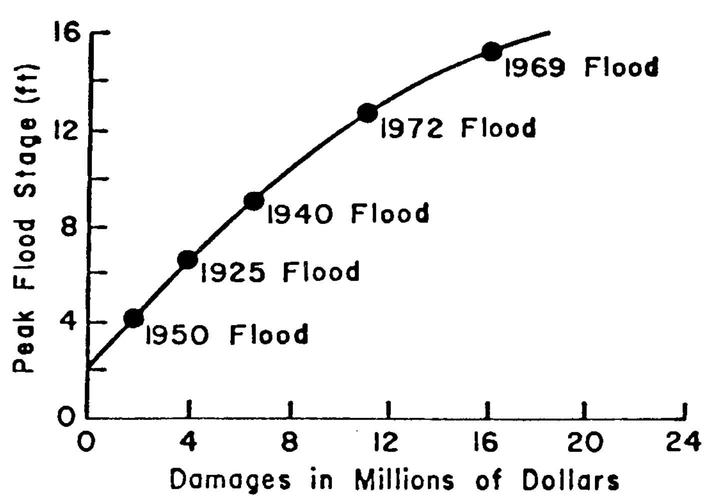


Figure 1. Typical Stage-Damage Curve

For current validity, damage costs must be corrected to present values by including additional developments in the floodplain and by correcting for inflation. This adjustment is necessitated by the fact that the amount of flood damages depends upon the extent of cropped areas, urban and rural housing and other structures and utilities, etc., existing in the floodplain at the time of flooding. Thus, if there is additional urban development and an expansion of cropped areas since the estimates of damages caused by a historical flood was recorded, the damage caused by a present flood of the same characteristics (depth, duration, affected area, etc.) as the historical flood will be more than the recorded estimate for the historical flood. Historical flood damages need to be adjusted upward on the basis of increases in urban areas, increases in cropped areas, changes in the types of crop, or other suitable indices reflecting changes in land use and additional development in the floodplain. Correction for inflation can be effected by reducing dollar values of damages for all years to a given base year index using appropriate economic indices for each type of damage. The stage-damage curve, so adjusted for additional development in the floodplain and for inflation, can be used to estimate damages from the peak stage reached by any flood.

3. Depth-damage curve method. This method requires the first floor elevations of the structures in the floodplain (or the elevation where flood waters enter the building), the depth-damage curves for structures in the study reach, and the total market value of structures and their contents. The damages as percentage of total value are related to the depth of water from the first floor to obtain depth-damage curves. Grigg and Helwegg (1975) have prepared standard depth-damage curves for various types of structures based on information from various agencies, such as: FIA (Federal Insurance Administration), SCS (Soil Conservation Service) and USACE (United States Army Corps of Engineers). Typical depth-damage curves are shown in figure 2.

Market values of structures can be obtained from property surveys of the floodplain. The values of contents (in structures) are estimated by using the empirical relations developed by various investigators and agencies. A statistical survey conducted by the Stanford Research Institute (1960) resulted in the development of the following regression equation (Grigg and Helweg, 1975):

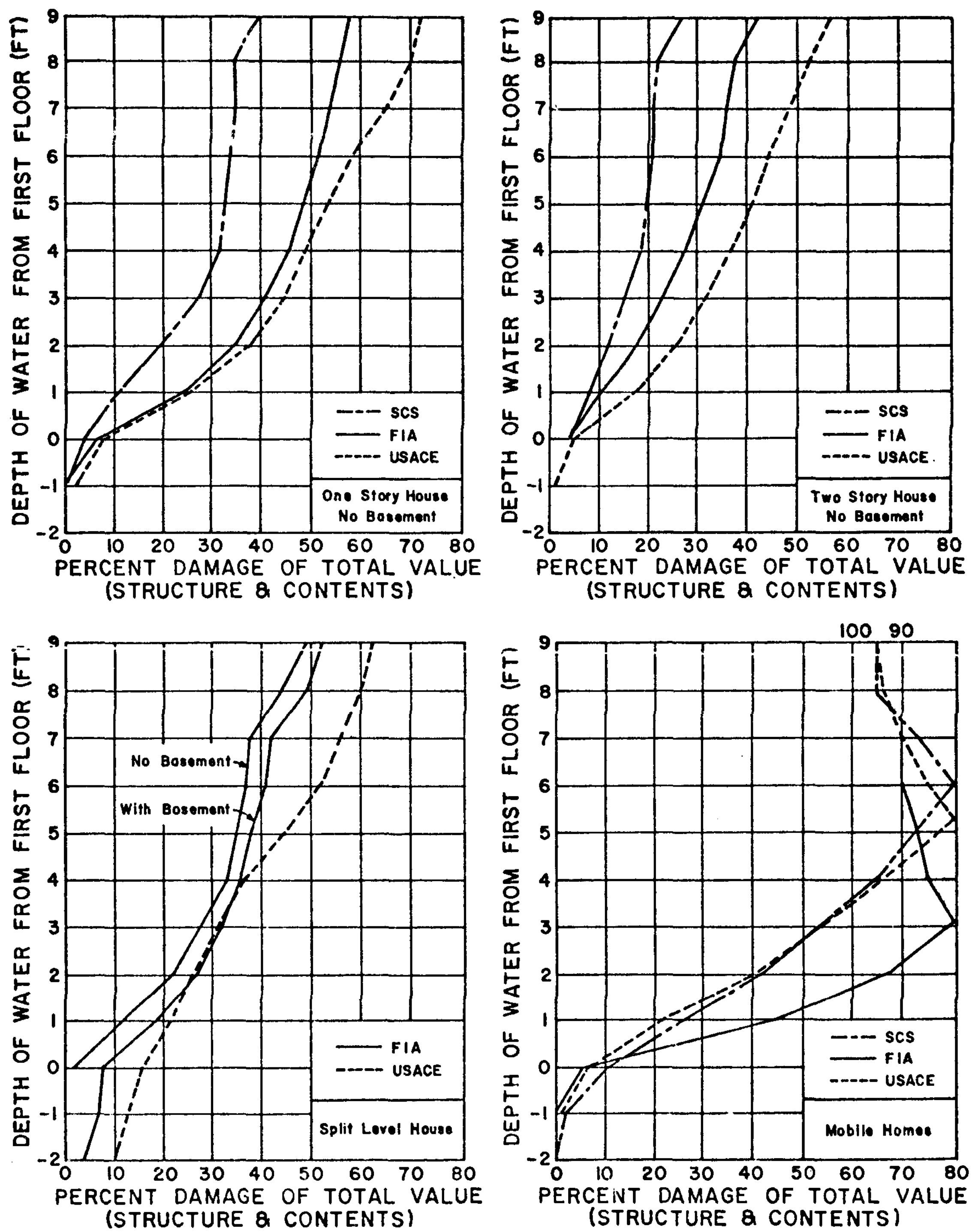


Figure 2. Typical Depth-Damage Curves

Source: Grigg, Neil S and Helweg, Otto J. State-Of-The-Art of estimating flood damage in urban areas. Water Resources Bulletin, Vol. 11, No. 2, April, 1975

$$100 \frac{V_C}{V_S} = 42.0818 - .00072\ V_S \qquad (2)$$

where V_C = market value of contents (\$); and V_S = market value of structures (\$).

A flood study conducted in 1964 by a federal agency used 32% of the structure value as the value of structure contents. A major insurance company uses 50% and states that this may be high or low, depending on the circumstances. Another federal agency feels that 30% of the structure value is a good approximation for the value of the contents (Grigg and Helweg, 1975). Market values of structures and contents enable estimation of damages for a particular depth of water:

$$C_D = F_D \cdot V_T \qquad (3)$$

where C_D = damages (\$); F_D = fraction of structure damaged, obtained from depth-damage curve (figure 2); and $V_T = V_C + V_S$ = total market value of structure plus contents in dollars.

C_D can be obtained for each type of structure and then totaled to get the total damages corresponding to a particular depth of water. Following the same procedure for different depths of water in the desired range, a depth-total damage curve is obtained for a particular reach of the river. Using relations between the depth of water in buildings to the river stage, damage-stage curves are finally obtained.

B. Crop Damages. As discussed earlier, crop damages are distinctly different from property damages since they depend heavily on the time of the year (i.e., the stage of growth of the crops). Different methods currently available can be divided into three broad categories: the aggregate formula approach, the historical damges method and the simulation approach. The historical damage method is essentially the same as that described earlier for property damages. The other two methods are briefly described below.

1. Aggregate formula approach. Cline (1968) suggests the following method for estimating expected annual crop damages. He also developed a computer program for this purpose.

$$C_D = (\text{CDA} + \text{CDAV} \times \text{Average depth}) \times (\text{Total area flooded}) \times (\text{fraction of the subwatershed in a given type of soil}) \times (\text{fraction of available land farmed}) \quad (4)$$

where CDA = fixed crop damages per unit area for a given type of soil ($/acre) determined from figure 3; CDAV = variable crop damages per unit area per unit depth for a given type of soil ($/acre/ft) determined from figure 3 and C_D = expected annual crop damages for a given type of soil ($). The estimates of CDA and CDAV in (4) are obtained as follows. CDA1, CDA2 and CDA3 are defined as fixed crop damages per acre for a given type of soil (or crop) for flood depths of one, two, and three feet respectively. They are estimated from relevant data with the help of the following equation.

CDA1 = [(damage fraction for one foot flood depth and for a given month and type of crop) x (flood threat probability for the month) x (crop yield per acre) x (crop price)] summed over each month of the year. (5)

CDA2 and CDA3 are defined in the same way as CDA1 but for flood depths of 2 and 3 feet respectively. Estimated values of CDA1, CDA2 and CDA3 are plotted as shown in figure 3 below (assuming linear variation is present).

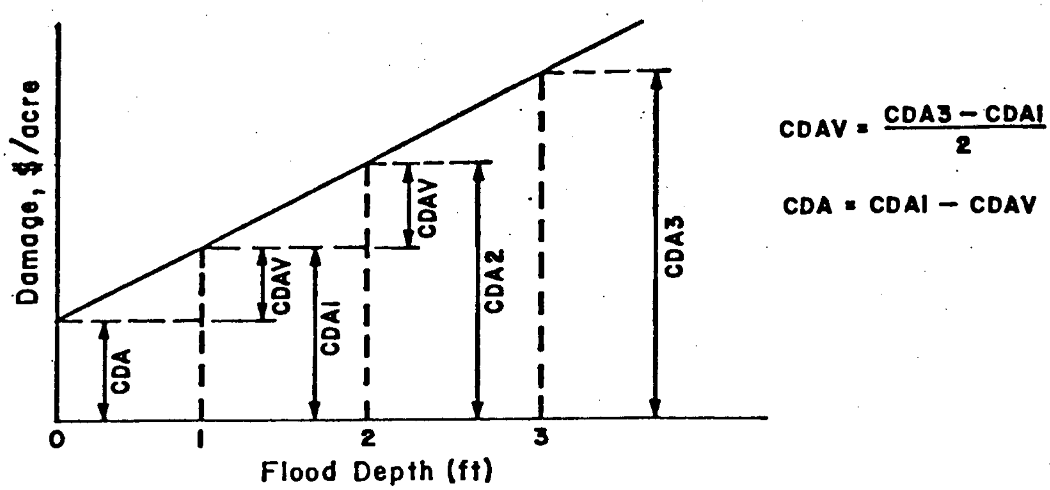


Figure 3. Variation of Crop Damage with Depth of Flooding (Adapted from Cline, 1968)

Values of CDA and CDAV are found from figure 3 as shown and this process is repeated to find CDA and CDAV values for each crop. Finally, the

CDA value for each crop is multiplied by the fraction of the particular type of soil devoted to that crop, and the products are summed to give the composite crop acre value for CDA. An analogous approach is used to obtain the composite crop acre value of CDAV.

Equation (4) gives the annual damages for a particular type of soil. The above process is repeated for each type of soil and summed to give the total expected annual crop damages.

The fixed crop damages (CDA) result from the act of flooding and are due to elimination of air in soil pores and sediment erosion and deposition. Variable damages (CDAV) represent the additional damages per foot of flood depth.

Typical values of CDA and CDAV, as estimted by Cline (1968) for the upper reaches of the North Fork of the Kentucky river near Hazard, Kentucky are as follows: CDA = \$1.02 and CDAV = \$0.368 for most productive soils, CDA = \$1.24 and CDAV = \$0.149 for intermediate soils, and CDA = \$0.01 and CDAV = \$0.009 for least productive soils.

2. Simulation approach. The simulation approach, as developed by Breaden (1973), is the most comprehensive method. This method is applicable to both property damages and crop damages or to other types of damages. The flood characteristics used in this analysis are depth of flooding, duration of flooding, season, and the sequential timing of flood flows. It also takes into account variations of damage with elevation differences on the flood-plain, with time increments over the flood hydrograph, and of the effect of repairing damages between floods. The objective of this method is to estimate damage variations with various characteristics of floods through continuous simulation of damages as they occur hour by hour throughout the total flood event. The basic mathematical model used in this method is:

$$D_m = D_{mn} (1 + D_f d(1 + t(T_f + I_f d))) \qquad (6)$$

where D_m = damages as fraction of market value; D_{mn} = initial damages (fraction) associated with the very fact of flooding; D_f = a factor representing the incremental increase in damages with depth; d = depth of flooding; t = duration of flood; T_f = a time factor representing the incremental fractional increase, per unit increase in duration, in damages at a given depth; and

I_f = a factor representing incremental changes in damages per unit increase in the product of depth times duration.

Separate sets of values of the parameters D_{mn}, D_f, T_f, and I_f are to be estimated from empirical measurements of flood damages for each major damage category (crop, structures, roads, etc.) and for each time period (January, February, March, etc.).

Equation (6) provides the power to estimate the flood damages which occur during any finite interval of time. This equation can be applied once for conditions applicable at the beginning of the period and a second time for conditions applicable at the end. The difference between the two estimates is an estimate of the damages inflicted during the period. In going from the beginning to the end of the period, the duration increases by the length of the period. For a flood stage rising to a new peak, the depth will increase from a beginning-of-the-period to an end-of-the-period value. For a falling flood stage, the assumption is that no additional damages occur to properties emerging from the inundated areas. The additional damages to properties remaining inundated can be estimated by using the end-of-the-period depth for the estimates at both ends of the interval. For a stage rising but still less than an immediately preceding peak, damages are also largely increased by extending the duration unless the water dropped low enough in between for some repairs to occur (Breaden, 1973).

This method also permits one to take into account the effect on flood damages of the time lapsed since the last flood. If consecutive flood events occur with very little time lapse between them, the damages caused by the second flood would be reduced to the duration effect on the deterioration of inundated property plus the losses from the extended interruption of human activities. However, to the degree lapsed time permits restoration of damaged property, additional damages occur. The additional amount can be estimated by keeping an account of the last time a property was damaged and how badly it was damaged and applying reasonable estimates of repair rates for different types of properties. (Breaden, 1973).

This method provides a powerful tool for estimating flood damages as they occur during a flood hydrograph. It is particularly useful for estimating damages caused by reservoir-operated releases since it has the ability to take into account all important characteristics, including duration, of floods. Unfortunately, the extensive data required by this method are usually not available for most floodplains. However, it serves as a suggestive model for future data collection.

VI. FLOOD DAMAGES DOWNSTREAM OF THE CORALVILLE DAM

The Coralville dam is located on the Iowa river about 5 miles upstream from Iowa City in Johnson County, Iowa. The project was constructed by the U.S. Army Corps of Engineers, Rock Island District and was put into operation in 1958. The reservoir behind the dam controls a drainage area of 3,084 square miles and has a maximum storage capacity of 492,000 acre-ft. About 80 miles downstream from the dam, the Iowa river discharges into the Mississippi river, after joining the Cedar river near Columbus Junction. A major tributary, the English river joins the Iowa river between the dam and Columbus Junction (locations are shown in figure 4). The flood damages are considered separately herein in the three reaches of the Iowa river between the Coralville dam and its downstream outfall on the Mississippi river. These reaches are designated as Reach 1, Reach 2A, and Reach 2B as shown in figure 4 and are named consistent with available data. Flood damages in areas upstream of the Coralville dam are discussed separately in a later section.

Total flood damages are divided into two groups: crop damages and property damages. As stated earlier, this classification is warranted by the fact that crop damages are heavily dependent upon the time of the year while property damages can be reasonably assumed to be independent of the time of the year. Fortunately, this classification also conforms to the available data. Flood damages in the Iowa river downstream of the Coralville dam have been considerably reduced since the operation of the reservoir started in 1958. This is indicated in table 1 of the Appendix which shows flood damages prevented by the Coralville reservoir as estimated by the Army Corps of Engineers, Rock Island District.

