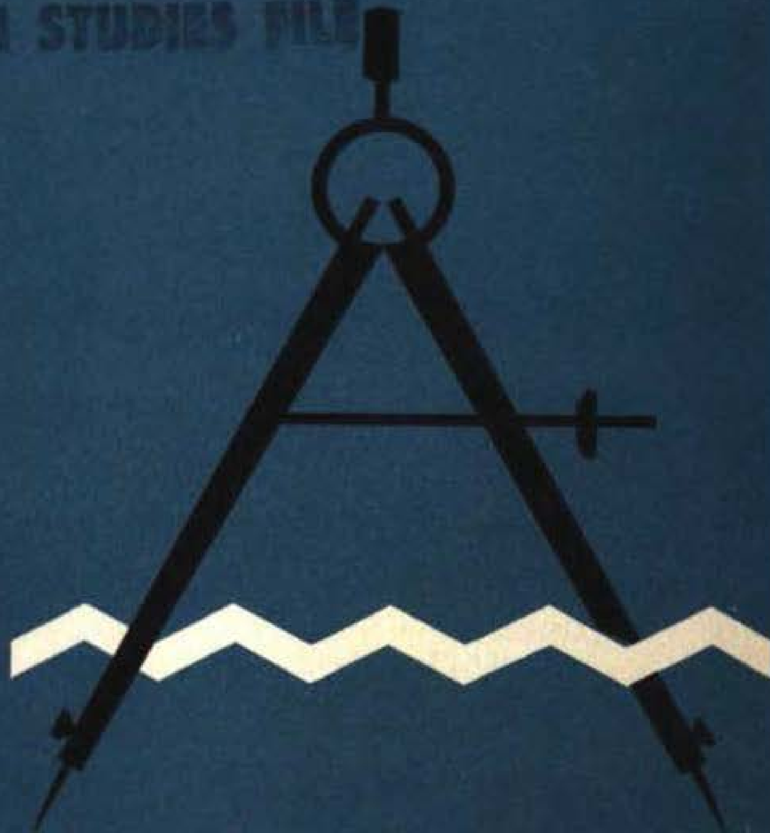
human adjustment to floods

by gilbert fowler white

Here is a comprehensive theory of the geographic approach to the problem of dealing with floods. Problems of the control and use of water, not the least of which are flood problems, have become increasingly important in our economic and political life. Although considerable progress has been made in thinking about flood problems since this monograph first appeared in 1945, a review of literature indicates that there is still no widespread comprehension of the general theory involved in a geographical approach to them. It has, therefore, been concluded that much would be gained by giving the volume a wider circulation. In response to a steady stream of inquiries, it is here reprinted in the hope that it will make a significant contribution to understanding of flood problems and their solution.



human adjustment to floods

gilbert fowler white

THE UNIVERSITY OF CHICAGO

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HUMAN ADJUSTMENT TO FLOODS

A GEOGRAPHICAL APPROACH TO THE FLOOD PROBLEM IN THE UNITED STATES

A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Editor's Introduction

In 1945 a monograph, submitted as a doctoral dissertation in the Department of Geography at the University of Chicago, entitled Human Adjustment to Floods: A Geographical Approach to the Flood Problem in the United States by Gilbert White was printed by the University of Chicago Press and privately distributed by the University of Chicago Libraries and by the author. In it the author essayed nothing less than a comprehensive theory of the geographic approach to the problem of dealing with floods. The few copies printed disappeared rapidly and the work shortly became unavailable. Despite the lack of publicity a steady stream of inquiries has reached the Department and the author ever since.

In the intervening period problems of the control and use of water, not the least of which are flood problems, have become increasingly important in our economic and political life. Although considerable progress has been made since 1945 in thinking about flood problems, a review of the literature indicates that there is still not a widespread comprehension of the general theory involved in a geographical approach to them. It has, therefore, been concluded that much would be gained by giving the volume a wider circulation. It is here reprinted as Volume 29 in the Department's Research Series in the hope that it will make a significant contribution to understanding of flood problems and their solution.

Wesley Calef
Editor
University of Chicago,
Department of Geography
Research Series

CHAPTER I

A COMPREHENSIVE VIEW OF THE FLOOD PROBLEM

The Flood Problem in the United States

Every year receding flood waters in one or more sections of the United States expose muddy plains where people were poorly prepared to meet the overflow. Small-town shopkeepers digging their goods out of Ohio River silt; Alabama farmers collecting their scattered and broken possessions; and New England manufacturers taking inventory in water-soaked warehouses, testify to the dislocating effects of floods and to the unsatisfactory adjustment which man has made to them in many valleys. For the most part, floods in the United States leave in their wake a dreary scene of impaired health, damaged property, and disrupted economic life.

The effects of floods are not everywhere disastrous, however, or even disturbing to the economy. Each year ebbing flood waters also reveal plains in which a relatively satisfactory arrangement of human occupance has taken place. Pittsburgh merchants returning to stores which, because of adequate preparations, suffered only minor losses; Montana ranchers appraising the increased yields of hay to be obtained because of fresh deposits of moisture; and New Orleans citizens carrying on their business behind a levee withstanding a flood crest high above the streets, illustrate wise adjustments to flood hazard.

It has become common in scientific as well as popular literature to consider floods as great natural adversaries which man seeks persistently to over-power. According to this view, floods always are watery marauders which do no good, and against which society wages a bitter battle. The price of victory is the cost of engineering works necessary to confine the flood crest; the price of defeat is a continuing chain of flood disasters. This simple and prevailing view neglects in large measure the possible feasibility of other forms of adjustment, of which the Pittsburgh and Montana cases are examples.

Floods are "acts of God," but flood losses are largely acts of man. Human encroachment upon the flood plains of rivers accounts for the high annual toll of flood losses. Although in a few drainage areas the frequency and magnitude of floods have increased as a result of exploitative use of the up-stream lands, the flood menace elsewhere has changed but little while man has moved into the natural paths of flooded rivers or has restricted the channels so as to heighten normal flood crests. Moreover, floods may be beneficial as well as harmful, and even where they are completely harmful there are remedies other than physical structures built to afford protection. Recognizing these facts, flood-plain occupance cannot be considered realistically as a matter solely of man against the marauder.

Dealing with floods in all their capricious and violent aspects is a problem in part of adjusting human occupance to the flood-plain environment so as to utilize most effectively the natural resources of the plain, and, at the same time, of applying feasible and practicable measures for minimizing the detrimental impacts of floods. This problem in the United States involves at least 35,000,000 acres of land known to be subject to flood. A large part of that land is not cultivated, but the cultivated portions are among the more productive agricultural resources of the nation. Of the 59 cities in the United States having a population of more than 150,000 in 1940, 19 or more suffer at times from high water. Eight of them (Springfield, Hartford, Pittsburgh, Cincinnati, Louisville, Kansas City, Denver, and Los Angeles) have serious flood hazards in highly important sections. In addition, two cities--Dayton and New Orleans--occupy land which has been protected fully from flood. Although most of the densely settled flood plains are in the Northeastern Manufacturing Belt and along the Lower Mississippi River, economically important encroachments have been made upon flood plains in all sections of the United States. For the nation as a whole, the mean annual property loss resulting from floods certainly is more than $75,000,000 and probably exceeds $95,000,000. The toll in human life is approximately 83 deaths annually. For the heavy damages to health and to productive activity no measuring units are available.

Purpose and Method of Analysis

Because of the great diversity in flood conditions and in flood plains and their occupance, it is impracticable to formulate more than a few generalizations with respect to flood problems in the United States. Solutions to such problems can be developed effectively only by examining the environmental and social conditions in each locality having a flood problem. No attempt is made in this dissertation to make that kind of an examination, locality by locality. It is believed, however, that specific local problems could be appraised more fully, and that better solutions could be found for them if a broader and essentially geographical approach to the flood problem were to be adopted. Such an approach would take account of all relevant factors affecting the use of flood plains, would consider all feasible adjustments to the conditions involved, and would be practical in application.

The remainder of this chapter outlines the points of view which have dominated public action in dealing with the flood problem in the United States, and suggests a more nearly comprehensive approach meeting the foregoing requirements as to breadth and practicability. Succeeding chapters attempt to show the validity and implications of that approach. Chapter II defines the concepts of flood, flood plain, and flood-plain occupance. Chapter III points out the chief factors--natural and social--which have been important in the occupation of American flood plains. The range of human adjustment to the flood hazard is described in Chapter IV. Finally Chapter V states the conclusions of the investigation, and suggests ways of applying them to public policy affecting the flood problem, and to geographical research.