A. Data Availability. Flood damage data for the Iowa river are collected by the U.S. Army Corps of Engineers, Rock Island District. Detailed

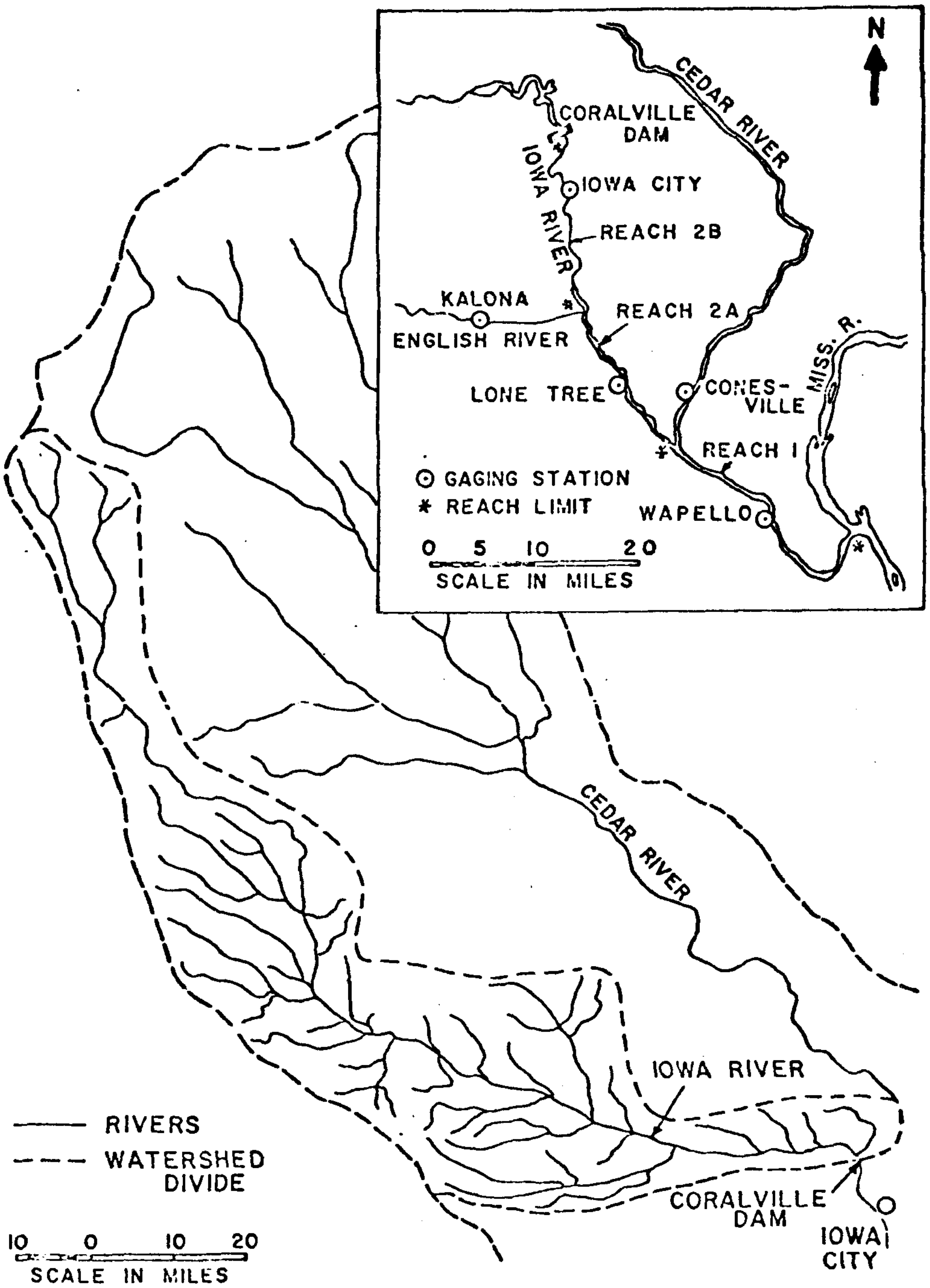


Figure 4. Location Map

flood damage data in both categories of crop and property damages for only two years, 1969 and 1973, were made available by the Corps. These data, along with gage height, discharge, and area flooded data are summarized in table 2 of the Appendix. In addition to this, the stage-area flooded, the stage-crop damage, and the stage-property damage curves prepared by the Corps in 1961 for Reaches 2A and 2B were collected. These are shown in figures 5 and 6. For Reach 1, the discharge vs. area flooded and the discharge vs. property damage curves were drawn from data supplied by the Corps and are shown in figures 7 and 8 respectively. Rating tables for gaging stations at Iowa City, Lone Tree, and Wapello and stage and discharge records for these stations were obtained from the Iowa City office of the USGS (United States Geological Survey).

Other useful results, though not completely adequate, are available concerning the influence of the time of flood on crop damages from the USDA (United States Department of Agriculture) and other investigators. Breaden (1973) gave flood damage factors for corn as a percentage of flood-free gross return for different months of the year (shown in table 3 of the Appendix). Table 4 in the Appendix gives similar data on crop damages as reported by Cline (1968). Beer (1968) carried out investigations on experimental plots of corn in 1966, 1967, and 1968 by flooding the plots at different stages of growth and for different durations of inundation. Two different levels of nitrogen fertility, high (350 lbs nitrogen/acre) and low (50 lbs/acre), were used in the plots. His results are summarized in tables 5, 6, and 7 in the Appendix.

B. Model Building. As discussed earlier, the characteristics of floods which influence damages are the depth and duration of flooding, the time of the year, the velocity of flow, the sediment content and the lapse of time since the last flood occurred. Also, the type and value of crops grown and the level of soil fertility influence the extent of damages to crops. An ideal approach would be to build a model which incorporates all these factors. But in most floodplains, as in the case of the Iowa river basin, available data is inadequate for the accounting of many of these factors. Inspection of flood hydrographs for the two years (1969 and 1973) of available data (see table 2) indicates that there were a series of small and large floods

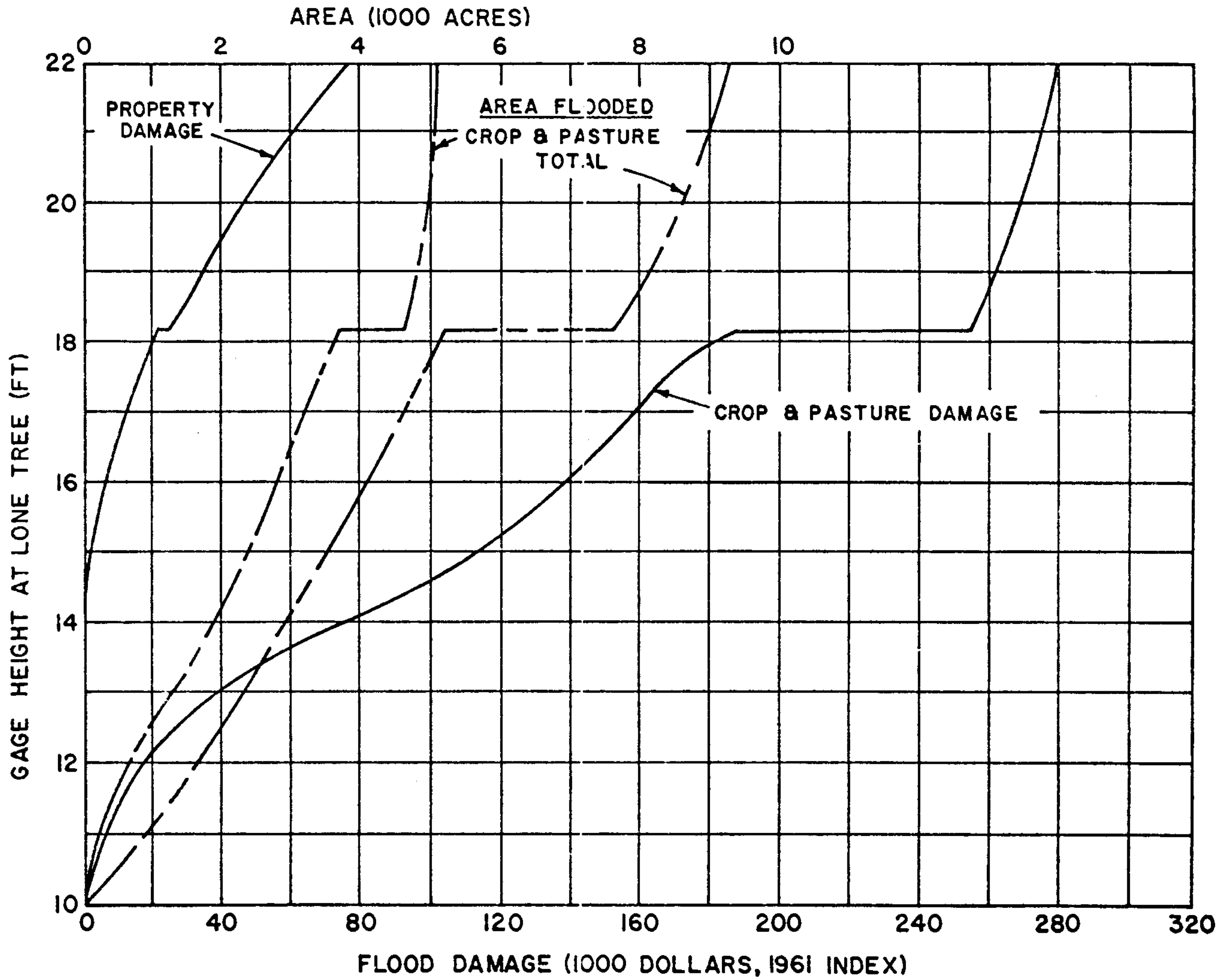


Figure 5. Stage-Area Flooded, Stage-Crop Damage and Stage-Property Damage Curves for Reach 2A

Source: U.S. Army Corps of Engineers, Rock Island, Illinois, Coralville Reservoir Iowa River, Iowa, Regulation Manual. February, 1961

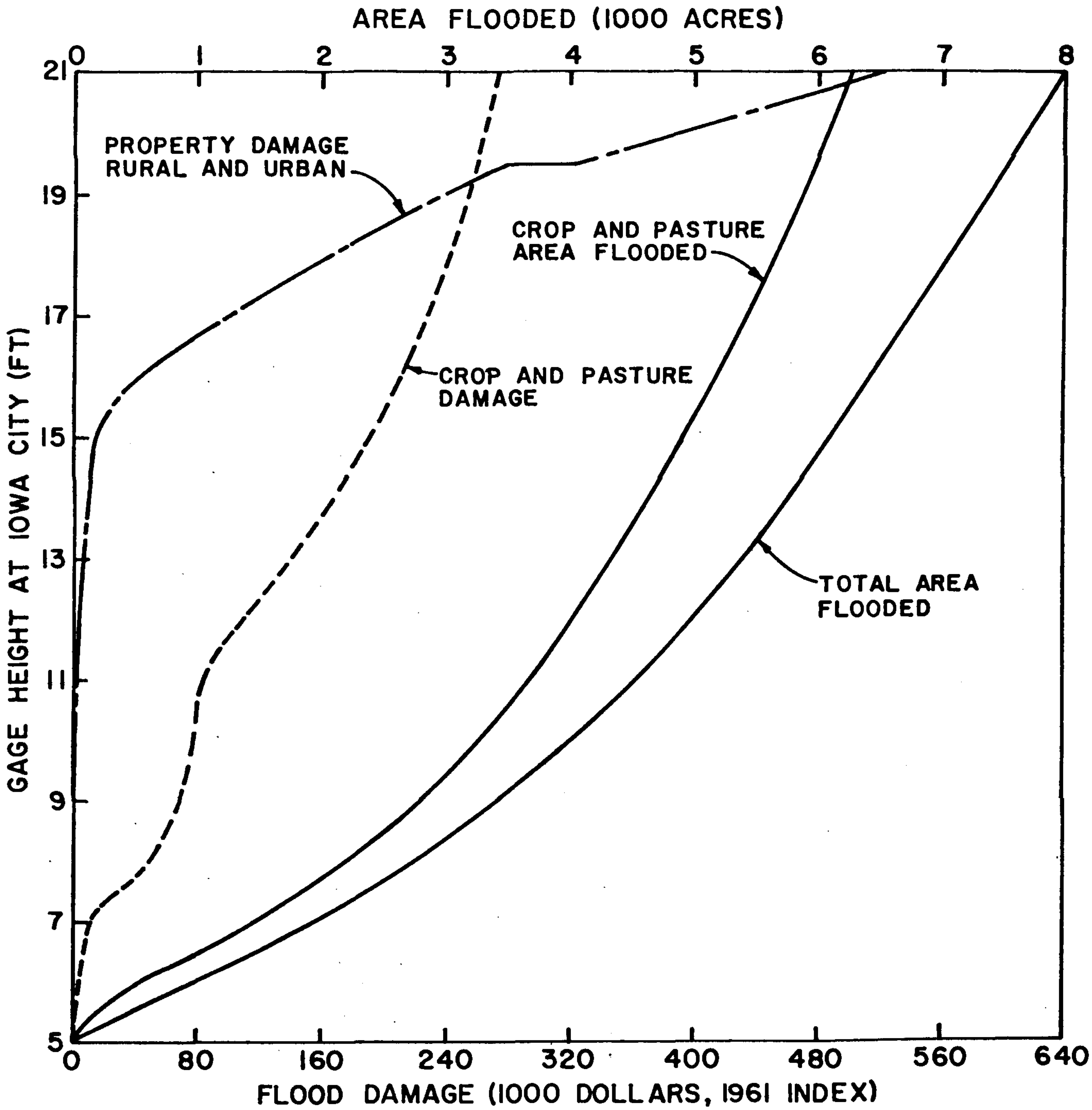


Figure 6. Stage-Area Flooded, Stage-Crop Damage and Stage-Property Damage Curves for Reach 2B

Source: U.S. Army Corps of Engineers, Rock Island, Illinois, Coralville Reservoir, Iowa River, Iowa, Regulation Manual. February, 1961

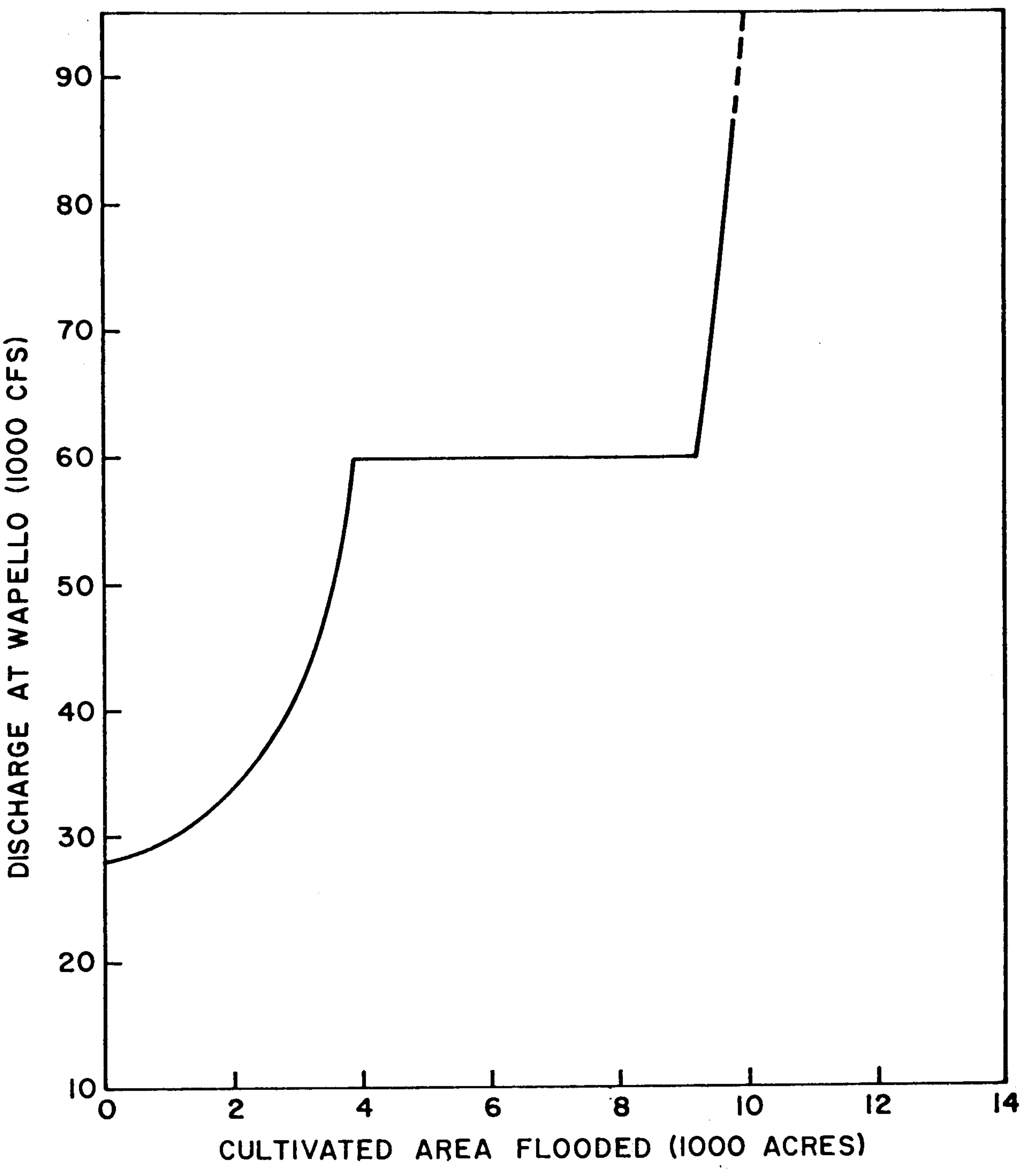


Figure 7. Discharge-Cultivated Area Flooded Curve for Reach 1

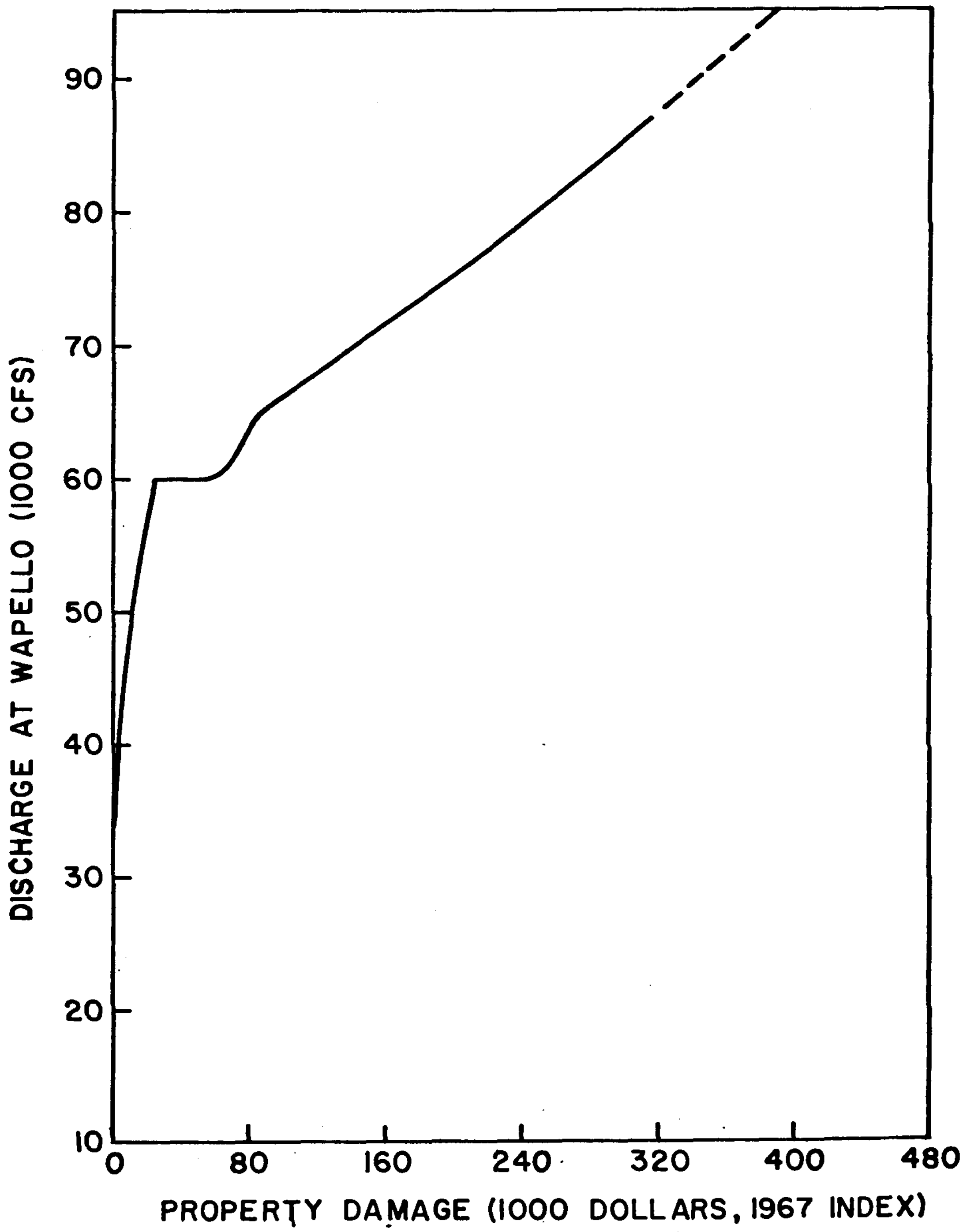


Figure 8. Discharge-Property Damage Curve for Reach 1

(see the flood hydrographs for the 1969 and 1973 floods in figures 9 and 10). In 1969, the peak flood stage occurred in July. For the 1973 flood, peak flood stage occurred in May. The damage survey by the Army Corps of Engineers was performed at the end of, or long after, the flood season. For the 1969 flood, the survey was completed during the first part of March, 1970. For the 1973 flood, the survey was taken in July and September, 1973. Thus, the damage figures in table 2 are the aggregate annual damages caused by all the floods which occurred during the relevant year and so they cannot be related to individual flood characteristics but only to the peak stage or discharge of the relevant year. Stage-area flooded and stage-damage curves in figures 5 and 6 also suffer from the same limitation. This implies that there is only one factor, namely, the annual peak stage or discharge, to which flood damages can be related.

An attempt was made, however, to construct a model incorporating the time of the year and the duration of flooding, which are particularly important for crop damages. For this purpose, the following model, which is a modified version of the simulation approach given by Breaden (1973), was considered:

$$C_D = [C_1 + K(d - d_f)\{1 + t(D_f + I_f(d - d_f))\}] \times M_f, \; d \geq d_f \qquad (7)$$

where C_D = flood damges; C_1 = initial damages associated with the act of flooding; K = damages per unit increase in stage over flood stage d_f; d = stage; d_f = flood stage or bankful stage; t = duration of flood (stage over d_f); D_f = duration factor representing incremental fractional increase, per unit increase in duration, in damages at given depth; I_f = interaction factor representing incremental fractional change in damages per unit increase in the product of depth times duration; and M_f = a factor representing the effect of the time of the year.

Equation (7) has four unknowns C_1, K, D_f, I_f, requiring 4 sets of data for their solution (assuming M_f is adequately estimated). But only two years of data are available. So, assuming $C_1 = 0$ and $I_f = 0$, (7) reduces to:

$$C_D = [K(d - d_f)\{1 + t\,D_f\}] \times M_f, \; d \geq d_f \qquad (8)$$

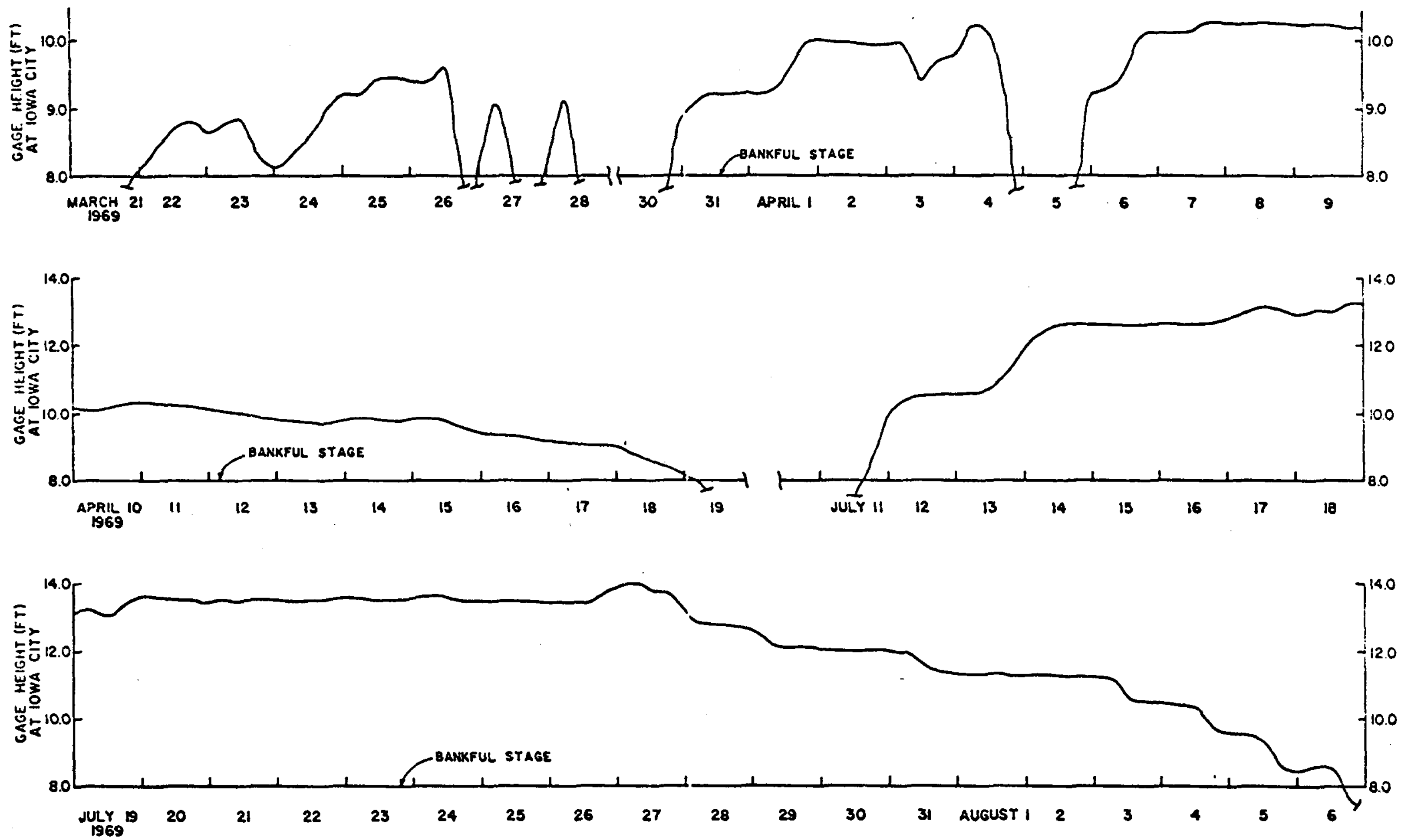


Figure 9. Flood Hydrograph (1969) at Iowa City

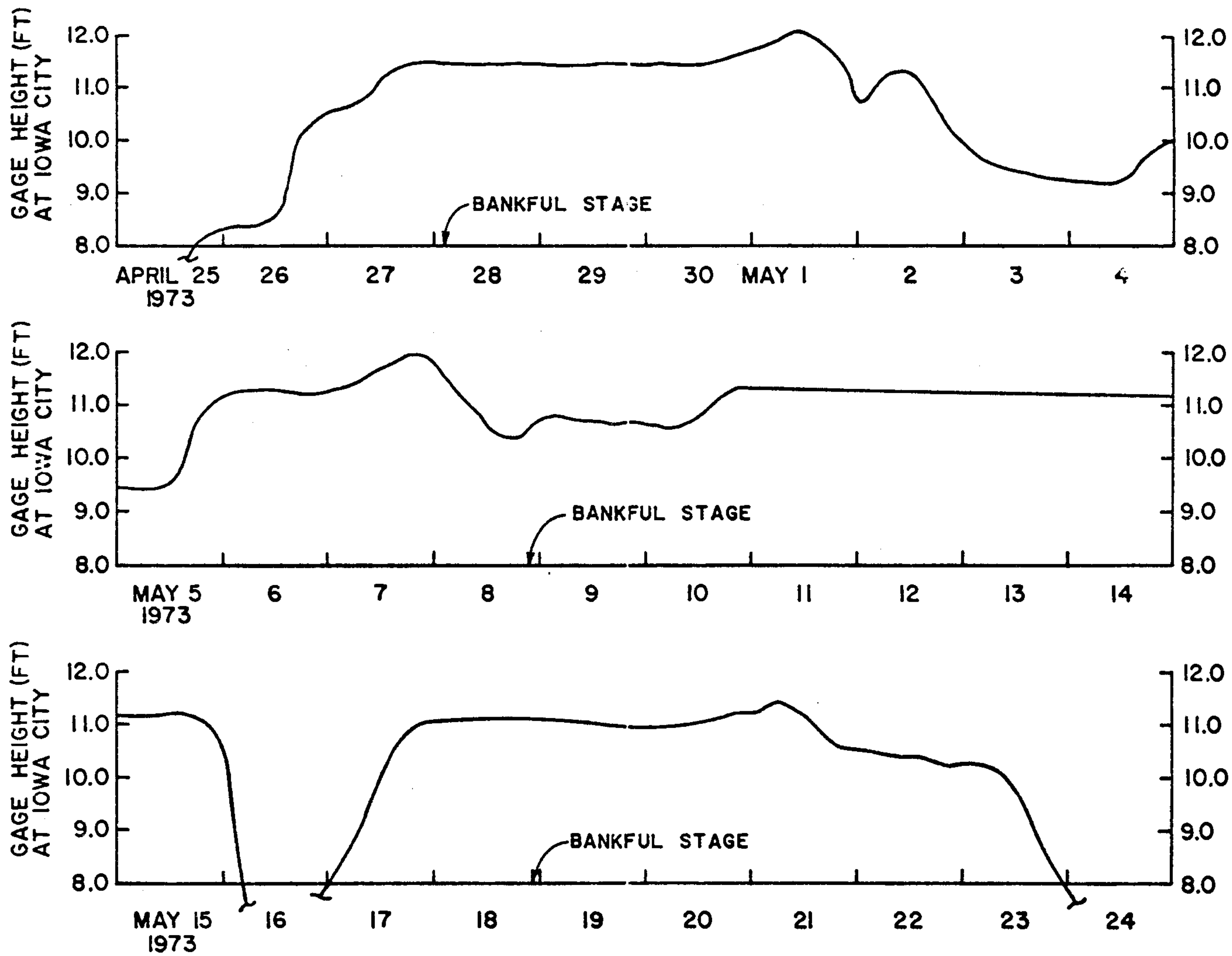


Figure 10. Flood Hydrograph (1973) at Iowa City

Equation (8) was applied for estimating crop damages. The time factor M_f was estimated from table 3 in the Appendix. Values of d and t were obtained by averaging over the entire flood period because of the difficulty, as discussed before, of attributing damages to any single flood. Unfortunately, no meaningful values of K and D_f could be obtained in this way. Failure of this approach may be explained by two factors. First, there was little confidence in the estimated values of M_f. Secondly, averaging values of d and t do not represent adequately the actual phenomenon. Considering these limitations, the endeavor is henceforth restricted to the development of a simple physical model based upon available data and making realistic assumptions. Crop damages and property damages are considered separately in the following sections.

1. Crop damages. An intuitive approach to introduce various factors indirectly into a model is given by the following equation:

$$C_D = K \cdot A. \tag{9}$$

where C_D = flood damages ($); K = unit crop damages per cultivated area flooded ($/acre); and A = cultivated area (acres) flooded.

In (9), the unit crop damage factor is considered as a function of various flood characteristics and cultivated area flooded, A is a function of stage or discharge.

Damages to corn are maximum in June or July, depending upon the depth and duration of flooding; see table 3. Table 3 also indicates some interaction between depth, duration, and the time of the year. For a given depth and duration, flood damages are negligible in April and May, maximum in June and July, and minimum in November. Table 4 indicates the same general pattern and also gives variations due to different yields of corn. Tables 5 through 7 indicate somewhat different damage patterns. Beer's experiments show that corn yields are affected most when flooding occurs at the early stages of growth (i.e. at the end of May to early June). The percent reduction in yield on low-nitrogen plots was significantly higher than that for high-nitrogen plots. At the 6" stage of growth, the low-nitrogen plot yields were reduced by 30 percent after 96 hours of flooding, but the high-nitrogen plot yields were reduced by only 6 percent after 96 hours of flooding. At later stages of growth (30 inch height and silking), yield reduction on low-nitrogen plots was considerable but lower than that for the early stages of growth. For high-nitrogen plots, the yield reduction was very small at later stages of growth. Analysis of variance of his 1967 data showed that the period of flooding and nitrogen level were all significant at the one percent level. Also, from observation on naturally flooded lands, he concluded that damages under natural flooding conditions would be more than those for the experimental plots flooded artificially.