These findings are the results of an examination of the available literature on flood problems in the United States, comprising chiefly the reports of the U. S. Corps of Engineers and the U. S. Department of Agriculture on their flood-control surveys; reports of state and municipal engineering surveys; bulletins on floods prepared by the U. S. Geological Survey and the U. S. Weather Bureau; geographical studies of flood plains; and relevant statements in technical and trade journals. They also reflect a large body of unpublished material which the author was privileged to review while associated with the National Resources

Planning Board and its predecessors. As the major findings began to take shape from the review of the literature on floods, they were tested by reconnaissance studies of flood plains selected for their diversity of conditions and lying within the Potomac, Delaware, Upper Ohio, and Los Angeles basins.

Three Public Approaches to the Flood Problem

Public action with respect to floods in the United States has emerged from three streams of thought, each reflecting a distinct social technique, and each fostered by a separate professional group.

The engineer has approached the problem by inquiring "Is flood protection warranted?" He has utilized levees, dams, floodways, channel improvements, and similar engineering devices to curb flood flows. The public welfare official has sought to determine "How best to alleviate flood distress?" He has relied upon soup kitchens, rescue boats, emergency grants, rehabilitation loans and like measures to cushion the social effects of flood. The property owner has been aided somewhat by the meteorologist who, asking "When will the next flood occur and how high will it be," has made forecasts that enable public officials and property owners alike to evacuate some of their goods and to prepare in other ways for the on-coming flood. Each approach has helped to reduce flood losses and to increase the utility of flood-plain resources. Each has developed fruitful methods of coping with floods. These three approaches, either singly or in combination, do not point, however, to solutions of the flood problem which promise maximum use of all flood plains with minimum social costs.

Engineering

The traditional public attack upon the flood problem in the United States has been to determine whether or not the flood plain under consideration could and should be protected from floods. This is the engineering approach. Under it the cost of building protective works is calculated, the prospective benefits from protection are estimated, and if the benefits seem to exceed the cost, the work is recommended for construction. This has been the prevailing Federal policy since 1917, and it has dominated the flood-protection work of state and county agencies before and since.

Federal policy.--Although the Federal government did not assume responsibility for flood protection on a national scale until 1936, it began much earlier to construct engineering works on the Lower Mississippi and Sacramento Rivers, and to plan similar projects on other streams. Attention first was directed to the largest single flood plain, the alluvial valley of the Mississippi River below Cairo, Illinois, where levee construction had begun in the Eighteenth Century. Since 1850, when the Congress first directed the Corps of Engineers to study flood control in the Lower Mississippi Valley, the Federal government has enlarged progressively its participation in that work. These studies resulted in the monumental reports by Ellet and by Andrew A. Humphreys and Henry L. Abbott which together outlined most of the efforts which were to follow for controlling the Mississippi River.[1] Private levee systems grew during the next eight years (1850-58) under the sponsorship of planters in the alluvial valley, but they were widely breached by a series of great floods beginning in 1859. Neglect during the Civil War combined with military operations to leave levees in a sad state of disrepair at the end of the War.[2] By 1878 the levee system had disintegrated, and much of the valley land had been abandoned for agricultural purposes. The scattered and uncoordinated efforts of local agencies to control the river had failed miserably.

A commission was created by the Congress, following the serious flood of 1874, to prepare a permanent plan for reclamation of the alluvial valley. The first Federal appropriation for relief of flood sufferers was made during the same year. Five years later, in 1879, the Mississippi River Commission was established as a permanent agency in the War Department to draw up standard plans for flood control and to supervise the expenditure of Federal funds for them. Initially the Commission confined its aid to the repair of damaged levees and to the strengthening of

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[1] Andrew A. Humphreys and Henry L. Abbott, Report upon the Physics and Hydraulics of the Mississippi River (Washington: Government Printing Office, 1876). Charles Ellet, Jr., The Mississippi and Ohio Rivers (Philadelphia: Lippencott, Grambo, and Co., 1853).

[2] Arthur DeWitt Frank, The Development of the Federal Program of Flood Control on the Mississippi River (New York: Columbia University Press, 1930), pp. 28-36.

existing levees, but in 1895 it began to use direct Federal appropriations to help the state and local levee districts in the construction of new levees.[1] All of its flood-control work was authorized under the thin pretext of improving navigation, and the "levees-only" theory which guided the work was justified as an integral part of the authorized Federal plan to maintain and improve the navigability of the Mississippi River.

Then the flood of 1916 breached numerous weak levees along the lower river, and revealed the need for direct expenditures by the Federal government in order to obtain early completion of the levee system at the standard grade established by the Commission. The Lower Mississippi flood problem was proving itself too large and too complex to be handled as a phase of navigation improvement. Accordingly, the Congress enacted legislation in 1917 to provide for expenditure by the Commission of not more than $45,000,000 on works on the Mississippi River between Rock Island, Illinois and its mouth and on the lower reaches of tributary watercourses. Federal contributions were made subject to the contribution of funds in at least equal amounts by the interested states and levee districts, and subject also to agreement by those interests that they would provide all necessary rights of way for the levee enlargement and would maintain the completed levees.[2] (Appropriations and expenditures for flood protection under this act and subsequent acts affecting the Lower Mississippi River are given in Table 1.)

The same act authorized the expenditure of $5,600,000 for levees, channel improvement, and weirs in the Sacramento Valley of California in conformity with the flood-protection plans of the California Debris Commission, and in that connection the act imposed conditions of local participation identical with those applying to Lower Mississippi projects.

The Act of 1917 directed also that preliminary examinations and surveys for flood control should be made thereafter by the Corps of Engineers under the terms of legislation then applying to investigations of proposed river and harbor improvements, and that, in making flood-control surveys, due attention should

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[1] Ibid., pp. 134-36.

[2] 39 U.S. Statutes 948. Act of March 1, 1917.

TABLE 1

FUNDS APPROPRIATED AND EXPENDED FOR LOWER MISSISSIPPI RIVER FLOOD CONTROL, FISCAL YEARS 1917-1941[a]

Fiscal Year	Total Appropriation	Expenditures		
		New Work	Maintenance	Total
1917	$ 6,000,000	$ 4,450,242	.....	$ 4,450,242
1918	6,670,000	4,027,730	$ 1,675,731	5,703,461
1919	6,670,000	4,054,514	1,998,312	6,052,826
1920	6,670,000	5,275,207	1,997,254	7,252,461
1921	6,670,000	7,287,880	2,280,042	9,567,922
1922	7,770,000	6,041,097	1,850,622	7,891,719
1923	5,986,600	4,793,486	1,995,798	6,789,284
1924	10,000,000	4,858,207	1,548,572	6,406,779
1925	10,000,000	8,835,840	2,812,740	11,648,580
1926	10,000,000	7,356,327	1,910,064	9,266,391
1927	10,000,000	6,644,921	3,898,548	10,543,469
1928	33,500,000	8,035,371	5,016,367	13,051,738
1929	30,800,000	18,700,364	5,855,739	24,556,103
1930	35,400,000	20,263,344	3,873,585	24,136,929
1931	38,400,000	3,338,072	231,563	3,569,634
1932	32,400,000	25,936,207	1,712,950	27,649,157
1933	20,001,424	33,341,348	5,049,520	38,390,868
1934	29,341,291	39,795,969	7,249,686	47,045,655
1935	15,499,400	28,694,775	7,118,812	35,813,587
1936	15,811,309	26,389,030	3,303,286	29,692,316
1937	45,300,000	25,203,515	3,344,751	28,548,266
1938	31,800,000	22,602,531	3,092,062	25,694,593
1939	39,800,000	24,214,385	2,177,672	26,392,057
1940	30,800,000	30,161,426	3,377,352	33,538,778
1941	22,000,100	26,835,356	3,784,949	30,620,305
Total	$507,290,124	$397,137,144	$77,095,977	$474,233,121

[a]Source: Annual reports of the Chief of Engineers, 1917-1941.

be given to possibilities of water-power development, navigation, and related development, utilizing the help of other interested Federal departments and agencies.[1] No areas for preliminary examination and survey were named in the act, so that it was only as additional legislation was enacted that the contemplated surveys were undertaken. Surveys of the Atchafalaya, Red and Black rivers in Louisiana, of the Yazoo and Mississippi rivers, and of

[1]Under the routine procedures of the Corps of Engineers, a preliminary examination is a reconnaissance study to determine whether or not a detailed survey should be made.

the Calaveras River, California, were authorized in 1921.[1] The Act of May 31, 1924, authorized preliminary examinations of 15 drainage areas, chiefly in the Western Gulf and Arkansas and Red basins, and surveys of the North Branch of the Susquehanna River in Pennsylvania and New York, the Puyallup River, Washington, and the Allegheny and Monongahela rivers.[2] The Allegheny and Monongahela survey was to cost $50,000, of which one-half was to be contributed by Pennsylvania. Preliminary examinations were authorized for the Caloosahatchee River, Florida, in 1924,[3] and for the Skykomish, Snoqualami, Snokomish, Stillaguamish, and Nooksack rivers, Washington, in 1925.[4] With the exception of a special survey of a possible flood-diversion scheme on the Atchafalaya outlet of the Mississippi River,[5] no other surveys were authorized until the River and Harbor Act of January 21, 1927 launched the series of so-called "308" investigations.[6]

Those investigations were undertaken in accordance with a program recommended to the Congress by the Corps of Engineers and the Federal Power Commission in House Document No. 308, Sixty-ninth Congress, first session, and were designed to provide plans for the development of navigation, hydroelectric power, and irrigation opportunities and for the control of floods in each of the specified drainage basins. Most of the major drainage areas, except the Colorado Basin, which was understood to be the special province of the Bureau of Reclamation, were named in the House Document or in the supplemental list included in the Act. Altogether, more than 188 separate reports had been transmitted to the Congress by 1941.[7] As the first large-scale and adequately financed effort to plan for multiple-purpose use of water re-

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[1] 41 U.S. Statutes 1354 (1921); 42 U.S. Statutes 146 (1921); and 42 U.S. Statutes 171 (1921).

[2] 43 U.S. Statutes 249 (1924).

[3] 43 U.S. Statutes 961 (1924).

[4] 43 U.S. Statutes 1000 (1925).

[5] 44 U.S. Statutes 300 (1926).

[6] 44 U.S. Statutes 1010 (1927).

[7] U. S. War Department, Annual Report of the Chief of Engineers for the Year Ending June 30, 1941 (Washington: Government Printing Office, 1941), II, Part I, 2134.

sources in the United States, the 308 investigations were a monumental enterprise which became the groundwork for much construction that followed.[1] Neither House Document 308 nor the authorizing act contained specific directions as to the point of view or techniques to be employed in dealing with the flood aspects of drainage-basin improvement. They simply requested plans for the control of floods. Because the Chief of Engineers likewise did not issue instructions with respect to investigative methods, each district engineer was free to attack the flood problem as he saw fit, and the result was a series of reports displaying a considerable variety in methods. Some of the significant differences among those reports are analyzed in Chapter IV. In general, all of the reports adopted a strict engineering approach making the economic justification for flood protection dependent upon the ratio of direct benefits to construction costs.

The 308 reports were submitted to the Congress over a period of more than twelve years. During that time there appear to have been several pronounced trends in the thinking of the engineers concerned with their preparation. Increasing attention was given to the practicability of reservoir control in lieu of levees, diversions, and channel improvements. Consideration of allied purposes, such as wildlife conservation and pollution abatement, became more prominent. Flood problems of a type which in early reports were dismissed from consideration as being purely local problems, were treated in later reports, and particularly after the passage of the Flood Control Act of 1936, as proper objects of Federal investigation.[2] Finally, the studies of probable flood

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[1]Among the areas in which 308 reports have been used as the basis for important construction programs are the Tennessee Valley, the Ohio Basin, the Illinois Basin, and the Red Basin. The data collected for these and other 308 reports were also the basis for the comprehensive reservoir plan for the Mississippi Basin to which reference is made later.

[2]The original 308 report for the Alabama-Coosa Basin concluded that "The flood protection of Selma and Montgomery are local problems which are not a large or serious magnitude, and are therefore not considered as subject to Federal aid or cooperation." 74th Cong., 1st Sess., Alabama-Coosa Branch of Mobile River System, House Doc. No. 66 (Washington: Government Printing Office, 1935), p. 93. A comprehensive flood control, navigation, and power program was recommended by the Chief of Engineers for the basin in a report dated October 15, 1941.

A similar instance is the Housatonic Basin, Connecticut frequency and of the magnitude of probable maximum floods became more precise, with the result that infrequent flood hazards were recognized far more in later reports than in early ones. Thus, it seems probable that the earlier reports, by comparison with later reports, underemphasized the importance of flood protection.

The year 1927 witnessed a tremendous flood disaster in the Lower Mississippi valley, one which exceeded any previous flood in the extent and amount of the damage wrought. Plans for flood protection in the Lower Mississippi area were revised once more, and, after long controversy over the feasibility of various engineering remedies, an act was approved on May 15, 1928 to authorize the expenditure of $325,000,000 on a system of levees and diversion floodways to be constructed at Federal expense.[1] Local interests were required only to furnish lands, damages and rights of way for the necessary works. This new expression of Congressional policy admitted the inadequacy of the old "levees only" theory on the Lower Mississippi River, and it assigned the Federal government virtually complete financial responsibility for new works.

No change was made in the basic legislation affecting other sections of the country, although many additional flood-control surveys and examinations were authorized in separate acts.[2]

Prompted by the severe floods of 1935 and 1936 in the Northeastern States, the Congress declared in the latter year that flood control on navigable waters or their tributaries is a proper activity of the Federal government, inasmuch as destructive floods menace the national welfare by destroying property and life, impairing interstate commerce, and otherwise upsetting orderly so-

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for which it was reported in 1932, "The damage which has occurred is more or less local in character, and subject to local remedies." 72d Cong., 1st Sess., House Doc. No. 246 (Washington: Government Printing Office, 1932), p. 28.

Another instance in which the reporting officer considered that Federal interest did not extend to problems of "local" flood protection is, 72d Cong., 1st Sess., Illinois River, Illinois, House Doc. No. 182 (Washington: Government Printing Office, 1932), p. 72.

[1] 45 U.S. Statutes 534 (1928).

[2] In all, between 1929 and June 22, 1936, 68 bills providing for preliminary examinations and five bills providing for surveys for flood control were enacted by the Congress in accordance with the Flood Control Act of 1917.

cial processes.[1] Under that act it was provided that Federal funds might be used to improve or participate in the improvement of streams for flood control if "the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected." Local interests were required to contribute the costs of lands, rights of way, and damages, but in no instance were they to carry more than half the total cost of a project. They also were required to maintain the protective works after completion, unless more than three-quarters of the benefits accrued to areas outside of the state in which the project was located, in which case Federal maintenance was authorized. Thus the policy which had been adopted for the Lower Mississippi area was applied in modified form to other sections of the United States. This policy applied to 211 projects, having a total estimated cost of more than $310,000,000 that were authorized for construction by the Corps of Engineers.

The 1936 act reiterated the responsibility of the War Department for surveys for flood control and allied purposes, and it declared that the Department of Agriculture should prosecute surveys looking to runoff and waterflow retardation and soil-erosion prevention in the same drainage areas. These grants of authority were not to interfere with investigations relating to irrigation which the Bureau of Reclamation might wish to make. Two hundred twenty-two drainage areas or localities were named for preliminary examinations and surveys, most of them areas already studied in connection with the 308 reports. The act contemplated the preparation of plans dealing with land-management practices upstream as well as with protective works, but it did not authorize the prosecution of land-management programs.

The Flood Control Act of 1936 marks the initiation of flood protection on a national scale, and of surveys of land-management problems in connection with engineering surveys. In these respects it undoubtedly owes much to the example set by the operations of the Tennessee Valley Authority. Under the terms of the Tennessee Valley Act of May 18, 1933,[2] the Authority had

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[1] 49 U.S. Statutes 1570. Act of June 22, 1936.