From the above discussion and an inspection of tables 3 through 7, it appears that the unit crop damage K is a function of the depth and duration of flooding, the time of the year, the nitrogen level on the land and the crop yield. Furthermore, the time of the year appears to be the most significant factor influencing K. As already indicated, data availability precludes estimation of many factor effects on K and only the time-of-year variation of K is estimated. The data in tables 3 through 7 in the Appendix along with crop damage data on the Iowa river for 1969 and 1973 (table 2) are used to estimate K values for different months of the year. Weighted averages are used, with more weight given to higher depths (>2 ft.), larger durations (>24 hours), and available Iowa river data for 1969 and 1973. Estimated values of K for different months of the year are given in table 8 of the Appendix. For each reach, the estimated K values are different, as is expected since topography, level of protection, type of crops, soil characteristics, and crop patterns are likely to vary from reach to reach. It should be mentioned that the data in tables 3 through 7 are for corn only. Since relevant data for other crops are not available, it is assumed herein that these data are generally representative for the Iowa river. This assumption is reasonable since corn is the dominant crop in the areas under consideration. The breakdown for different crops in counties which lie between the Coralville dam and the Mississippi river is given in table 9 in the Appendix.

Values of cultivated areas flooded in (9) for different discharges are obtained from the discharge vs. cultivated area flooded curves shown in figures 7, 11, and 12 for Reaches 1, 2A, and 2B respectively. Discharge-cultivated area flooded curves were obtained by combining area flooded vs. stage and stage vs. discharge curves. Proportions of cultivated areas to

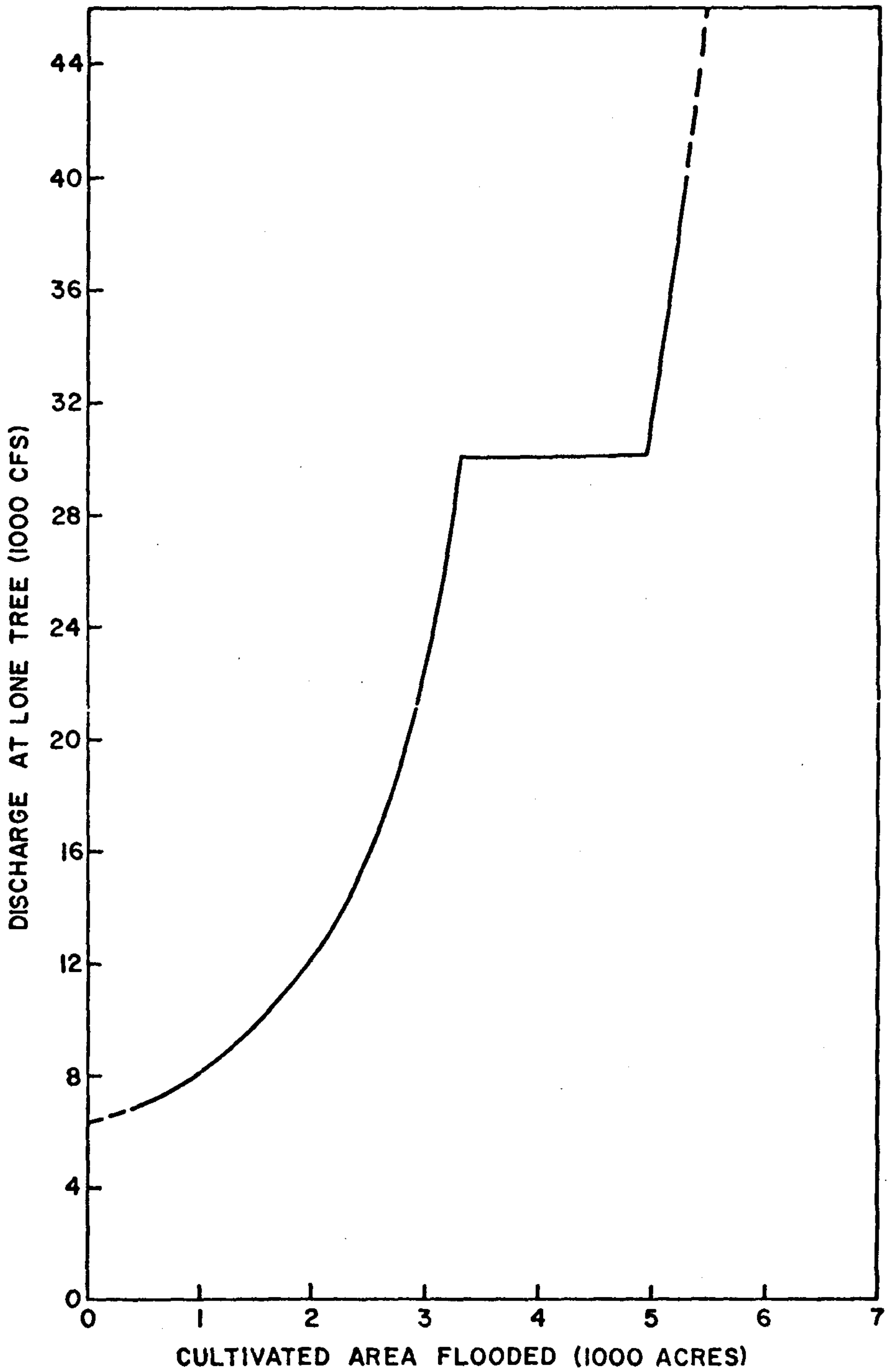


Figure 11. Discharge-Cultivated Area Flooded Cruve for Reach 2A

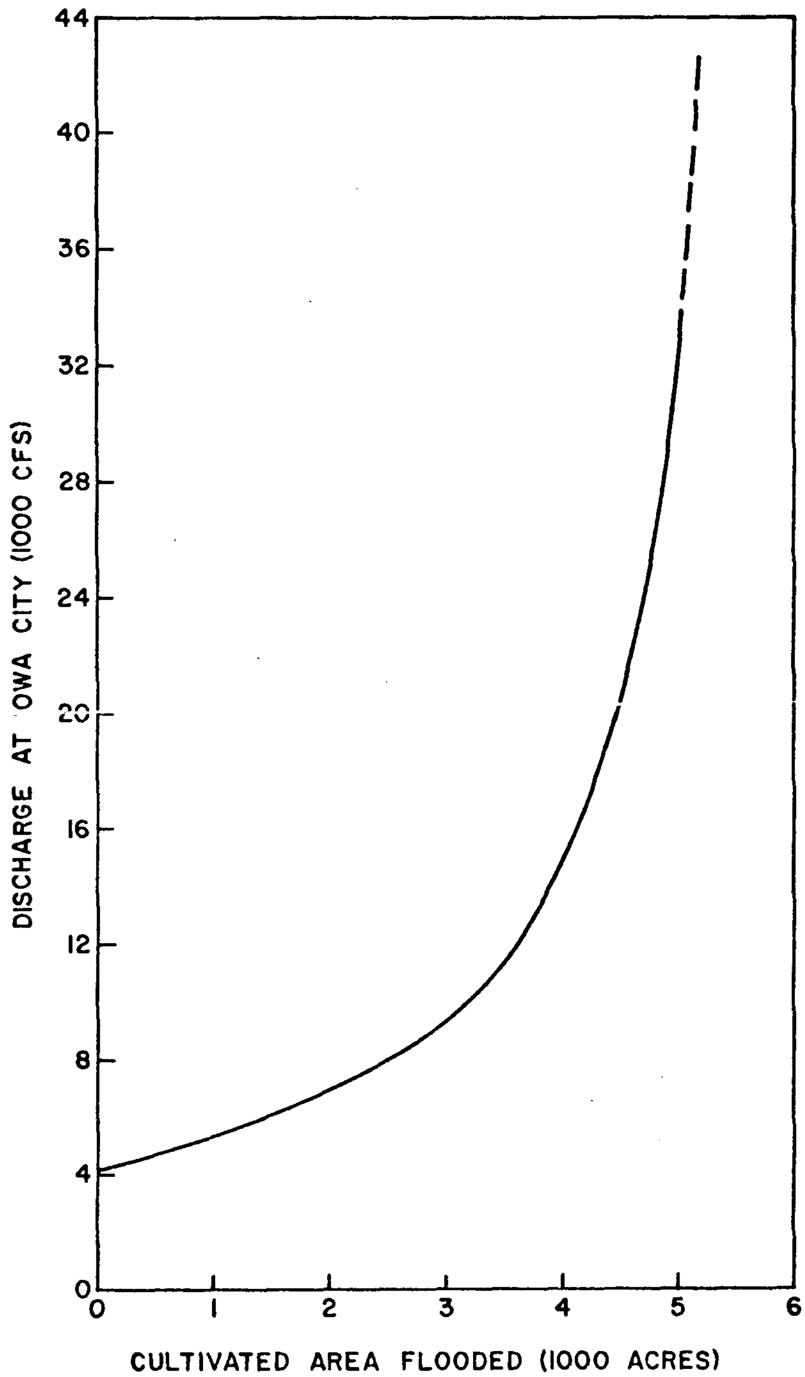


Figure 12. Discharge-Cultivated Area Flooded Curve for Reach 2B

total areas for each reach are taken from 1973 data, so that figures 7, 11, and 12 reflect 1973 conditions. It can be seen from figures 7 and 11 that there are jumps in the discharge-area flooded curves at certain discharges. This is due to the presence of levees in some portions of Reaches 1 and 2A.

For any particular discharge in each reach, crop damages at any time of the year can be estimated by multiplying the corresponding cultivated area flooded obtained from figures 7, 11,or 12 with the corresponding K values from table 8.

2. Property damages. Unlike crop damages, property damages caused by floods do not depend upon the time of year for all practical purposes. This fact enables the use of historical stage-property damage curves directly. Stage-property damage curves given in figures 5 and 6 are used for estimating property damages in Reaches 2A and 2B, respectively. These curves were prepared by the Army Corps of Engineers based on 1959, 1960, and earlier floods, and were updated by 75% (x 1.75) to account for additional construction in the floodplain since 1960. This figure was estimated by comparing earlier damage values with those for 1969 and 1973 floods. These updated stage-property damage curves were combined with stage-discharge curves to obtain discharge-property damage curves, as shown in figures 13 and 14. For Reach 1, the discharge-property damage curve (figure 8) was obtained from data supplied by the Army Corps of Engineers, Rock Island District. Updating property damages for Reach 1 was not attempted since relevant data was not available. Property damages for any discharge in any reach can be read directly from these curves.

3. Total flood damages. The objective is to estimate total flood damages in all reaches downstream of the dam corresponding to different discharges at Iowa City. Iowa City was selected as the reference gaging station since it is the nearest downstream station from the Coralville dam (within 5 miles). Inflows into the Iowa river between the dam and Iowa City are negligible; releases from the Coralville reservoir can be approximated then by discharges at Iowa City. To obtain total flood damages corresponding to different peak discharges at Iowa City, it is necessary to consider two questions. (1) What are the peak discharges at Lone Tree (Reach 2A) and at Wapello (Reach 1)

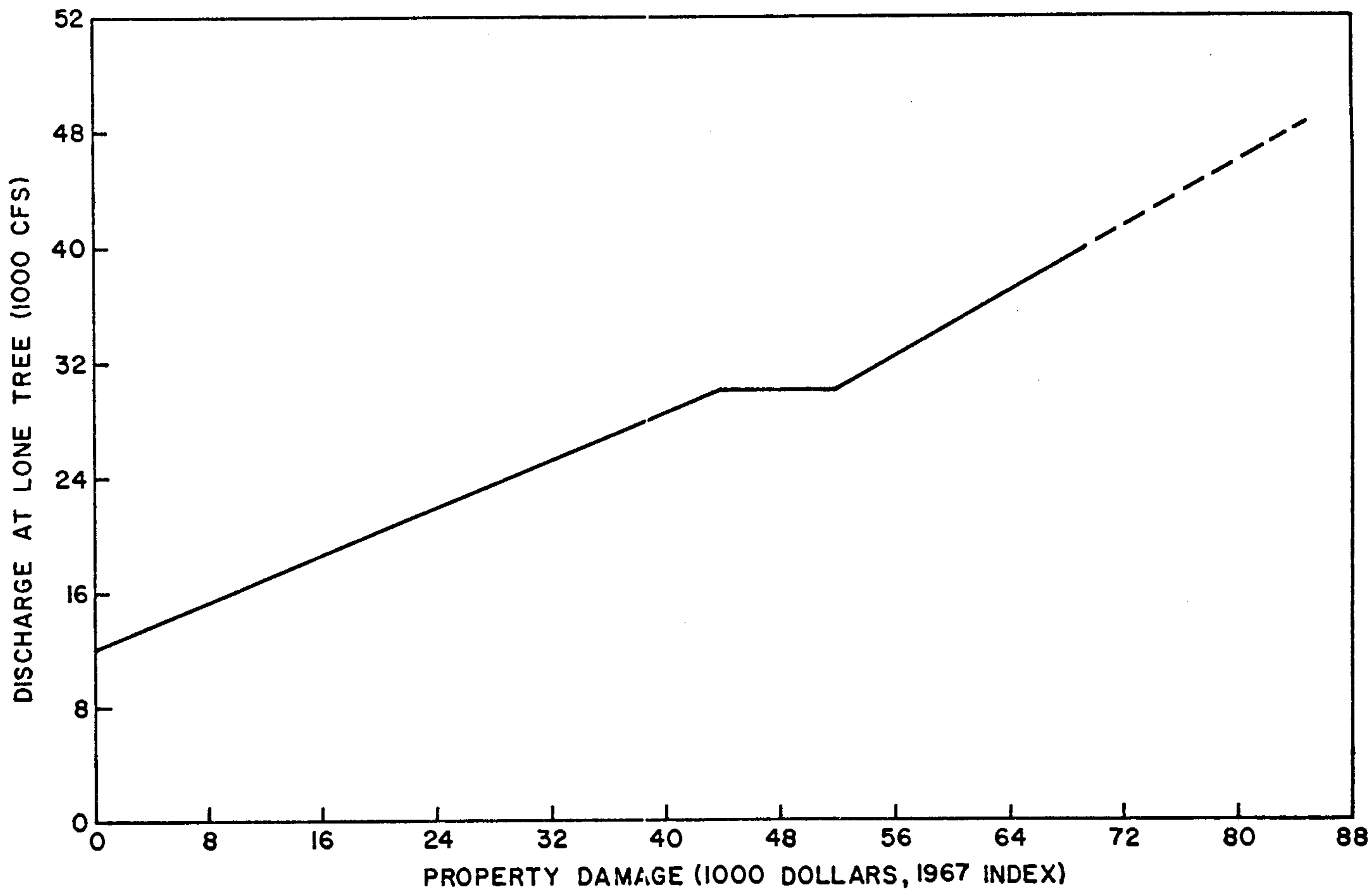


Figure 13. Discharge-Property Damage Curve for Reach 2A

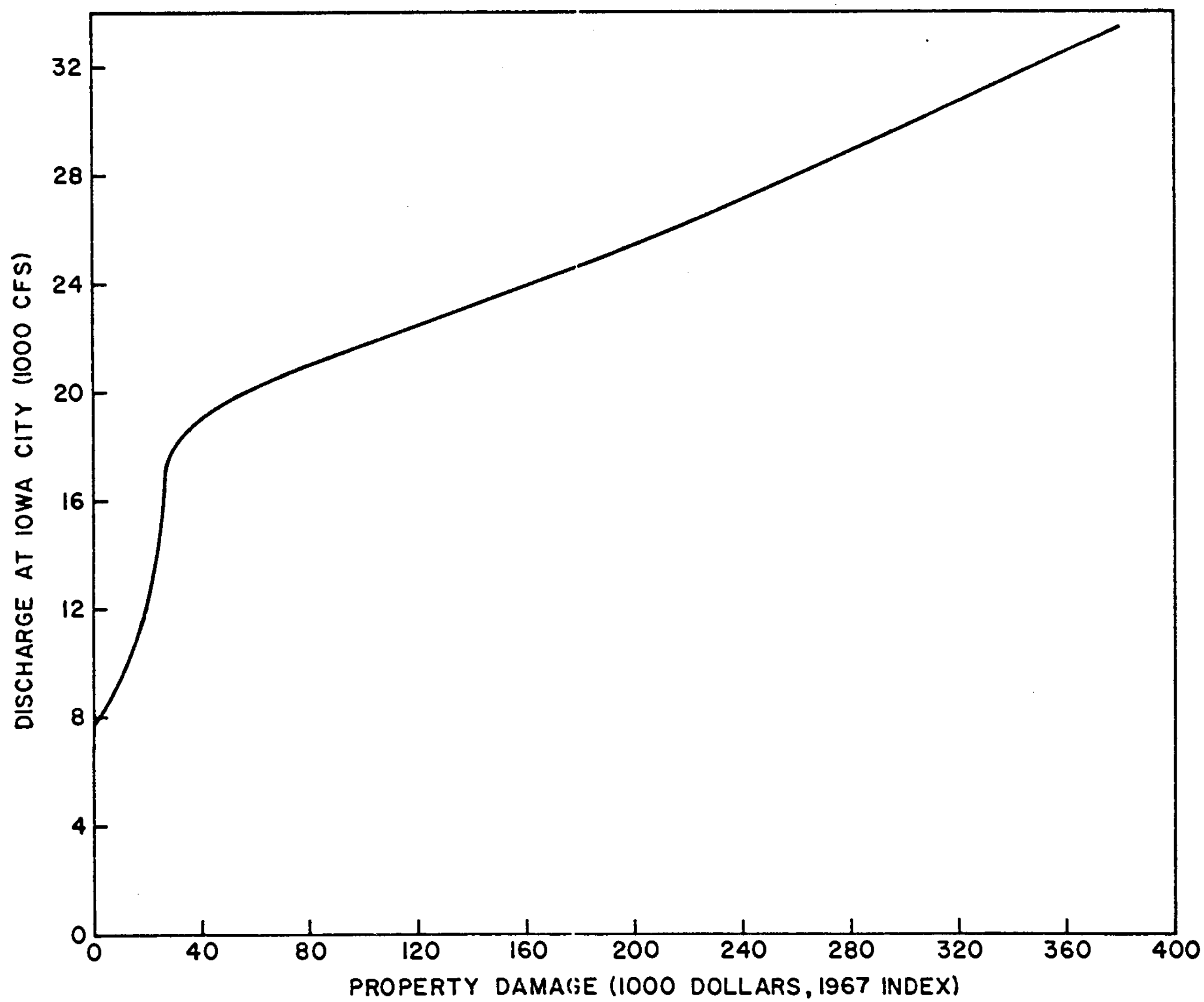


Figure 14. Discharge-Property Damage Curve for Reach 2B

corresponding to a given peak discharge at Iowa City (Reach 2B)? (2) What proportion of the damages in the downstream reaches can be attributed to the Iowa river flow as controlled by the Coralville reservoir? Both these questions were resolved with approximation methods, since more elaborate and complicated methods were not considered justified with regard to the adequacy of the existing data.