[2] 48 U.S. Statutes 58.

launched the construction of a system of reservoirs for the joint purposes of flood control, navigation, and hydroelectric power development. Those reservoirs were visible demonstrations of the practicability of flood protection by such means, and they were undertaken solely at Federal expense. The Authority had been directed to combine studies of forest and soil conservation with its engineering work, and for the first time in legislative history the desirability of integrated development of resources on a regional basis had been recognized. These accomplishments and other conditions combined to promote public support for Federal participation in somewhat similar types of work in other sections of the country. There had been little precedent for Federal participation in flood protection outside of the Lower Mississippi, Sacramento, and Tennessee valleys. The construction of works at Federal expense had been authorized for the Lowell[1] and Salmon rivers,[2] Alaska, in 1933, for the Lower Rio Grande in 1933,[3] and for Niobrara, Nebraska, in 1935.[4]

Work under the 1936 act was slow in starting even though work-relief funds were made available to supplement the first regular appropriation for the fiscal year 1938 (See Table 2). Within a year, the Congress, in response to public demand for action to remedy the causes of the great disaster of January-February, 1937, in the Ohio Valley, authorized the construction of additional levees and flood walls at cities and towns along the Ohio River.[5] The same act, approved August 28, 1937, expanded the authority of the Department of Agriculture by declaring that as a condition to prosecuting remedial runoff and waterflow

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[1] 47 U.S. Statutes 802 (1933).

[2] 48 U.S. Statutes 991 (1933).

[3] 49 U.S. Statutes 660. Act of August 19, 1935.

[4] 49 U.S. Statutes 1306. War Department Appropriation Act of May 15, 1936.

[5] 50 U.S. Statutes 876. Act of August 28, 1937. The local-protection projects authorized by this act were to be selected by the Chief of Engineers from a list of projects prepared by the Chief of Engineers. The individual projects were listed in, 75th Cong., 1st Sess., Levees and Flood Walls, Ohio River Basin, Hearings before House Committee on Flood Control on H.R. 7393 and H.R. 7647 (Washington: Government Printing Office, 1937), pp. 45-48.

TABLE 2

FUNDS APPROPRIATED AND OBLIGATED FOR GENERAL FLOOD CONTROL, FISCAL YEARS, 1938-1942[a]

(Exclusive of Emergency Funds)[b]

Fiscal Year	Total Appropriation	Obligations During Year					
		New Work	Examinations & Surveys	Office of Chief of Engineers	Maintenance of Completed Works	Agriculture Surveys	Geological Survey & Weather Bureau Studies
1938	$ 30,000,000	$ 24,452,034	$ 488,549	$ 100,755	......	$ 500,000	$ 21,000
1939	82,000,000	51,945,000	2,929,423	112,341	......	3,000,000	92,970
1940	133,000,000	125,325,096	3,942,470	233,512	$198,316	3,000,000	826,162
1941	70,055,000	91,688,969	3,188,837	269,678	301,184	2,000,000	607,379
1942	98,780,000	89,613,323[c]	3,434,742[c]	310,240[c]	389,500[c]	998,342[c]	475,000[c]
Total	$413,835,000	$383,024,422	$13,984,021	$1,026,526	$889,000	$9,498,342	$2,222,511

[a]Source: Annual Budgets of the United States, 1939-1943.

[b]It is estimated that approximately $143,000,000 of Federal emergency relief funds were expended on flood protection during 1933-1938 in addition to the funds regularly appropriated as shown in Tables 1 and 2.

[c]Estimated.

retardation and soil-erosion prevention works on private lands, the Secretary of Agriculture could require the enactment and proper enforcement of state and local regulations affecting land use, the negotiation of agreements or covenants affecting such lands, and contributions of money, services, or materials. In so far as the local protective works in the Ohio Basin were concerned, the President was empowered to waive the requirements of local cooperation, stipulated in the Flood Control Act of 1936, by as much as 50 per cent if he found that the local interests were unable to pay because of the crippling effects of a flood disaster.

Requirements of local cooperation were waived still further in the Flood Control Act of 1938.[1] Because of difficulties in negotiating local contributions from groups of states benefiting from reservoir construction,[2] and also in response to an apparent desire of the public-power groups to insure that full Federal authority to develop hydroelectric power at flood-control dams would not be impaired by state control of reservoir operations, as contemplated in the proposed interstate compacts for the Connecticut and Merrimack rivers, the financing of reservoir projects was made a complete Federal responsibility.[3] By this means, the major flood-protection works proposed for many sections of the country became solely Federal in ownership and operation. Local requirements were removed for channel improvements, but they remained in effect for levees and other local-protective works.

In connection with local-protective works, the Chief of Engineers was authorized, in lieu of constructing such works, to contribute equivalent funds to those municipalities or sections of municipalities that preferred to relocate on higher ground rather than to benefit from protection at their old locations. This

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[1] 52 U.S. Statutes 1215. Act of June 28, 1938.

[2] The problems of obtaining local cooperation in reservoir construction are described in 75th Cong., 3d Sess., Hearings before the Committee on Flood Control, U. S. House of Representatives, on Report of Chief of Engineers, April 6, 1937, House Flood Control Committee Document No. 1, 75th Congress, 1st Session, and Subsequent Reports of the Chief of Engineers, and Amendments to the Flood Control Acts of June 15, 1936, June 22, 1936, and August 28, 1937 (Washington: Government Printing Office, 1938).

[3] Judson King, Why the Power Joker in the New England Flood-Control Compacts? (Washington: National Popular Government League, 1937).

provision recognized the possibility of a change in land use as an alternative to protective works, but has not been applied.

The 1938 act authorized twenty-five additional construction projects and an additional expenditure of $375,000,000 as well as the sum of $10,000,000 for surveys by both Departments. Of the one hundred localities named for surveys, most had been covered by previous authorizations. An appropriation of $2,000,000 per annum for five years also was authorized for use by the Department of Agriculture in its remedial work on the drainage areas of streams on which Federal navigation or flood-control works were authorized, but only $1,410,000 had been allocated for those purposes by 1941. Among the important new projects authorized were comprehensive reservoir systems for the Ohio, Upper Mississippi, Missouri, White, Arkansas, and Red basins, all of these systems having flood reduction on the Lower Mississippi and on its tributaries among their principal objectives.

The act approved August 11, 1939, named still further localities for survey, but it did not alter basic Federal policy.

The requirements of local contributions to the cost of projects were tightened by the Act of August 18, 1941, which provided that local interests should pay the costs of lands, rights of way, and damages for channel improvements. The President's authority to waive as much as 50 per cent of the cost of local protective projects in the Ohio Valley was revoked, and it was declared that authorized projects involving local cooperation would not be considered as such unless, within a period of five years, guarantees of prescribed cooperation were made by local interests. The act broadened the authority of the Corps of Engineers in survey work by providing that surveys might be made in any part of the United States and that reports on previous surveys might be reviewed and revised whenever considered necessary by the Secretary of War. It also required that funds appropriated under authority of the act for the runoff-retardation and erosion-prevention works of the Department of Agriculture could not be used for works the Department was authorized otherwise to construct, and it thus prevented duplication of activities which formed a normal part of the soil conservation, forest conservation, and other land-use adjustment programs of the Department. The significance of these changes in policy will be examined in Chapter IV. It is enough at this point to summarize the major trends of policy to

August, 1941.

By that time, construction works having an estimated Federal cost of $1,879,139,400 had been authorized, appropriations in the amount of $1,020,476,000 had been authorized and $413,835,000 actually had been appropriated for those projects. Including the 308 reports, the Corps' surveys had covered or were in process of covering all of the important drainage areas of the country. Agriculture's completed surveys had covered only a relatively small area.

The history of Federal participation in flood protection since the first Federal flood survey was initiated in 1850 reveals a spasmodic widening of Federal financial responsibility, with greatest activity in the period from 1936 to 1941. By 1941, all costs of flood-protective projects other than the expense of lands, damages, and rights of way for levees and channel improvements, were to be paid from the Federal treasury. During the same period, the scope of surveys and of authorized works was broadened to include multiple-purpose water projects, land-management measures upstream, and relocations of urban settlement. Engineering works for flood protection remained, however, the pivotal activities with which the government was concerned. The Federal interest in such measures was recognized in the above-mentioned statutes and also by the courts. In the decision in the Denison Dam case, Mr. Justice Douglas stated for the Supreme Court an opinion widely held by the American people when he said:

> . . . . There is no constitutional reason why Congress under the commerce power should not treat the watersheds as a key to flood control on navigable streams and their tributaries. Nor is there a constitutional necessity for viewing each reservoir project in isolation from a comprehensive plan covering the entire basin of a particular river. We need no survey to know that the Mississippi is a navigable river. We need no survey to know that the tributaries are generous contributors to the floods of the Mississippi. And it is common knowledge that Mississippi floods have paralyzed commerce in the affected areas and have impaired navigation itself. We have recently recognized that "Flood protection, watershed development, recovery of the cost of improvements through utilization of power are . . . . parts of commerce control." And we now add that the power of flood control extends to the tributaries of navigable streams.[1]

This decision seems truly to mirror the popular and technical opinion then prevailing that the Federal government had the pri-

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[1] Oklahoma ex rel. Phillips v. Atkinson Co. et al., 313 U.S. 508 (1940).

mary responsibility for curbing floods in order to prevent the disruption of commerce and the destruction of lives and property.

State and local policy.--While the Federal government shouldered larger responsibilities, the state and local governments for a time expanded their activities with respect to flood protection, and then, after 1938, contracted those activities rapidly. Prior to 1917, all flood-protective work in the country, with the exception of certain Federal channel improvements along the Lower Mississippi River, as noted above, was undertaken by land owners, municipalities, counties, states, or special-improvement districts. There are records of scattered levee improvements by plantation owners on the lower reaches of the Roanoke,[1] Mississippi, and other Southeastern rivers, in the eighteenth and early nineteenth centuries. Municipalities, other than New Orleans, did not begin to concern themselves with flood protection in more than a few instances until the early 1900's, when Pittsburgh made its monumental investigation of possible methods of flood protection there.[2] No remedial work resulted immediately from the Pittsburgh report. In later years, Rochester, New York,[3] Columbus, Ohio,[4] and Tacoma, Washington,[5] were among the cities that employed engineers to design remedial works for floods. Levees, channel improvements, or reservoirs were recommended in each case.

The large flood-protective enterprises during the period of state and local activity were sponsored and financed by levee and drainage boards organized under state law. Stimulated by the Federal Swamp Land Acts which in 1849, 1850, 1855, 1857, and 1860

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[1] 74th Cong., 1st Sess., Roanoke River, Virginia, House Doc. No. 65 (Washington: Government Printing Office, 1935).

[2] Flood Commission of Pittsburgh, Report (Pittsburgh: The Commission, 1912).

[3] Edwin A. Fisher, Report to Hon. Harold W. Baker, City Manager, of a Study of Flood Conditions in the Genesee River, Having Specific Relation to a Civic Center, Also to the General Subject of Flood Protection for the City of Rochester (Rochester, 1937).

[4] John W. Alvord and Charles B. Burdick, A Report to the Mayor and City Council on Flood Protection for the City of Columbus, Ohio (Columbus, 1913).

[5] Work at Tacoma was undertaken by the Inter-county River Improvement Commission. 74th Cong., 2d Sess., Puyallup River, Washington, Senate Commerce Committee Print (Washington: Government Printing Office, 1936).

provided for the conveyance to the respective states all of the wet and overflow lands owned therein by the Federal government, districts were organized to protect such lands from floods and to construct the drainage facilities necessary to render them cultivable when cleared and leveled.[1] Under the Swamp Land Acts, approximately 64,800,000 acres of land were transferred to the states with the understanding that the proceeds from their sale would be applied as far as necessary for land reclamation by means of levees and drains, and for the improvement of sanitation, such activities not being considered a Federal responsibility. Those lands having important flood problems were located principally in North Carolina, Mississippi, Louisiana and Arkansas.[2] These were poorly-drained sectors along river valleys in the Atlantic and Gulf Coastal plains, and along river valleys and lacustrine plains in Indiana and Ohio. In practice, the states claimed much land that was not swampy, and they lost little time in disposing of their holdings without attempting to make the anticipated improvements.[3] The lands promptly fell into the hands of large-scale operators who, in turn, helped organize special-improvement districts as a means of financing the drainage work. The history of drainage development is recorded elsewhere,[4] but it may be noted here that a very large part of the drainage district activity leading to land settlement in the above-mentioned areas involved extensive levee and channel-improvement works as well as drainage facilities. Some of the districts, such as the Yazoo Levee District, had high-calibre engineering staffs and expended large sums on new construction and on repair work. In 1930, out of a total of 84,408,000 acres reported by the Census to be in organized drainage enterprises, 8,374,000 acres were served by a combination of ditches and levees, and 254,651 acres by a combination of ditches, levees

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[1] Public Land Statutes of the United States, 1931, pp. 641 et seq.

[2] Thomas Donaldson, The Public Domain (Washington: Government Printing Office, 1884), pp. 219-221.

[3] John Ise, The United States Forest Policy (New Haven: Yale University Press, 1920), p. 46.

[4] "Land Available for Agriculture through Reclamation," Supplementary Report of the Land Planning Committee of the National Resources Board, Part IV (Washington: Government Printing Office, 1936), pp. 35-41.

and tile drains. The total capital investment in those works amounted to $104,873,000.[1]

In addition to levee and drainage enterprises for reclamation of cultivable wet lands, a few public districts were organized under state law primarily to facilitate the construction of engineering works for the protection of urban areas. The Ohio Conservancy Act of 1914 authorized state courts to create districts empowered to prepare engineering plans, to carry out approved plans, and to levy assessments against beneficiaries for the financing of such work.[2] Originally drafted in order to make possible protection against floods on the Miami River at Dayton, Hamilton, and nearby urban areas, the Ohio Conservancy Act resulted in the creation of the Miami Conservancy District, the Muskingum Conservancy District, and several such districts as the Scioto District. The Ohio law established a pattern of action for dealing with flood problems that was followed in a general way by thirteen or more state legislatures. Those enabling acts resulted, however, in the organization of only a few active districts for flood protection. Under the stimulation of Arthur E. Morgan, the moving spirit behind the drafting of the Ohio Act, Colorado passed a general conservancy act in 1922[3] and on the basis of that law, established a district for the construction of channel improvements at Pueblo. New Mexico passed a conservancy act in 1923[4] which aided in the organization of the Middle Rio Grande Conservancy District to provide flood protection and irrigation water for the Rio Grande valley of New Mexico above the Elephant Butte Reservoir. Both these state districts completed their scheduled work, although the district in New Mexico ran into severe financial and engineering difficulties with which it still is struggling.

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[1] U. S. Bureau of the Census, Fourteenth Census of the United States: 1930. Drainage of Agricultural Lands (Washington: Government Printing Office, 1932).

[2] Act of February 17, 1914. The events leading up to the passage of this act are described in C. A. Bock, History of the Miami Flood Control Project, Technical Reports (Dayton: Miami Conservancy District, 1918), Part II.

[3] Colorado Laws of 1922.

[4] New Mexico Laws of 1923, c. 140 and New Mexico Laws of 1927, c. 45.

In 1920 New York provided enabling legislation for the creation of river-regulating districts having flood control, power generation, and water supply as their major purposes.[1] To date, successful regulating districts have been established in the Hudson and Black basins.[2]

In 1918 Texas passed a General Conservancy District Act on the basis of which in subsequent years 15 separate districts were created, each district being empowered to construct flood protective, power, irrigation, and associated water-conservation works.[3] All but two of these districts were organized during the period 1933-1935.

Only one state organization outside of the Lower Mississippi Valley received Federal aid for flood protection prior to 1936. It was the Okeechobee Flood Control District, which cooperated with the United States under the terms of the Rivers and Harbors Act of July 3, 1930[4] in building a new levee system around Lake Okeechobee, Florida, as a means of protection against high waters caused by hurricane action over the lake.[5] The act provided that local interests should contribute at least $2,000,000 toward a project having a total estimated cost of $18,470,000.

By 1936, at least 17 states, in an effort to cope with flood problems within their borders, had established state agencies to investigate and solve the problems, or had provided for the creation of intrastate districts for the same purposes. In 13 of these states, agencies were authorized to make engineering surveys looking to flood protection. A few of the 13 agencies, such as those in California, Illinois, Minnesota, and Texas, under-

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[1]New York Laws of 1920, c. 463. Baldwins Consolidated Laws, 1938, sec. 413.

[2]Edwin S. Cullings, "Local Flood Control," Engineering News-Record, CVI (June 25, 1936), 915.

[3]Acts of 1918, Art. 8194. Vernon's Texas Statutes, 1936.