The relation between peak discharges at Iowa City, Lone Tree, and Wapello were obtained by a simple graphical method. The observed annual peak discharges at these three stations (given in table 10 of the Appendix) for the period 1958-1974 were used. It is intended herein to estimate flood damages caused by the Iowa river flow (modified by Coralville reservoir operation) as it exists now and so the pre-1958 flow record, when the Coralville dam did not exist, is excluded from considerations. Homogeneity of data reflecting present conditions is then preserved. As there are considerable inflows into Reaches 2A and 1 and since the peaks are often for different floods, the plots of peak discharge of one station against that of another showed considerable scatter. It was found that a log-log plot (i.e. a power relation) gave the best fit to the mean line. Annual peak discharges at Iowa City are plotted against those at Lone Tree in figure 15. Annual peak discharges at Lone Tree are plotted against those at Wapello in figure 16. The average relative error for both of these plots was about 24% (see tables 11 and 12 in the Appendix) which is considerable. Particularly, error for Reach 1 (Wapello) is large. Fortunately, the weight given to Reach 1 is small as will be seen shortly. Approximate estimates of annual peak discharges at Lone Tree and Wapello, corresponding to a given annual peak discharge at Iowa City, can be made from figures 15 and 16. Although this "routing" is entirely inadequate for practical purposes, it aids in the apportionment of damages on the river to river flows at the Coralville dam, in the absence of better data. It is used in this accounting procedure only.

Several tributaries join the Iowa river downstream of the dam and their flows are partially responsible for the flood damages caused in the downstream reaches. So, the contribution of the river flow at the dam to the damages downstream diminishes. Damages in each reach are arbitrarily apportioned herein to contributing flows in proportion to the peak values of the contributing flows. The proportion (or weight) for each reach is computed

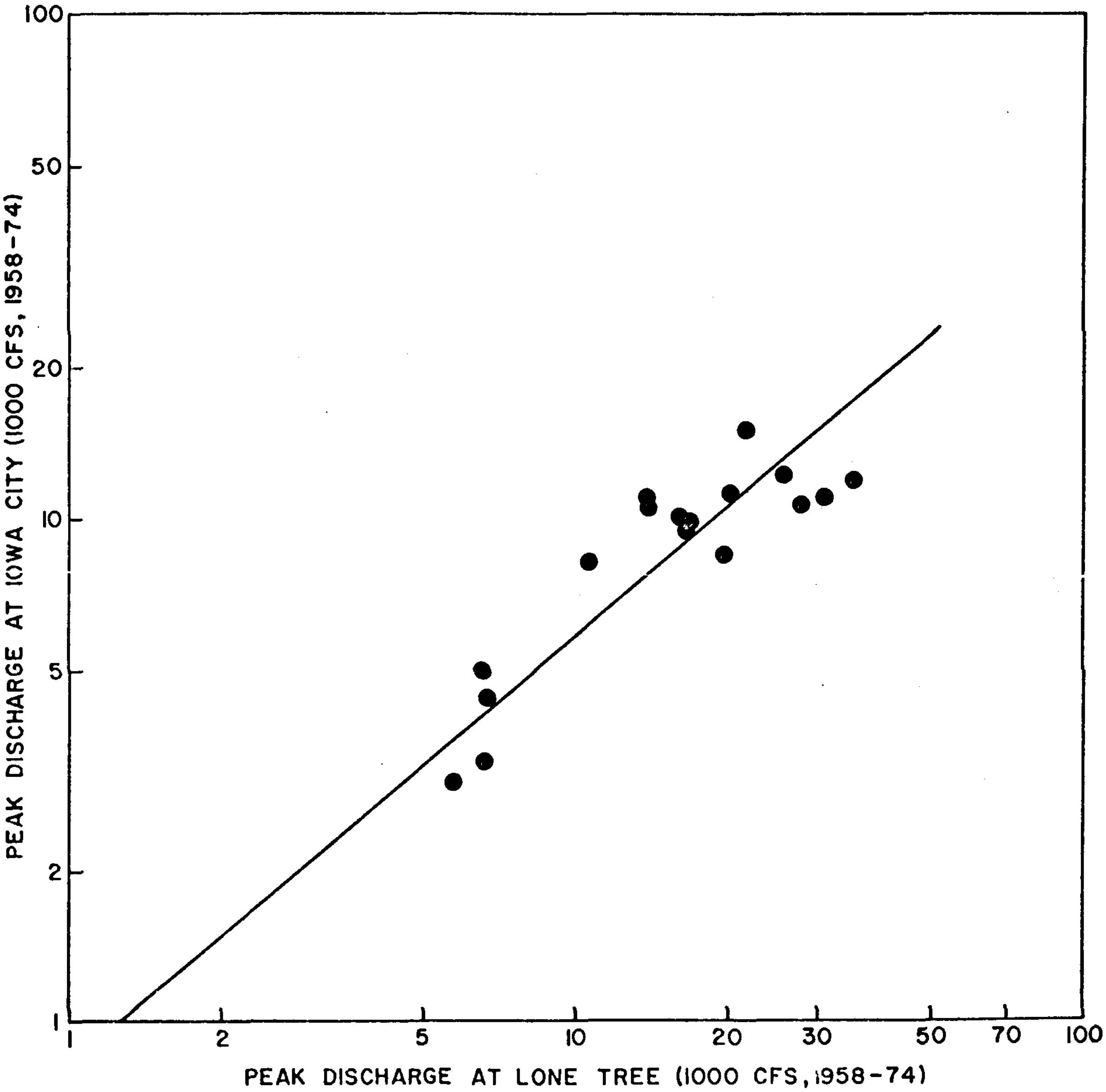


Figure 15. Peak Discharge at Iowa City Vs. Peak Discharge at Lone Tree

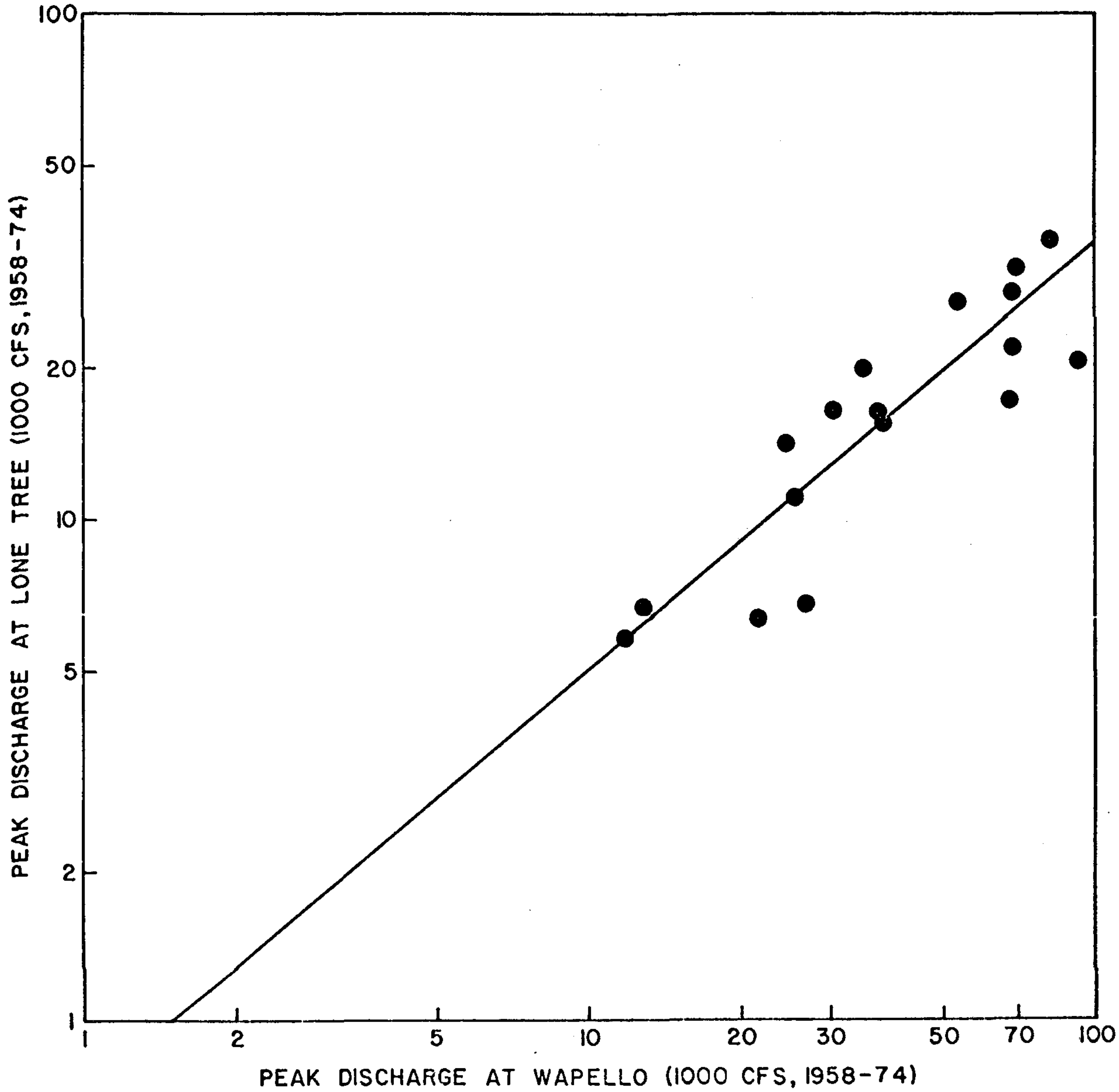


Figure 16. Peak Discharge at Lone Tree Vs. Peak Discharge at Wapello

by averaging the ratios for each year of the peak flows of the Iowa river just before it enters the reach and the sum of this flow and the peak flow of tributaries joining the reach. This method assumes that peak flows in the Iowa river and the tributaries are synchronized (which is not true most of the times). Also, it can be seen from figure 3 that the gaging stations are not located exactly at the starting point of each reach. This method also assumes that inflows from the intervening areas between the gaging stations on the Iowa river or the tributaries and the starting point of a reach are negligible. Although these assumptions will introduce some errors, this method is justified by the inadequacy of available data and is only used herein as an accounting procedure to relate downstream damages to river flows at the Coralville dam.

Two small creeks, Rapid creek and Clear creek, join the Iowa river in Reach 2B. Their discharges are small compared to Iowa river discharges at Iowa City. The weight for Reach 2B, relating damages in Reach 2B to flows at Iowa City, is, therefore, considered as unity. The inflows to Reaches 2A and 1 are considerable, however. The English river joins the Iowa river in Reach 2A and the Cedar river enters in Reach 1. The drainage areas and selected discharges of the English river, the Cedar river, and the Iowa river at different stations are given in table 13 of the Appendix. Inspection of table 13 reveals that these tributary flows are sizeable compared to the Iowa river flows prior to the junctions. The weight for Reach 2A is computed from peak discharges at Iowa City and at Kalona. The relative proportion of damages in Reach 1 to Iowa river flows entering it are calculated from peak discharges at Lone Tree and at Conesville. Since the flows in Reach 2A contain contributions from the English river, this relative proportion is further multiplied by that for Reach 2A to relate damages on Reach 1 to discharges at Iowa City. Computations for weights for Reaches 2A and 1 are included in table 14 of the Appendix. The weights for Reaches 2A and 1 are found to be 0.54 and 0.19 respectively.

Total flood damages downstream of the Coralville reservoir for different discharges at Iowa City now can be computed. Computations start with 4000 cfs, since damages below this discharge are zero. All dollar values were reduced to the 1967 index value using index prices (Economic Report Of The President Transmitted To The Congress, January, 1974) for crop and property damages separately. The procedure used to compute total flood damages is summarized as follows.

1) For a given flood discharge at Iowa City, the corresponding discharges at Lone Tree and Wapello are determined from figures 15 and 16.

2) The corresponding cultivated areas flooded for each reach are read from figures 7, 11, and 12.

3) For a particular period of the year, the values obtained in step 2 are multiplied by the corresponding unit crop damage (K) value from table 8 to get crop damages for each reach.

4) These values are then weighted and added to get the total weighted crop damages (for all reaches).

5) The property damages corresponding to the discharges of step 1 are obtained from figures 8, 13, and 14 for each reach.

6) These values are weighted and added to get the total weighted property damages (for all reaches).

7) The total weighted crop damages of step 4 are added to the total weighted property damages of step 6 to get the total flood damages.

This procedure is repeated for each discharge at Iowa City and for each time period. Computations of total flood damages for all periods are included in tables 15a through 15f of the Appendix. Total flood damages at different times of the year are summarized in table 16 of the Appendix and are plotted against discharge at Iowa City in figure 17.

VII. FLOOD DAMAGES UPSTREAM OF THE CORALVILLE DAM

In the preceding sections, flood damages on the Iowa river downstream of the Coralville dam and up to its outfall on the Mississippi river were considered. As a result of impounding large volumes of water in the reservoir behind the dam since the operation of the reservoir began in 1958, large areas of farmlands upstream of the dam became subject to damage throughout the year. The extent of area inundated varies with the time of the year, as different pool levels are maintained in the reservoir in different seasons under the current operation plan. Thus, while impoundment of water in the reservoir has considerably reduced flood damages in areas downstream of the dam, flood damages in the upstream areas have increased at the same time. Increased upstream damages were considered at the time of project preparation and compensations or "easement" payments were paid by the Federal Government to the owners of all lands which are subject to increased damages. These

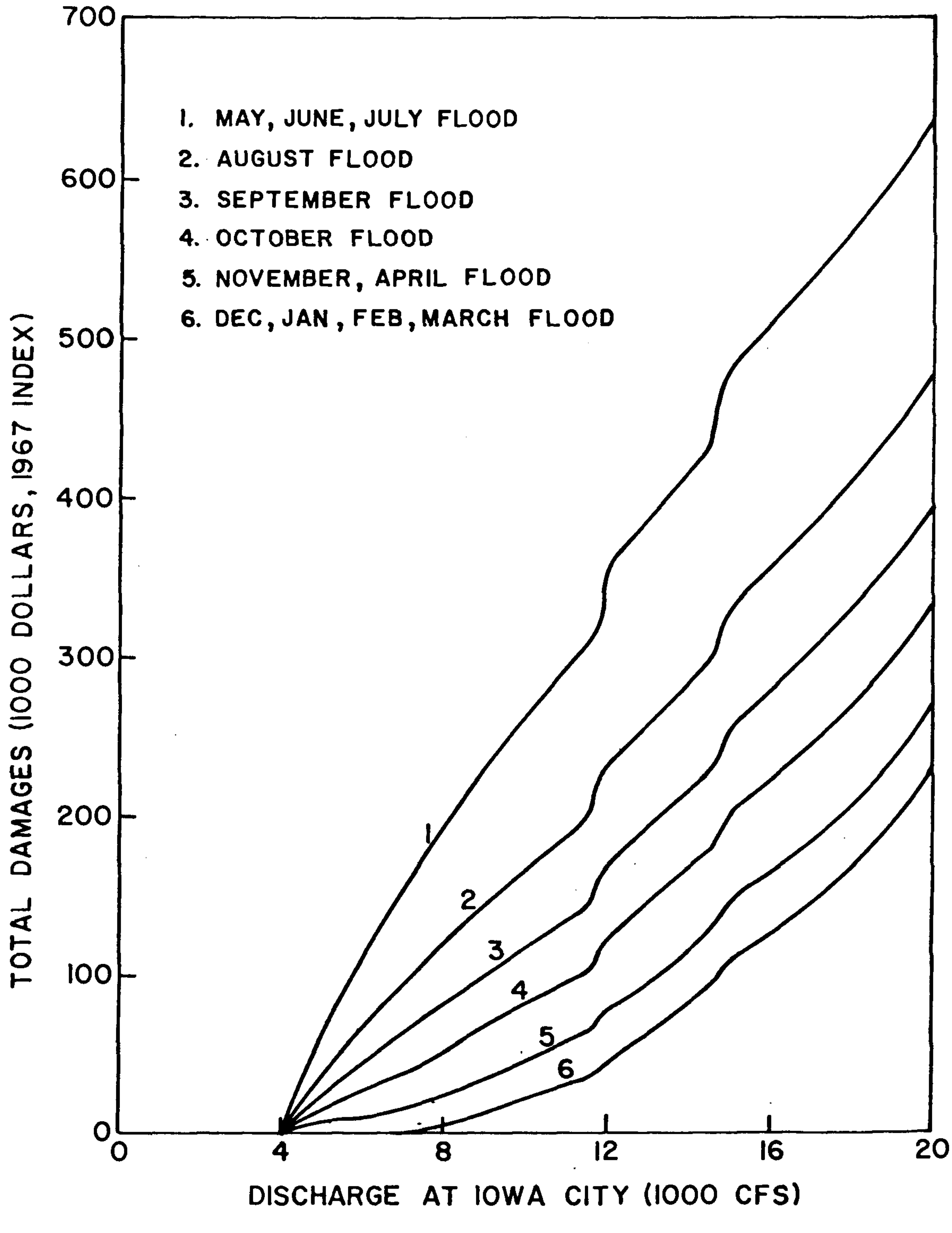


Figure 17. Total Flood Damages Downstream of Coralville Dam Vs. Discharge at Iowa City

"easement" areas are owned by the Federal Government and so damages related to the operation of the reservoir are not considered "effective" damages. Consequently, very little effort has been made to estimate flood damages in areas upstream of the dam. The only data available for upstream damage estimation is for the 1969 flood. As upstream flood damages are not of primary interest in the present context, rough estimates of damages as a function of reservoir pool elevation based on the 1969 flood data are presented herein to give an idea of the order of magnitude of upstream flood damages.

In the absence of other data, damages estimated are based on the "easement" area magnitudes which may be considered as a measure of the flood-affected area. Based upon data obtained from the Army Corps of Engineers, Rock Island District, the "easement" area vs. reservoir pool elevation is plotted in figure 18. From peak reservoir elevation data and estimated damages for 1969, and by assuming a linear variation between damage and "easement" area, the damage vs. reservoir pool elevation relationship is obtained from figure 18 and is plotted as figure 19.

VIII. SUMMARY AND CONCLUSIONS

A potential conflict exists between the flood control use and the recreation use of the Coralville reservoir on the Iowa river. The aim of this report is to estimate the flood damages associated with the different discharges of the Iowa river at the dam. These flood damage values are to be used in a separate trade-off study for evolving operation plans for flood control and recreation purposes.

Recognizing the limitations imposed by the inadequacy of the available data, a simple physical model has been developed herein to estimate flood damages. Total flood damages on the Iowa river downstream of the Coralville dam have been divided into two categories - crop damages and property damages. Crop damages are heavily dependent upon the time of occurrence of the flood while property damages can be considered as independent of the time of the year for all practical purposes. Because of the time-independence characteristics, property damages are estimated by using historical stage-damage relations directly. The crop damages, for which the time of occurrence

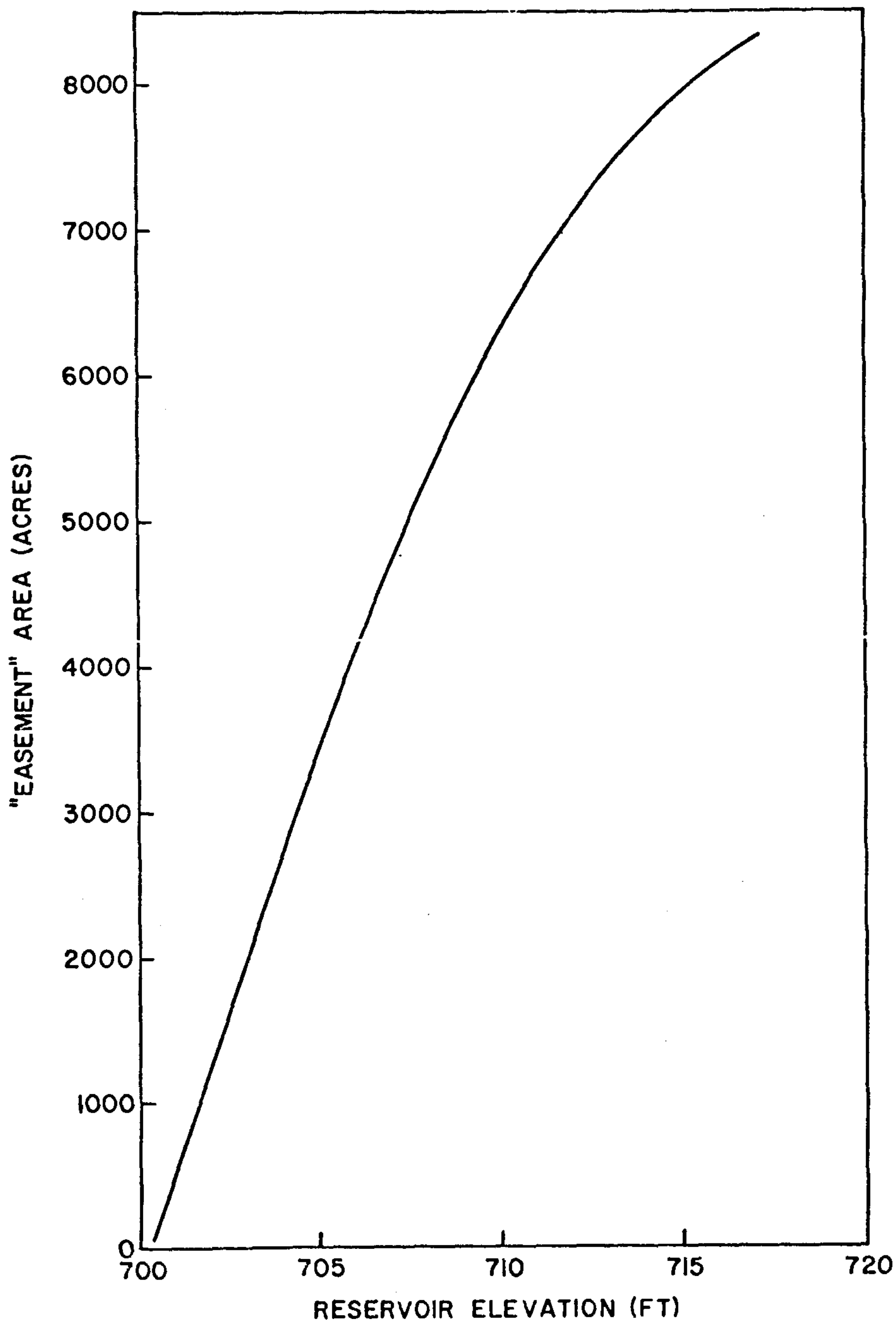


Figure 18. "Easement Area" Vs. Reservoir Pool Elevation

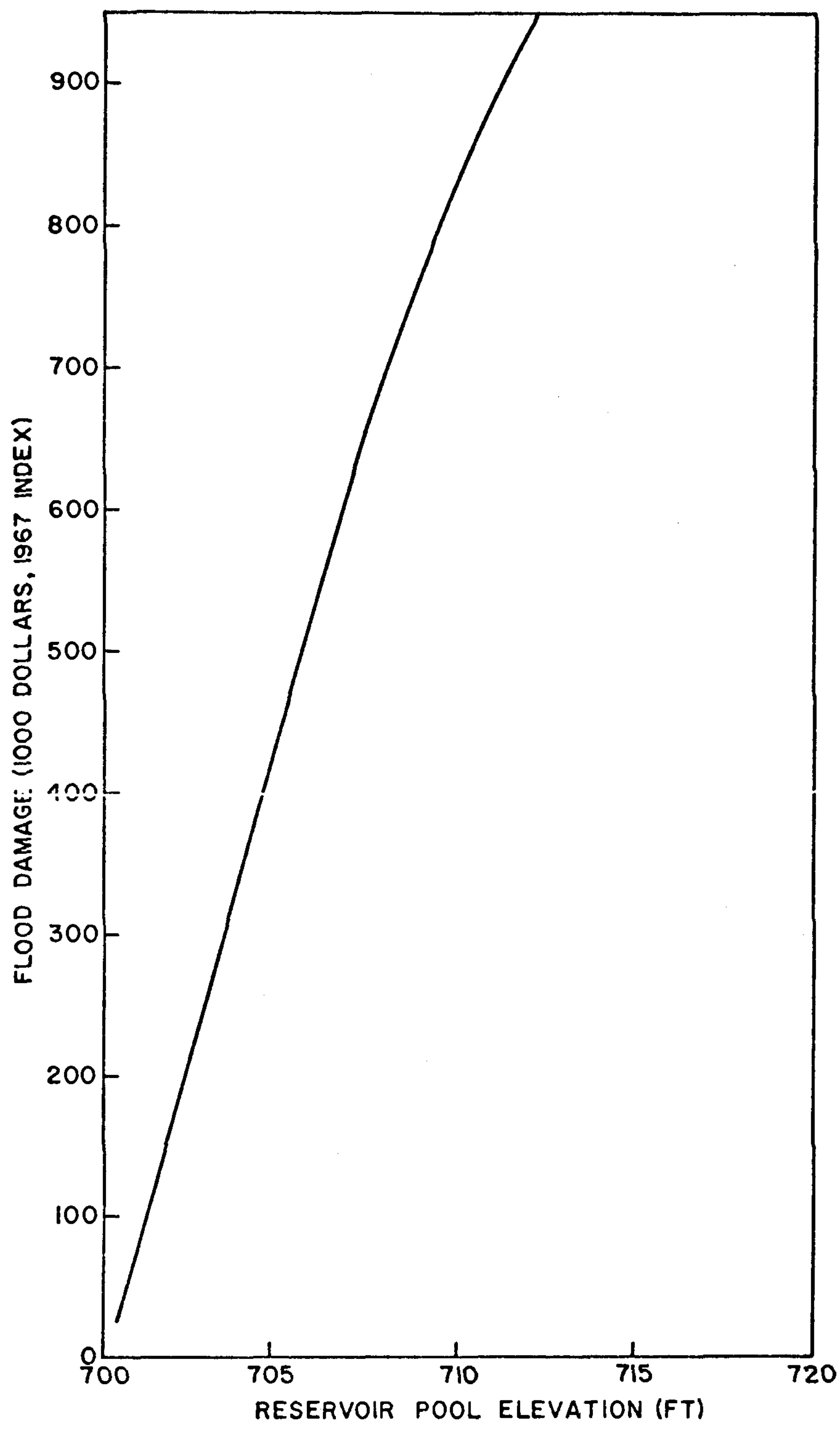


Figure 19. Upstream Flood Damage vs. Reservoir Pool Elevation

of flood is of primary importance in determining the extent of damages, are estimated in a different manner. The method consists essentially of calculating crop damages by multiplying cultivated area flooded by a unit crop damage value, K ($/cultivated acre). The factor K may be considered in general as a function of depth, duration, time of the year, etc., but estimations can consider only those present in available data. Thus, this method can be applied to areas with little data as well as areas with much data. In the present study, only the variation of K with the time of the year has been considered; other factors influencing K are ignored since inadequate data exists.

Certain assumptions and interpretations have been made which restrict the applicability of the results. The unit crop damage factors (K) are estimated from only 2 years of flood damage data, as surveyed by the Army Corps of Engineers, and from data available for other areas of the United States. Although these data were for corn, they were assumed applicable to areas downstream of the dam. Since several tributaries join the Iowa river downstream of the dam, the contribution of the Iowa river flow (at the dam) to downstream damages diminishes. Damages in each reach are apportioned to contributing flows in proportion to the peak values of the contributing flows. Although this method ignores flood peak timings of the Iowa river and the tributaries and the component hydrograph characteristics, more complex methods were not justified because of the inadequacy of available data. The duration of flooding, which is an important characteristic in determining damages, could not be accounted for due to the inadequate data. Under these circumstances, the Iowa river flood damage estimates, as presented herein, should be regarded as indicative values, rather than definitive values. However, the flood damage values presented herein may be considered sufficient for preliminary planning requirements.

Flood damages on the Iowa river upstream of the Coralville dam are not considered effective damages by the managing agency of the reservoir since all adjoining lands subject to damage are owned by the Federal Government. However, a rough estimate of the upstream flood damage is also included herein separately.

IX. REFERENCES

1. BEER, CRAIG E. 1968. Evaluation of flood damage to corn from controlled depth and frequency of flooding. Iowa State Water Resources Research Institute.

2. BREADEN, JOHN P. 1973. The generation of flood damage time sequences. University of Kentucky Water Resources Institute, Lexington, Kentucky, Research Report No. 32.

3. CLINE, JAMES N. 1968. Planning flood control measures by digital computer. University of Kentucky Water Resources Institute, Lexington, Kentucky, Research Report No. 11.

4. CROLEY, THOMAS E. II & RAO, K.N.R. 1976. Multipurpose reservoir operation using stochastic trade-off analysis. Second International IAHR Symposium on Stochastic Hydraulics, University of Lund, Lund, Sweden.

5. Economic Report of the President Transmitted to the Congress. January, 1974.

6. GRIGG, NEIL S. & HELWEG, OTTO J. 1975. State-of-the-art of estimating flood damage in urban areas. Water Resources Bulletin, American Water Resources Association, Vol. 11, No. 2, 379-390.

7. IOWA Department of Agriculture, 1973. Iowa Annual Farm Census, 1973 (Preliminary). Division of Agricultural Statistics, USDA Statistical Reporting Services, Des Moines, Iowa.

8. JAMES, L.D. 1964. A time-dependent planning process for combining structural measures, land use and flood proofing to minimize the economic cost of floods. Stanford University, Project on Engineering-Economic Planning, Report EEP-12.

9. JAMES, L.D. 1972. Role of economics in planning floodplain land use. Journal of the Hydraulics Division 98: HY6, 981-992.

10. JOHNSON, GEORGE E. 1970. A review of reservoir regulation: Coralville reservoir. M.S. thesis, Iowa State University, Ames, Iowa.

11. KATES, R.W. 1965. Industrial flood losses: damage estimation in the Lehigh Valley. University of Chicago, Res. Paper No. 98, Univ. of Chicago Press.

12. U.S. ARMY CORPS OF ENGINEERS. 1974. Water Spectrum, Vol. 6, No. 3.

X. APPENDIX

Tables 1 through 16

Table 1

Flood Damages Prevented by Coralville Reservoir since 1959

Year	Damages Prevented ($)
1959	24,500
1960	3,448,400
1961	150,000
1962	225,000
1963	72,800
1964	91,300
1965	1,490,000
1966	850,000
1967	--
1968	--
1969 (April)	264,900
1969 (July)	1,404,000
Total	8,020,900

Source: Johnson, George E. A Review of Reservoir Regulation: Coralville Reservoir. Iowa State University, Ames, 1970.

Table 2

Iowa River Floods of 1969 and 1973

	Reach 1 (Mouth to Cedar River)		Reach 2A (Cedar River to Highway 22)		Reach 2B (Highway 22 to dam)	
	1969	1973	1969	1973	1969	1973
1. Gage station representing the reach	Wapello		Lone Tree		Iowa City	
2. Peak gage height	17.40	18.63	16.92	16.62	13.93	12.04
3. Peak discharge (cfs)	69,200	92,000	21,700	20,300	15,000	11,300
4. Cultivated area flooded (acres)	-	9,845	1,872	2,883	3,305	3,317
5. Estimated damage (1967 $)						
Crop damage	303,000	344,800	87,100	116,600	171,400	165,500
Property damage	34,200	129,500	13,100	21,800	19,500	18,000
6. Unit crop damage (1967 $) per cultivated acre	-	35.02	46.52	40.44	51.86	49.89

Source: U.S. Army Corps of Engineers, Rock Island District.