[4]46 U.S. Statutes 918. This was amended by the Act of August 30, 1935, which reduced the required initial local contribution to $200,000, and shifted the burden of maintenance costs to the Federal government. The district was organized under state law in 1929.

[5]1934 Cumulative Supplement to 1927 General Laws of Florida, Art. 4, p. 299.

took relatively detailed investigations.[1] Others, such as the special commissions in Maine and Vermont, made state-wide reports and then retired from active work, leaving to other groups the task of carrying out their recommendations.[2] Three of the states, New Jersey, Pennsylvania, and Washington, undertook to regulate, by licensing provisions, further encroachments upon flood plains within their borders (see Chapter IV).

To the extent that specific plans for flood-protective works were available, and that public support for them had been aroused, these agencies took advantage of the liberalized financing arrangements prevailing under the public-works and works-relief programs of 1933-36 to obtain construction of desired projects. The Winooski detention reservoirs in Vermont, the Muskingum Conservancy District in Ohio, and the Brazos and Colorado River conservancy districts in Texas were among those that benefited from emergency spending prior to the establishment of a national flood-control policy.

The point of view of the engineers who planned the drainage and flood-protective work of these non-Federal projects is reflected in large measure in the literature on flood protection. Major attention centered on (1) methods of determining maximum probable flood flows, (2) design of engineering works, particularly channel improvements and reservoirs, and (3) estimation of benefits to be expected from protection, with special reference to land drainage associated with flood protection.[3]

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[1] Typical surveys by those agencies are given in the following reports: California, Department of Public Works, Santa Ana River Basin, Bulletin No. 31 (Sacramento: California State Printing Office, 1930).

Illinois, Division of Waterways, Flood Control Report, 1929.

Minnesota, Department of Drainage and Waters, First Biennial Report of the Commissioner of Drainage and Waters (E. V. Willard, Commissioner, 1921).

New Jersey, State Water Policy Commission, Control of Floods on the Passaic River, Special report No. 2 (Trenton: The Commission, 1931). This followed a long series of reports by state agencies on Passaic River problems.

[2] For example, see Maine Development Commission, Maine Rivers and Their Protection from Possible Flood Hazards (Augusta, 1929).

[3] John W. Alvord and Charles B. Burdick, Relief from Floods (New York: McGraw-Hill Book Co., 1918).

Wellington George Pickels, Drainage and Flood-control

Major trends in public policy.--In non-Federal as in Federal flood protection from 1850 to 1941 the emphasis was upon curbing flood waters by engineering. Alternative forms of adjustment were not taken into account in drafting state legislation or in district plans. Evaluation of benefits received somewhat more detailed treatment, however, in state than in Federal statutory directive policies, and this might well be expected inasmuch as state work required direct assessment of a part of the costs on the benefiting property owners and public bodies. Such assessments became relatively less frequent, of course, with the adoption of the new Federal policy in 1936.

Among the first reactions to the Flood Control Act of 1936 was the authorization of state agencies to cooperate in financing and reviewing the plans for projects adopted by the Congress. New York State created a special Flood Control Commission for that purpose in 1936,[1] and in the same year Pennsylvania appropriated funds for use by its Department of Forests and Waters.[2] The Flood Control Act of 1938 brought most of those state activities to an abrupt halt. Cooperation in reservoir construction was abandoned, except in New York where the state continued to acquire land on behalf of the Federal government and where the remaining cooperation in levees and channel improvements could be handled readily by municipalities and counties without the participation of state agencies. Illinois and Pennsylvania also continue to give some financial assistance to local communities for flood protection. During the period 1936-1938 there were the beginnings of interstate agencies to facilitate cooperation with the Federal government in the financing of reservoir programs for the Merrimack, Connecticut, and Ohio basins. The 1938 act eliminated any need for cooperation, and relegated state participation to the role of criticizing and promoting Federal reservoir plans.

During the 90 years that have passed since large-scale flood-protective operations first began in the United States there has been a progressive widening of interest in the engineering

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Engineering (New York: McGraw-Hill Book Co., 1925).

Bernard A. Etcheverry, Land Drainage and Flood Protection (New York: McGraw-Hill Book Co., 1931).

[1] New York Laws of 1936, c. 16.

[2] Pennsylvania Laws of 1936, Act. No. 46.

structures to control or abate floods. The early interest in channel improvement and in levees was supplemented by the development of diversion structures and detention reservoirs, and, more recently, by multiple-purpose storage reservoirs. Attention also has been given to the possibilities of land-management measures, and of permanent shifts in the use of flood plains. While the number of engineering works has increased, the area of interest in flood protection also has grown. Not only has survey work spread far from the banks of the Lower Mississippi, but the scope of individual surveys has been broadened to include consideration of all possible types of engineering works in association with works for the use or control of water for other purposes. Drainage basins now are being treated as study units, and, within them, water conservation programs are being developed in an effort to serve all feasible human purposes.

Increasing use of large-scale levee structures and reservoirs has led to the assumption by the Federal government of large responsibility for planning and construction. For 67 years after 1850, county, municipal, and other intrastate organizations were mainly responsible for flood-protection. Beginning in 1917 the Federal activities expanded slowly until 1936, when a national policy of Federal aid was established. That policy at first encouraged state and interstate organizations for flood protection, but in 1938 the trend was reversed and Federal responsibility was extended to encompass all protection programs involving reservoirs.

The early intrastate efforts laid heavy stress upon identification of flood-protection benefits and assessment of costs, this interest reaching its peak during the rapid drainage and levee district expansion of the first two decades of the twentieth century. Federal surveys prior to the 1930's paid only slight attention to benefit and cost analysis. Beginning in the 1930's much more precise studies of those factors were made, and the trend is now in the direction of even greater detail and precision.

Notwithstanding these and many other changes in policy governing public aid to flood protection, the basic approach has remained essentially the same. "Is flood protection warranted," continues to be the prevailing question.

During the entire period under discussion, public action has unfolded in response to gradually widening realization of the flood menace, but it has been translated into legislation only at irregular intervals determined for the most part by hydrologic conditions. Each flood of national importance since 1915 has given rise to a change in Federal flood-protection policy: each major change in policy prior to 1941 has been made within a year or two after a great flood. National catastrophes have led to insistent demands for national action, and the timing of the legislative process has been set by the tempo of destructive floods.

Forecasting

Except in the few areas where complete protection has been afforded by engineering works, dwellers of flood plains require as early a warning as possible of the coming of floods in order that people and property can be evacuated, and in order that other precautions can be taken against flood losses. The U. S. Weather Bureau and its predecessors established the first flood forecasting service along the Lower Mississippi River in 1870, and received regular appropriations from the Congress for a separate service after 1891.[1]

Inasmuch as the early forecasts were based upon the stages of rivers upstream from the reaches subject to flood, the system was applied most extensively and yielded best results along the lower reaches of large rivers such as the Mississippi, Ohio, Red, and Arkansas. By 1936, the Weather Bureau had organized more than 70 centers from which forecasts of river stage were released. The forecasts utilized rainfall as well as stage data, and involved numerous empirical formulae developed by the Bureau's forecasters in the light of previous flood experiences.

In 1937 the Bureau, in cooperation with the Commonwealth of Pennsylvania and the U. S. Geological Survey, launched a new type of forecasting for the Susquehanna Basin, drawing upon telephonic reports on weather conditions and upon the unit-hydrograph method of estimating stream flow so as to build up the expected flow for any desired point. The Bureau has since expanded such methods to a few other large streams, and recently has laid plans to expedite service to the headwater reaches where heretofore, because of small drainage area, high rate of runoff concentration,

[1] U. S. Signal Office, Annual Report of the Chief Signal Officer, 1891 (Washington: Government Printing Office, 1892), pp. 13-16.

and probability of intense precipitation, the Bureau has not been able to make forecasts.

Prior to 1937 the system grew slowly, and made only a few advances in forecasting techniques. It was understaffed, and it received little public attention except in time of flood. In some areas the War Department developed its own independent and superior service.

The Bureau's forecasts, even on large streams, have not always been successful, and there are instances, such as along the Lower Ohio River during the flood of January, 1937, when the forecasted peaks were as much as 6 feet below the actual peaks occurring 24 hours later. At Pittsburgh during the March, 1936, flood the crest one morning was 9 feet above that predicted on the preceding day, although that prediction was for a stage exceeding any previously recorded stage.