Table 3.

Flood Water Damage Factors For Corn As a Percentage of Flood-Free Gross Return

Yield: 75 bushels/acre Source: USDA
Location: Southern portion of Northeast United States

		Growing season for corn							
Depth	Duration	April	May	June	July	Aug.	Sept.	Oct.	Nov.
<2'	<24 hr.	1	8	29	21	8	3	2	1
>2'	<24 hr.	1	10	42	54	25	17	14	3
<2'	>24 hr.	2	11	40	29	15	7	4	1
>2'	>24 hr.	2	13	51	64	35	26	20	4

Source: Breaden, John P. The Generation of Flood Damage Time Sequences, Research Report No. 32, University of Kentucky, Water Resources Research Institute, Lexington, Kentucky, 1973.

Table 4

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>									
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

Source: Cline, James Norris. Planning Flood Control Measure by Digital Computer, Research Report No. 11, University of Kentucky Water Resources Institute, Lexington, Kentucky, 1968.

Table 5

Average Yields of 1966 Corn-Flooding Experiment

Period of Flooding	Duration of Flooding (hours)	Nitrogen Level	Average Yield Bu./acre
6-inch height (Approx. end of May to early June)	72	High	102.6
	72	Low	81.2
	48	High	105.5
	48	Low	93.0
	24	High	107.8
	24	Low	98.4
30-inch height (Approx. middle to end of June)	72	High	127.6
	72	Low	101.4
	48	High	116.3
	48	Low	99.7
	24	High	126.4
	24	Low	103.7
Silking (Approx. end of July to middle of August)	72	High	137.5
	72	Low	118.5
	48	High	127.1
	48	Low	122.8
	24	High	139.7
	24	Low	117.5
No Flooding		High	125.9
		Low	120.0

Source: Beer, Craig E. Evaluation of Flood Damge to Corn From Controlled Depth and Frequency of Flooding, Iowa State Water Resources Research Institute, August, 1968.

Table 6

Average Yields of 1967 Corn-Flooding Experiment

Period of Flooding	Duration of Flooding (hours)	Nitrogen Level	Average Yield Bu./acre
6-inch height	96	High	140.2
	96	Low	98.6
	72	High	149.1
	72	Low	93.9
	48	High	149.7
	48	Low	98.7
30-inch height	96	High	140.8
	96	Low	98.4
	72	High	142.2
	72	Low	104.2
	48	High	151.4
	48	Low	110.3
Silking	96	High	147.3
	96	Low	118.2
	72	High	157.0
	72	Low	118.3
	48	High	157.3
	48	Low	122.8
No Flooding		High	148.9
		Low	141.0

Source: Beer, Craig E. Evaluation of Flood Damage to Corn from Controlled Depth and Frequency of Flooding, Iowa State Water Resources Research Institute, August, 1968.

Table 7

Average Yields of 1968 Corn-Flooding Experiment

Period of Flooding	Duration of Flooding (hours)	Nitrogen Level	Average Yield Bu./acre
6-inch height	96	High	144.2
	96	Low	92.4
	72	High	143.6
	48	High	151.4
	48	Low	93.3
30-inch height	96	High	148.7
	96	Low	102.2
	72	High	145.8
	72	Low	105.4
	48	High	148.6
	48	Low	122.4
Silking	96	High	161.4
	96	Low	125.9
	72	High	155.8
	72	Low	125.0
	48	High	124.9
	48	Low	120.1
No Flooding		High	135.2
		Low	130.6

Source: Beer, Craig E. Evaluation of Flood Damage to Corn from Controlled Depth and Frequency of Flooding, Iowa State Water Resources Research Institute, August, 1968.

Table 8

Estimated Unit Crop Damage Factor (K) in Dollars (1967 Index)
Per Cultivated Acre

	Reach 1	Reach 2A	Reach 2B	Normalized values w.r.t. May
May	35.00	40.00	50.00	1.00
June	35.00	40.00	50.00	1.00
July	35.00	40.00	50.00	1.00
August	21.00	24.00	30.00	0.60
September	14.00	16.00	20.00	0.40
October	8.75	10.00	12.50	0.25
November	3.50	4.00	5.00	0.10
December	0	0	0	0
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	3.50	4.00	5.00	0.10

Table 9

Acreage of Crops in Iowa River Basin Downstream
of the Coralville Dam

Crop \ County	Cedar	Johnson	Muscatine	Louisa	Washington	Total
Field Corn	131,722	108,594	87,902	77,876	117,278	523,372
Oat	19,478	17,436	9,469	4,369	10,885	61,637
Soybean	81,687	64,235	55,097	56,082	79,060	336,161
Sorghum	180	83	120	17	254	654
Wheat	-	71	949	797	401	2,218
Rye	20	23	677	339	15	1,074
Timothy Seed	43	39	4	10	4	100
Red Clover	-	14	30	-	148	192
White Corn	190	140	300	50	628	1,308
Popcorn	-	707	7	3	-	717
Hay	24,517	28,167	15,137	8,505	25,765	102,091
Other Crops	201	230	2,064	494	362	3,351
Total	258,038	219,739	171,756	148,542	234,800	1,032,875
% Corn	51.12	49.80	51.35	52.46	50.21	50.86

Source: Iowa Annual Farm Census, 1973 (Preliminary), Iowa Department of Agriculture, Division of Agricultural Statistics, USDA Statistical Reporting Service, Des Moines, Iowa.

Table 10

Observed Peak Discharges at Iowa City, Lone Tree & Wapello (1958-74)

	Iowa City		Lone Tree		Wapello	
Year	Peak discharge (cfs)	Date	Peak discharge (cfs)	Date	Peak discharge (cfs)	Date
1958	5,000	Sept. 7, 1958	6,610	Sept. 7, 1958	13,000	Feb. 27, 1958
1959	9,380	Apr. 14, 1959	16,600	Mar. 21, 1959	37,200	Mar. 22, 1959
1960	10,700	Apr. 16, 1960	28,100	Apr. 1, 1960	69,000	Apr. 5, 1960
1961	9,940	Mar. 13, 1961	17,000	Mar. 15, 1961	68,000	Apr. 3, 1961
1962	12,300	July 14, 1962	26,600	Mar. 21, 1962	53,700	Apr. 6, 1962
1963	8,220	Mar. 20, 1963	10,700	Mar. 20, 1963	25,100	Mar. 21, 1963
1964	3,000	June 27, 1964	5,770	June 24, 1964	11,800	June 25, 1964
1965	11,100	Apr. 24, 1965	31,200	Sept. 22, 1965	70,800	Apr. 13, 1965
1966	10,100	Feb. 10, 1966	16,200	Feb. 11, 1966	30,300	May 25, 1966
1967	4,420	June 7, 1967	6,760	June 11, 1967	26,700	June 9, 1967
1968	3,310	Nov. 2, 1967	6,300	Nov. 3, 1967	21,500	Aug. 10, 1968
1969	15,000	July 27, 1969	21,700	July 20, 1969	69,200	July 15, 1969
1970	8,540	Mar. 10, 1970	19,900	Mar. 5, 1970	34,600	Mar. 6, 1970
1971	11,100	Feb. 26, 1971	15,400	Feb. 27, 1971	38,000	Feb. 28, 1971
1972	10,600	July 17, 1972	14,000	Aug. 7, 1972	24,500	Aug. 8, 1972
1973	11,300	May 1, 1973	20,300	Apr. 22, 1973	92,000	Apr. 22, 1973
1974	11,900	June 9, 1974	35,700	May 19, 1974	82,200	May 19, 1974

Source: Iowa City office of the USGS.

Table 11

Computation of Average Relative Error for Peak Discharge Relation: Iowa City vs. Lone Tree

Year	Q_I (cfs)	Q_L (cfs)	Q'_L (cfs)	$\|Q_L - Q'_L\|$ (cfs)	Error % $\frac{\|Q_L - Q'_L\|}{Q_L} \times 100$
1958	5,000	6,610	8,300	1690	25.56
1959	9,380	16,600	17,500	900	5.42
1960	10,700	28,100	20,500	7600	27.04
1961	9,940	17,000	18,750	1750	10.29
1962	12,300	26,600	24,000	2660	10.00
1963	8,220	10,700	15,000	4300	40.18
1964	3,000	5,770	4,600	1170	20.27
1965	11,100	31,200	21,400	9800	31.41
1966	10,100	16,200	19,000	2800	17.28
1967	4,420	6,760	7,200	440	6.51
1968	3,310	6,300	5,100	1200	19.04
1969	15,000	21,700	30,500	8800	40.55
1970	8,540	19,900	15,750	4150	20.85
1971	11,100	15,400	21,400	6000	38.96
1972	10,600	14,000	20,500	6500	46.42
1973	11,300	20,300	22,000	1700	8.37
1974	11,900	35,700	23,500	12,200	34.17
Total					402.37

Average relative error $= \frac{402.37}{17} = 23.67\%$

Q_I = observed discharge at Iowa City

Q_L = observed discharge at Lone Tree

Q'_L = computed discharge at Lone Tree

Table 12

Computation of Average Relative Error for
Peak Discharge Relation: Lone Tree vs. Wapello

Year	Q_L (cfs)	Q_W (cfs)	Q'_W (cfs)	$\lvert Q_W - Q'_W \rvert$ (cfs)	Error % $\frac{\lvert Q_W - Q'_W \rvert}{Q_W} \times 100$
1958	6,610	13,000	13,800	800	6.15
1959	16,600	37,200	41,000	3,800	10.21
1960	28,100	69,000	76,500	7,500	10.87
1961	17,000	68,000	41,000	27,000	39.70
1962	26,600	53,700	72,000	18,300	34.07
1963	10,700	25,100	24,500	600	2.39
1964	5,770	11,800	11,800	0	0
1965	31,200	70,800	87,000	16,200	22.88
1966	16,200	30,300	40,000	9,700	32.01
1967	6,760	26,700	14,200	12,500	46.81
1968	6,300	21,500	13,000	8,500	39.53
1969	21,700	69,200	56,500	12,700	18.35
1970	19,900	34,600	51,000	16,400	47.39
1971	15,400	38,000	38,000	0	0
1972	14,000	24,500	33,500	9,000	36.73
1973	20,300	92,000	52,000	40,000	43.47
1974	35,700	82,200	100,000	17,800	21.65
Total					412.27

$$\text{Average relative error} = \frac{412.27}{17} = 24.25\%$$

Q_L = observed discharge at Lone Tree

Q_W = observed discharge at Wapello

Q'_W = computed discharge at Wapello

Table 13

Comparison of the Discharges of Iowa River, English River and Cedar River

	Iowa River at Iowa City	English River at Kalona	Iowa River at Lone Tree	Cedar River at Conesville	Iowa River at Wapello
1. Drainage area (sq. miles)	3,271	573	4,293	7,785	12,499
2. Average discharge					
cfs	1,638	372	2,842	4,444	6,673
acre-ft/year	1,187,000	269,500	2,059,000	3,220,000	4,835,000
in/year	6.80	8.52	8.99	7.75	7.25
3. Maximum discharge (cfs)					
Recorded maxm.	42,500 (1918)	20,000 (1965)	35,700 (1974)	70,800 (1961)	94,000 (1947)
1974 maxm.	11,900 (June 9)	18,400 (May 18)	35,700 (May 19)	43,500 (May 18)	82,200 (May 19)
Maximum for 1958-74	15,000 (1969)	20,000 (1965)	35,700 (1974)	70,800 (1961)	92,000 (1973)

Source: Water Resources Data for Iowa, 1974: USGS, Department of the Interior.

Table 14

Computation of Weights for Reaches 1 & 2A

Year	Peak Discharge at Iowa City Q_{IC} (cfs)	Peak Discharge at Kalona Q_K (cfs)	$W_{2A} = \frac{Q_{IC}}{Q_{IC}+Q_K}$	Peak Discharge at Lone Tree Q_{LT} (cfs)	Peak Discharge at Conesville Q_C (cfs)	$\frac{Q_{LT}}{Q_{LT}+Q_C} = W'_1$	$W_1 = W'_1 \times W_{2A}$
1958	5,000	2,200	0.694	6,610	7,800	0.458	0.317
1959	9,380	8,960	0.511	16,600	26,100	0.388	0.198
1960	10,700	18,500	0.366	28,100	58,800	0.323	0.118
1961	9,940	6,120	0.619	17,000	70,800	0.224	0.138
1962	12,300	13,200	0.482	26,000	47,700	0.358	0.172
1963	8,220	3,000	0.732	10,700	15,500	0.408	0.299
1964	3,000	3,030	0.497	5,770	6,440	0.472	0.235
1965	11,100	20,000	0.357	31,200	68,100	0.314	0.112
1966	10,100	7,820	0.563	16,200	27,000	0.375	0.211
1967	4,420	5,370	0.451	6,760	29,200	0.188	0.085
1968	3,310	1,590	0.675	6,300	21,000	0.231	0.156
1969	15,000	7,060	0.679	21,700	55,200	0.282	0.192
1970	8,540	13,200	0.393	19,900	20,200	0.496	0.195
1971	11,100	5,300	0.677	15,400	25,100	0.380	0.257
1972	10,600	6,790	0.609	14,000	20,400	0.407	0.248
1973	11,300	9,980	0.531	20,300	54,800	0.270	0.143
1974	11,900	18,400	0.392	35,700	43,500	0.450	0.176
Total			9.228				3.252
Average			0.54				0.19

Weight for Reach 2A = 0.54

Weight for Reach 1 = 0.19

Table 15a

Computation of Total Flood Damages for May-June-July Flood

Discharge at Iowa City	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2200	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage @ $35.0/acre (1000$)	-	-	-	-	-	-	28.0	56.0	77.0	96.25	105.0	115.5	122.50	127.75	131.25	133.7	323.75
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.00
Weighted crop damage (1000$)	-	-	-	-	-	-	5.32	10.64	14.63	18.28	19.95	21.94	23.27	24.27	24.93	25.40	61.51
Weighted property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage @ $40.0/acre (1000$)	-	30.00	44.0	56.0	66.0	70.0	82.0	88.0	94.0	98.0	103.0	106.4	110.8	114.0	117.2	120.0	122.8
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)	-	16.2	23.76	30.24	35.64	37.80	44.28	47.52	45.36	52.92	55.62	57.45	59.83	61.56	63.29	64.80	66.31
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.15
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acres)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage @ $50.0/acre (1000$)	-	17.50	37.0	55.0	72.5	87.50	100.0	111.35	125.0	135.0	145.0	152.5	160.0	166.25	171.25	176.25	180.0
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	33.70	60.76	85.24	108.14	125.30	149.82	171.11	188.15	214.85	233.12	248.95	264.99	277.70	290.91	301.33	355.50

Discharge at Iowa City	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	16500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	9750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage @ $35.0/acre (1000$)	327.75	329.70	332.5	336.0	338.8	341.25	344.4	346.8	349.6	351.7	354.5	358.0	360.8	363.6	366.5	369.9
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	690.0
Weighted crop damage (1000$)	62.27	62.64	63.17	63.84	64.37	64.83	65.43	65.89	66.42	66.82	67.35	68.02	68.55	69.08	69.63	70.28
Weighted property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage @ $40.0/acre (1000$)	124.8	126.8	128.8	130.0	131.6	198.0	201.0	202.4	205.6	207.6	209.0	209.0	211.0	212.4	214.0	216.0
Property damage (1000$)	29.97	32.73	36.14	38.47	41.66	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)	67.39	68.47	69.55	70.20	71.06	106.92	108.54	109.29	111.02	112.10	112.86	112.86	113.94	114.69	115.56	116.64
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.49	28.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acres)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4460
Crop damage @ $50.0/acre (1000$)	185.0	188.5	192.5	195.0	198.75	201.25	203.7	206.2	208.7	211.2	213.0	215.5	217.5	219.5	221.2	223.0
Property damage (1000$)	20.29	20.99	22.74	23.44	24.26	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	368.61	383.35	400.91	413.15	428.05	481.08	495.37	507.30	521.56	533.44	547.11	563.99	580.82	597.50	616.36	638.33

(Dollars correspond to 1967 index)

Table 15b

Computation of Total Flood Damages for August Flood

Discharge at Iowa City	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2200	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage @ $21.0/acre (1000$)	-	-	-	-	-	-	16.8	33.6	46.2	57.75	63.0	69.3	73.5	76.65	78.75	80.22	194.25
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.0
Weighted crop damage (1000$)	-	-	-	-	-	-	3.19	6.38	8.77	10.97	11.97	13.16	13.96	14.56	14.96	15.24	36.90
Weighted property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage @ $24.0/acre (1000$)	-	18.0	26.4	33.6	39.6	42.0	49.2	52.8	56.4	58.8	61.8	63.84	66.48	68.4	70.32	72.0	73.68
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)	-	9.72	14.25	18.14	21.38	22.63	26.57	28.51	30.45	31.75	33.38	34.47	35.83	36.93	37.97	38.88	39.78
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.51
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acre)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage @ $30.0/acre (1000$)	-	10.5	22.2	33.0	43.5	52.5	60.0	66.81	75.0	81.0	87.0	91.5	96.0	99.75	102.75	105.75	108.0
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	20.22	36.45	51.14	64.88	75.18	89.98	103.30	117.38	132.37	145.40	156.19	167.74	176.86	187.12	194.75	232.36

(Dollars correspond to 1967 index)

Discharge at Iowa City	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	9750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage @ $21.0/acre (1000$)	196.35	197.82	199.5	201.6	203.28	204.75	206.64	208.11	209.79	211.05	212.73	214.83	216.51	218.19	219.87	221.97
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	680.0
Weighted crop damage (1000$)	37.30	37.58	37.90	38.30	38.62	38.90	39.26	39.54	39.86	40.09	40.42	40.81	41.13	41.45	41.77	42.17
Weighted property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage @ $24.0/acre (1000$)	74.88	76.08	77.28	78.0	78.96	118.8	120.6	121.44	122.4	123.36	124.56	125.4	126.6	127.44	128.4	129.6
Property damage (1000$)	29.97	32.73	36.14	38.47	41.65	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)	40.43	41.08	41.73	42.12	42.63	64.15	65.12	65.57	66.09	66.61	67.26	67.71	68.36	68.81	69.33	69.98
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.43	28.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acre)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4460
Crop damage @ $30.0/acre (1000$)	111.0	113.1	115.5	117.0	119.25	120.75	122.25	123.75	125.25	126.75	127.8	129.3	130.5	131.7	132.75	133.8
Property damage (1000$)	20.29	20.99	22.74	23.44	24.25	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	242.68	255.50	270.82	281.53	294.37	331.88	344.33	354.78	366.62	376.77	389.37	405.43	420.82	436.25	453.82	474.36

(Dollars correspond to 1967 index)

Table 15c

Computation of Total Flood Damages for September Flood

Discharge at Iowa City (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2200	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage @ $14.0/acre (1000$)	-	-	-	-	-	-	11.2	22.4	30.8	38.5	42.0	46.2	49.0	51.1	52.50	53.48	129.5
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.00
Weighted crop damage (1000$)	-	-	-	-	-	-	2.13	4.25	5.85	7.31	7.98	8.77	9.31	9.71	9.97	10.16	24.60
Weighed property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage @ $16.0/acre (1000$)	-	12.0	17.6	22.4	26.4	28.0	32.8	35.2	37.6	39.2	41.2	42.56	44.32	45.6	46.88	48.0	49.12
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)	-	6.48	9.50	12.09	14.25	15.12	17.71	19.08	20.30	21.16	22.25	22.98	23.93	24.62	25.31	25.92	26.52
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.15
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acres)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage @ $20.0/acre (1000$)	-	7.0	14.8	22.0	29.0	35.0	40.0	45.4	50.0	54.0	58.0	61.0	65.0	66.50	68.50	70.5	72.0
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	13.48	24.30	34.09	43.25	50.12	60.06	70.33	79.31	91.12	100.78	109.81	119.13	126.45	135.22	141.46	170.80

Discharge at Iowa City (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	9750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage @ $14.0/acre (1000$)	130.9	131.88	133.0	134.4	135.52	136.5	137.76	138.75	139.86	140.70	141.82	143.22	114.34	145.46	146.58	147.98
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	680.0
Weighted crop damage (1000$)	24.87	25.05	25.27	25.54	25.75	25.93	26.17	26.36	26.57	26.73	26.94	27.21	27.42	27.63	27.85	28.11
Weighed property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage @ $16.0/acre (1000$)	49.92	50.72	51.52	52.0	52.64	79.2	80.4	80.96	81.6	82.24	83.04	83.6	84.4	84.96	85.6	86.4
Property damage (1000$)	29.97	32.73	36.14	38.47	41.66	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)	26.95	27.33	27.82	28.08	28.42	42.77	43.41	43.71	44.06	44.41	44.84	45.14	45.57	45.87	46.22	46.65
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.49	28.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acres)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4460
Crop damage @ $20.0/acre (1000$)	74.0	75.4	77.0	78.0	79.5	80.5	81.5	82.5	83.5	84.5	85.2	86.2	87.0	87.8	88.5	89.2
Property damage (1000$)	20.29	20.99	22.74	23.44	24.26	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	179.77	191.57	205.78	215.73	227.54	257.28	268.78	278.49	289.55	298.80	310.88	326.16	340.82	355.59	372.54	392.37

(Dollars correspond to 1967 index)

Table 15d

Computation of Total Flood Damages for October Flood

Discharge at Iowa City (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2200	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage @ $8.75/acre (1000$)	-	-	-	-	-	-	7.0	14.0	19.25	24.06	26.25	28.87	30.62	31.93	32.81	33.42	80.93
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.00
Weighted crop damage (1000$)	-	-	-	-	-	-	1.33	2.66	3.65	4.57	4.98	5.48	5.82	6.06	6.23	6.35	15.37
Weighted property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage @ $10.0/acre (1000$)	-	7.5	11.0	14.0	16.50	17.50	20.50	22.0	23.50	24.50	25.75	26.60	27.70	28.50	29.30	30.0	30.70
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)	-	4.05	5.94	7.56	8.91	9.45	11.07	11.88	12.69	13.23	13.90	14.36	14.95	15.39	15.82	16.2	16.57
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.15
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acres)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage @12.5/acre (1000$)	-	4.37	9.25	13.75	18.12	21.87	25.0	28.37	31.35	33.75	36.25	38.12	40.0	41.56	42.81	44.06	45.0
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	8.42	15.19	21.31	27.03	31.32	37.62	44.51	50.75	60.20	67.68	75.02	82.66	88.63	96.30	101.49	124.62

Discharge at Iowa City (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	9750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage @ $8.75/acre (1000$)	81.81	82.42	83.12	84.0	84.7	85.31	86.1	86.71	87.41	87.93	88.63	89.51	90.21	90.91	91.61	92.48
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	650.0
Weighted crop damage (1000$)	15.54	15.66	15.79	15.96	16.09	16.20	16.36	16.47	16.60	16.71	16.84	17.00	17.14	17.27	17.40	17.57
Weighted property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage @ $10.0/acre (1000$)	31.20	31.70	32.20	32.50	32.90	49.50	50.25	50.60	51.00	51.40	51.90	52.25	52.75	53.10	53.50	54.0
Property damage (1000$)	29.97	32.73	36.14	38.47	41.66	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)	16.85	17.12	17.39	17.55	17.76	26.73	27.13	27.32	27.54	27.75	28.02	28.21	28.48	28.67	28.89	29.16
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.49	28.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acres)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4460
Crop damage @12.5/acre (1000$)	46.25	47.12	48.12	48.75	49.68	50.31	50.93	51.56	52.18	52.81	53.25	53.87	54.37	54.87	55.31	55.75
Property damage (1000$)	20.29	20.99	22.74	23.44	24.26	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	132.59	143.64	156.99	166.37	177.40	201.32	212.12	221.27	231.74	240.59	252.01	266.69	280.82	295.10	311.57	330.89

(Dollars correspond to 1967 index)

Table 15e

Computation of Total Flood Damages for November-April Flood

Discharge at Iowa City (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2200	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage @ $3.5/acre (1000$)	-	-	-	-	-	-	2.80	5.6	7.7	9.62	10.50	11.55	12.25	12.77	13.12	13.37	32.37
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.00
Weighted crop damage (1000$)	-	-	-	-	-	-	0.53	1.06	1.46	1.83	1.99	2.19	2.32	2.42	2.49	2.54	6.15
Weighted property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage @ $4.0/acre (1000$)	-	3.0	4.4	5.6	6.6	7.0	8.2	8.8	9.4	9.8	10.3	10.64	11.08	11.4	11.72	12.0	12.28
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)	-	1.62	2.37	3.02	3.56	3.78	4.43	4.75	5.07	5.29	5.56	5.74	5.98	6.15	6.33	6.48	6.63
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.15
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acres)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage @ $5.0/acre (1000$)	-	1.75	3.7	5.5	7.25	8.75	10.0	11.35	12.5	13.5	14.5	15.25	16.0	16.62	17.12	17.62	18.0
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	3.37	6.07	8.52	10.81	12.53	14.65	18.76	22.19	29.27	34.60	40.24	46.19	50.81	57.38	61.52	78.46

Discharge at Iowa City (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	9750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage @ $3.5/acre (1000$)	32.72	32.97	33.25	33.6	33.88	34.12	34.44	34.68	34.96	35.17	35.45	35.80	36.08	36.36	36.64	36.99
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	680.0
Weighted crop damage (1000$)	6.21	6.26	6.31	6.38	6.43	6.48	6.54	6.59	6.64	6.68	6.73	6.80	6.85	6.91	6.96	7.03
Weighted property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage @ $4.0/acre (1000$)	12.48	12.68	12.88	13.0	13.16	19.8	20.1	20.24	20.4	20.56	20.76	20.9	21.1	21.24	21.4	21.6
Property damage (1000$)	29.97	32.73	36.14	38.47	41.66	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)	6.74	6.84	6.95	7.02	7.10	10.69	10.85	10.92	11.01	11.10	11.21	11.28	11.39	11.47	11.55	11.66
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.49	28.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acres)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4460
Crop damage @ $5.0/acre (1000$)	18.5	18.85	19.25	19.5	19.87	20.12	20.37	20.62	20.87	21.12	21.3	21.55	21.75	21.95	22.12	22.30
Property damage (1000$)	20.29	20.99	22.74	23.44	24.26	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	85.40	95.69	108.20	117.01	127.27	145.37	155.46	164.05	173.94	182.22	193.14	207.24	220.82	234.62	250.60	269.40

(Dollars correspond to 1967 index)

Table 15f

Computation of Total Flood Damages for Dec.-Jan.-Feb.-March Flood

Discharge at Iowa City (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
1) Reach 1 (Wapello)																	
Discharge (cfs)	13250	15800	17500	21000	24400	26600	29500	32300	35000	39000	41500	45000	48000	51400	55000	58000	62000
Cult. area flooded (acres)	-	-	-	-	-	-	800	1600	2000	2750	3000	3300	3500	3650	3750	3820	9250
Crop damage /acre (1000$)	-	-	-	-	-	-											
Property damage (1000$)	-	-	-	-	-	-	-	-	1.00	3.00	4.5	7.0	9.2	13.0	18.0	21.50	73.00
Weighted crop damage (1000$)	-	-	-	-	-	-											
Weighted property damage (1000$)	-	-	-	-	-	-	-	-	0.19	.57	.85	1.33	1.75	2.47	3.42	4.08	13.87
2) Reach 2A (Lone Tree)																	
Discharge (cfs)	6400	7400	8400	9400	10400	11500	12500	13500	14500	15750	16750	17800	19000	20000	21250	22250	23500
Cult. area flooded (acres)	-	750	1100	1400	1650	1750	2050	2200	2350	2450	2575	2660	2770	2850	2930	3000	3070
Crop damage /acre (1000$)																	
Property damage (1000$)	-	-	-	-	-	-	0.42	2.97	5.51	8.50	10.88	13.59	16.78	19.12	22.10	24.66	28.06
Weighted crop damage (1000$)																	
Weighted property damage (1000$)	-	-	-	-	-	-	0.22	1.60	2.97	4.59	5.87	7.34	9.06	10.32	11.93	13.31	15.15
3) Reach 2B (Iowa City)																	
Discharge (cfs)	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000
Cult. area flooded (acres)	-	350	740	1100	1450	1750	2000	2270	2500	2700	2900	3050	3200	3325	3425	3525	3600
Crop damage /acre (1000$)																	
Property damage (1000$)	-	-	-	-	-	-	-	-	-	3.49	5.83	8.39	11.08	12.83	16.09	17.49	18.66
TOTAL DAMAGE (1000$)	-	-	-	-	-	-	0.22	2.97	3.16	8.65	12.55	17.06	21.89	25.62	31.44	34.88	47.68

Discharge at Iowa City (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
1) Reach 1 (Wapello)																
Discharge (cfs)	65500	69000	73000	76300	80000	84000	88500	92000	96000	99000	103000	108000	112000	116000	120000	125000
Cult. area flooded (acres)	9350	9420	9500	9600	9680	5750	9840	9910	9990	10050	10130	10230	10310	10390	10470	10570
Crop damage /acre (1000$)																
Property damage (1000$)	92.00	132.00	176.00	210.00	248.00	284.00	330.00	364.00	402.0	431.0	469.0	517.0	555.0	594.0	632.0	680.0
Weighted crop damage (1000$)																
Weighted property damage (1000$)	17.48	25.08	33.44	39.90	47.12	53.96	62.70	69.16	76.38	81.89	89.11	98.23	105.45	112.86	120.08	129.20
2) Reach 2A (Lone Tree)																
Discharge (cfs)	24500	25750	27000	28000	29250	30500	31800	33000	34000	35100	36500	37600	39000	40200	41500	43000
Cult. area flooded (acres)	3120	3170	3220	3250	3290	4950	5025	5060	5100	5140	5190	5225	5275	5310	5350	5400
Crop damage /acre (1000$)																
Property damage (1000$)	29.97	32.73	36.14	38.47	41.66	52.72	53.90	56.50	58.60	60.80	63.70	65.90	68.30	70.80	73.50	74.65
Weighted crop damage (1000$)																
Weighted property damage (1000$)	16.18	17.67	19.51	20.77	22.49	26.46	29.10	30.51	31.64	32.83	34.39	35.58	36.88	38.23	39.69	40.31
3) Reach 2B (Iowa City)																
Discharge (cfs)	12500	13000	13500	14000	14500	15000	15500	16000	16500	17000	17500	18000	18500	19000	19500	20000
Cult. area flooded (acres)	3700	3770	3850	3900	3975	4025	4075	4125	4175	4225	4260	4310	4350	4390	4425	4400
Crop damage /acre (1000$)																
Property damage (1000$)	20.29	20.99	22.74	23.44	24.26	25.66	25.90	26.25	27.40	28.60	30.40	33.80	38.50	43.20	50.20	58.90
TOTAL DAMAGE (1000$)	53.95	63.74	75.69	84.11	93.87	103.08	117.70	125.92	135.42	143.32	153.90	167.61	180.83	194.29	209.97	228.41

(Dollars correspond to 1967 index)

Table 16

Summary of Total Flood Damages on the Iowa River
Downstream of the Coralville Dam
(In Thousands of Dollars, 1967 index)

Discharge at Iowa City (cfs)	May-June-July	August	September	October	November and April	December-January-February-March
4,000	0	0	0	0	0	0
4,500	33.7	20.22	13.48	8.42	3.37	0
5,000	60.76	36.45	24.30	15.19	6.07	0
5,500	85.24	51.14	34.09	21.31	8.52	0
6,000	108.14	64.88	43.25	27.03	10.81	0
6,500	125.30	75.18	50.12	31.32	12.53	0
7,000	149.82	89.98	60.06	37.62	14.65	0.22
7,500	171.11	103.30	70.33	44.51	18.76	2.97
8,000	188.15	117.38	79.31	50.75	22.19	3.16
8,500	214.85	132.37	91.12	60.20	29.27	8.65
9,000	233.12	145.40	100.78	67.68	34.60	12.55
9,500	248.95	156.19	109.81	75.02	40.24	17.06
10,000	264.99	167.74	119.13	82.66	46.19	21.89
10,500	277.70	176.86	126.45	88.63	50.81	25.62
11,000	290.91	187.12	135.22	96.30	57.38	31.44
11,500	301.33	194.75	141.46	101.49	61.52	34.88
12,000	355.50	232.36	170.80	124.62	78.46	47.68
12,500	368.61	242.68	179.77	132.59	85.40	53.95
13,000	383.35	255.50	191.57	143.64	95.69	63.74
13,500	400.91	270.82	205.78	156.99	108.20	75.69
14,000	413.15	281.53	215.73	166.37	117.01	84.11
14,500	428.05	294.37	227.54	177.40	127.27	93.87
15,000	481.08	331.88	257.28	201.32	145.37	108.08
15,500	495.37	344.33	268.78	212.12	155.46	117.70
16,000	507.30	354.78	278.49	221.27	164.05	125.92
16,500	521.56	366.62	289.55	231.74	173.94	135.42
17,000	533.44	376.77	298.80	240.59	182.22	143.42
17,500	547.11	389.37	310.88	252.01	193.14	153.90
18,000	563.99	405.43	326.16	266.69	207.24	167.61
18,500	580.82	420.82	340.82	280.82	220.82	180.83
19,000	597.50	436.25	355.59	295.10	234.62	194.29
19,500	616.36	453.82	372.54	311.57	250.60	209.97
20,000	638.33	474.36	392.37	330.89	269.40	228.41