The forecasting system has reduced flood losses materially, and has prevented much human distress, although, as will be shown in Chapter IV, it is difficult to make a close estimate of its value. On many flood plains it is an essential part of human adjustment to flood hazard. It is an integral phase of the operation of flood-control reservoirs. At no time has the Bureau tried, however, to stimulate more effective use of the forecasts in preventing flood losses, and it has not even made detailed studies to determine the degree to which forecasts have been applied.

The history of the forecasting effort reveals an early development of stage-forecasting methods which led to a long and somewhat unimaginative period of forecasting on the lower reaches of large rivers, followed, in 1937, by rapid improvement in methods of forecasting, with particular reference to smaller drainage areas upstream.

Public Relief

The third main line of public action consists of relieving human distress resulting from floods. From the earliest damaging floods, community assistance has been given to those who suffer impairment of health or damage to property. Prior to the organization of a national Red Cross, relief from flood disasters commonly was handled by groups of interested citizens. For example, after the Pittsburgh and Allegheny flood of July 26, 1874, which caused the death of more than 119 persons, a special committee was appointed by the mayors of the two cities to reduce the distress. That group raised $63,000 from local donations, and expended the entire amount in cash payments to deserving sufferers, in purchase of merchandise, in burials, and in a deposit for the benefit of children made orphans by the flood.[1] It prided itself upon not having to request outside aid and upon meeting all urgent demands for help. Federal assistance seems to have been given only in the assignment of troops to guard the scene of the disaster. Similarly, after the great Miami River flood of 1913, the people of Dayton, Ohio, raised a large fund to be used by the Dayton Citizens' Relief Committee for the aid of their fellow townsmen who had suffered losses, the fund later being given over to the Red Cross for administration.[2] These amounts now appear small by comparison with expenditures currently made for flood relief by Federal agencies.

The Federal government began in 1874 to make direct grants of food and shelter to flood sufferers, and appropriations were made for those purposes following each great flood thereafter, as shown in Table 3. The funds were disbursed chiefly by the Quartermaster Corps of the War Department, and were administered for the most part by local and state agencies and by the Red Cross.

As the annual toll of flood losses increased and as the American Red Cross enlarged and extended its field staff, its national and chapter organizations became the center of public-relief work. The Red Cross assisted in caring for the victims of a few of the serious floods in the 1920's and then during the great Mississippi River flood of 1927 it took over in large measure the work of administering aid by Federal as well as non-Federal agencies.[3] While other agencies such as the Corps of Engineers

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[1]Report of the Citizens' Executive Relief Committee of the Cities of Pittsburgh and Allegheny for the Relief of the Sufferers by the Flood of July 26, 1874 (Allegheny: Ogden and Vance, 1876), pp. 1-61.

[2]Bock, op. cit., pp. 11-14.

[3]The Congressional charter of organization approved by the Act of January 5, 1905 (33 U.S. Statutes 599) and amended by the Act of February 27, 1917 (39 U.S. Statutes 946), charges the American National Red Cross "To continue and carry on a system of

TABLE 3

FEDERAL APPROPRIATIONS FOR RELIEF OF FLOOD SUFFERERS, 1874-1942

Authorizing Act		Provision
Reference	Date	
18 U.S. 34	4/23/74	Authorizes issue of food and Army clothing to sufferers from overflow of lower Mississippi River; no amount specified.
18 U.S. 45	5/13/74	Appropriates $190,000 for the purchase of flood and clothing for relief of sufferers from overflow of Mississippi River.
22 U.S. 378	2/25/82	Appropriates $100,000 for purchase and distribution of subsistence stores for sufferers from overflow of Mississippi River.
22 U.S. 378	3/10/82	Authorizes use of Army hospital tents for shelter to sufferers from overflow of Mississippi River; no amount specified.
22 U.S. 378	3/11/82	Authorizes use of Government vessels for transportation and distribution of rations and supplies for sufferers from overflow of Mississippi River and tributaries; indefinite appropriation.
22 U.S. 379	3/21/82	Appropriates $150,000 for furnishing food for sufferers from floods in the Mississippi River and tributaries.
22 U.S. 379	4/1/82	Appropriates $100,000 for purchase and distribution of subsistence stores for sufferers from overflow of Mississippi River and tributaries.
22 U.S. 44	4/11/82	Appropriates $20,000 for purchase of seeds and distribution among sufferers from overflow of Mississippi River and tributaries.
22 U.S. 267	2/12/84	Appropriates $300,000 for purchase and distribution of subsistence stores, clothing, etc., for sufferers from overflow of Ohio River and tributaries.

TABLE 3 - Continued

Authorizing Act		Provision
Reference	Date	
23 U.S. 268	2/15/84	Authorizes use of Army tents for shelter to sufferers; use of Government vessels for transportation and distribution of supplies. Appropriates an additional $200,000 for same objects.
26 U.S. 33	3/31/90	Appropriates $25,000 for purchase of 2,500 tents to be loaned to state authorities for use of sufferers from floods, in Arkansas, Mississippi and Louisiana.
26 U.S. 33	4/25/90	Appropriates $150,000 for purchase and distribution of subsistence stores for sufferers from overflow of Mississippi River and tributaries. Use of Government vessels for transportation and distribution of supplies.
30 U.S. 219	4/7/97	Appropriates $200,000 for purchase and distribution of subsistence stores for sufferers from overflow of Mississippi River and tributaries and Red River of the North.
30 U.S. 221	6/9/97	Reappropriates $10,000 (remaining under resolution of April 7, 1897) for purchase and distribution of subsistence stores and payment of transportation, for suffers from overflow of Rio Grande near El Paso.
37 U.S. 633	5/9/12	Appropriates $1,239,179 for tents, rations, etc., for sufferers from floods in Mississippi and Ohio valleys.
37 U.S. 601	8/26/12	Appropriates $4,500 for mileage of Army officers and contract surgeons in connection with relief of flood sufferers in Mississippi and Ohio valleys.
38 U.S. 208	10/22/13	Credits Corps of Engineers for expenditures of $34,192 made for relief of flood sufferers, in Mississippi, Yazoo and Ohio basins.
38 U.S. 211	10/22/13	Appropriates $5,000 to reimburse life-saving service for rescue and relief of flood sufferers in the Middle West.

TABLE 3 - Continued

Authorizing Act		Provision
Reference	Date	
38 U.S. 215	10/22/13	Appropriates $654,448 to reimburse certain Army appropriations for relief of sufferers from floods, tornadoes, and fires in Mississippi and Ohio valleys. Peach tree, Ala., and Nebraska.
38 U.S. 216		Credits $42,431 to certain Army accounts for expenditures for relief of flood sufferers in Ohio and Indiana, and on Ohio and Mississippi river and tributaries.
39 U.S. 11	2/15/16	Authorizes loan, issue, or use of tents, provision and supplies and Quartermaster's and Medical Department for relief of sufferers from overflow of Mississippi River and tributaries, no amount specified.
39 U.S. 434 39 U.S. 534	8/3/16 8/24/16	Appropriates $545,000 for relief of flood sufferers in southern states, and West Virginia, including issue of seeds and Army supplies and supplying employment for destitute persons.
42 U.S. 19	6/8/21	Authorizes issue of subsistence and quartermaster's supplies to persons suffering from overflow of Arkansas River and tributaries in Colorado; no amount specified.
44 U.S. 1065	2/9/27	Authorizes issue of $936 quartermaster's supplies to persons suffering from overflow of Arkansas River and tributaries in Colorado; no amount specified.
44 U.S. 1792	2/25/27	Authorizes determination of losses to property owners near Hatch and Santa Teresa, New Mexico, by overflow of Rio Grande; and appropriates $75,000.
43 U.S. 53	1/26/28	Authorizes employment, by Secretary of Agriculture in cooperation with the states, of local agents necessary to aid in rehabilitation of farm lands in areas affected by floods of 1927.
45 U.S. 1306	2/25/29	Authorizes loans for purchase of seed, fertilizer, etc., in storm

TABLE 3 - Continued

Authorizing Act		Provision
Reference	Date	
		and flood stricken areas of southwestern states; $6,000,000 appropriated in deficiency act of March 4, 1929 (U. S. 1635).
46 U.S. 84	3/12/30	Appropriates $1,660,000 to aid state of Alabama in construction of roads, etc., damaged by floods in 1929.
46 U.S. 386	5/27/30	Appropriates $506,067 to aid state of Georgia in construction of roads, etc., damaged by floods in 1929.
46 U.S. 489	6/2/30	Appropriates $805,561 to aid state of South Carolina in construction of roads, etc., damaged by floods in 1929.
46 U.S. 829	6/28/30	Relieves state of Vermont from accountability for certain Federal property lost, etc., in connection with relief work incident to flood of November, 1927.

and the State Departments of Health defended the levee lines or guarded against epidemic, the Red Cross, under the general direction of Herbert Hoover as Secretary of Commerce, assumed the principal role of guiding emergency evacuation and of feeding, clothing, housing and providing medical services for the refugees. For the next ten years the Red Cross continued as the major national agency dealing with flood distress.

In 1929 and 1930 Congress appropriated funds for use by states in repairing flood losses (see Table 3). These appropriations were the first to place the Federal government squarely in the position of rehabilitating flood sufferers. After 1933 the newly-organized Federal relief agencies began to extend aid for such purposes, and during the Ohio River flood of 1937 a large

National and international relief in time of peace and to apply the same in mitigating the sufferings caused by pestilence, famine, fire, flood, and other National calamities, and to devise and carry on measures for preventing the same."

part of the total relief expenditures was made by those agencies directly (see Chapter IV).

After 1927 it became the common practice of municipal and state governments and of the Red Cross to provide for flood refugees while away from their homes, and to lend aid to those who needed cash or goods in order to regain their previous level of living. According to need, Red Cross grants of funds were used for repairs, food, clothing, and other essentials. Once returned to his home, a flood refugee received aid in cleanup, repairs, and rehabilitation only in so far as he could not finance those operations himself. The work-relief agencies and the Civilian Conservation Corps contributed additional help by participating in the cleanup activities and by repairing publicly-owned structures such as bridges and roads. Direct grants or assignments of work relief were made to flood sufferers in the lower income brackets. In 1934 the Reconstruction Finance Corporation received its first authorization to make loans for repairs of damages from floods and other catastrophes, and in 1937, the Disaster Loan Corporation was established to extend credit to individuals or corporations requiring help in rehabilitation.[1] These sources of aid, combined with the authority which the Congress gradually gave to the Corps of Engineers to repair levees and other flood-protection structures damaged by floods, covered a much wider range of flood losses than that encompassed by the Red Cross relief program. By 1941, the total public relief program, as described in detail in Chapter IV, had expanded to cover, by grant or loan, most of the serious losses from flood.

The Private Approach to the Flood Problem

In considering the action taken by public agencies in building flood-protective works, in forecasting floods, and in cushioning the harmful effects of floods, it should not be forgotten that flood losses have been reduced substantially by the action of individuals and corporations. Where public action to

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[1] 48 U.S. Statutes 589. Act of April 13, 1934. This was later extended through 1936.

50 U.S. Statutes 19. Act of February 11, 1937. The activities of the Corporation were extended through 1940 by the Act of March 4, 1939.

cope with floods is deferred or is not economically feasible, it remains for the property owners and other residents to deal with floods as best they can. It probably is neither unjust nor exaggerated to suggest that most such residents have made no special effort to meet or remedy the flood hazard. There are no national statistics to support this suggestion, but a review of the efforts of many flood-plain residents to adjust their activities to floods indicates that once the flood plain is occupied, other adjustments to floods are slow in coming and are the exception in so far as residential and commercial occupance is concerned.

Aside from making emergency preparations when an imminent flood threatens, flood-plain occupants have a choice of readjusting their patterns of land use, of altering buildings and other physical structures, and of laying aside adequate reserves or insurance against future catastrophes. Such readjustments have been made successfully in one or more sections of the United States, but they are untried for the most part, and they do not command the attention of Federal or national organizations. While the Federal government has devoted its efforts to engineering, hydrologic, and welfare activities affecting floods, property owners and residents have been left to themselves to find other practicable ways of reducing flood losses. In this effort they have had no systematic aid from Federal agencies.

In a few instances, city planners have sought to direct urban growth away from areas subject to flood hazard. Several states, as already indicated, have curbed, by use of the police power, undue encroachment upon stream channels. Certain industries, such as the railway and electric-power industries, have given special attention to techniques of reducing flood losses. Early but abortive attempts have been made to insure against flood losses. At least one Federal loan agency--the Federal Housing Administration--has discouraged building of new housing facilities in flood plains. Otherwise, flood-plain dwellers have been left to themselves to deal with the flood problem as best they can.

Summary of Prevailing National Policy

The policy declared by the Congress in the Flood Control Act of 1936, as amended, represents one segment only of the total national policy relating to the flood problem. Taking into account all phases of public action and inaction, the policy in essence is one of protecting the occupants of flood plains against floods, of aiding them when they suffer flood losses, and of encouraging more intensive use of flood plains. By providing plans and all or at least half of the cost of protective works, the Federal government, under the policy established in 1936 and 1938, reduces the flood hazard for the present occupants and stimulates new occupants to venture into some flood plains that otherwise might have remained unsettled or sparsely settled. Even though no protection is provided or planned, the Federal forecasting system tends to encourage continued use of flood plains by reducing the expectancy of loss and discomfort from flood disasters. Public relief is now so widespread that the threat of flood, while not pleasant, has lost many of its ominous qualities. If a community wishes to relocate outside of a flood plain, Federal help is given to the extent that funds might otherwise have been expended on local-protective works, but if a flood-plain occupant wishes to rehabilitate a relatively profitable business or desirable residence in the old location after a flood he may obtain Federal aid for that purpose.

At the same time, the occupants are themselves concerned in an important degree with reducing flood losses by emergency removal and by changes in land use and structures. Except in so far as the forecasting system promotes emergency removal, the prevailing public policy is largely neutral; it neither encourages nor discourages such activities.

Obviously, the flood plains of the United States will not be permanently evacuated and returned to nature merely because of the annual bill for their occupancy, which now approaches $95,000,000. Neither will they be occupied as intensely as consistent with other relevant physical and cultural conditions solely because, irrespective of cost, suitable engineering and land-use devices can be developed to curb or prevent floods. No general rule can be established as to the most satisfactory arrangement of land occupance in relation to local stream regimen and flood-plain conditions. In some instances, profound modifications in the stream regimen or channel have been necessary, and in other instances the cultural forms and patterns have been adjusted delicately to the earlier landscape. By and large, a fairly harmonious combination has been developed. Wherever the adjustments are not satisfactory, as attested by crippling flood losses, wherever a regressive occupance obtains, or wherever the flood-plain resources are not used as fully as practicable, a re-adjustment may be in the public interest. This, it has been shown, is the central flood problem: how best to readjust land occupance and flood-plain phenomena in harmonious relationship?

Outline of a Geographical Approach

From the three converging streams of public action with respect to the flood problem, and from corollary fields of action, such as land-use planning, we may draw an approach to this problem more comprehensive than any one of them. It is a view which considers all possible alternatives for reducing or preventing flood losses; one which assesses the suitability of flood-protective works along with measures to abate floods, to evacuate people and property before them, to minimize their damaging effects, to repair the losses caused by them, and to build up financial reserves against their coming. It is a view which takes account of all relevant benefits and costs. It analyzes the factors affecting the success of possible uses of a flood-plain. It seeks to find a use of the flood plain which yields maximum returns to society with minimum social costs, and it promotes that use.

Unless the major factors affecting flood-plain use are appraised, there can be no assurance that the recommended use is beneficial. Unless all possible forms of adjustment to floods are canvassed, the less expensive ones cannot be selected with certainty. Unless the analysis leads to practicable forms of re-adjustment, there is little purpose in examining these possibilities.

Analyses of this character have not been made in the past, and even the need for them has been stated only in general terms.

Marsh, while primarily interested in the prevention and protection phases of the flood problem, appears to have recognized these propositions in his discussion of floods in 1898.[1] McGee called attention in 1891 to several possible adjustments and noted with a tinge of pessimism that, "As population has increased, men have not only failed to devise means for suppressing or for

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[1]George P. Marsh, The Earth as Modified by Human Action--A Last Revision of "Man and Nature" (New York: Charles Scribners Sons, 1898), pp. 472-474, 498.

escaping this evil, but have, with singular short-sightedness, rushed into its chosen paths."[1] Semple in 1911 described several types of riverine adjustments but did not analyze the problem of reducing flood losses.[2] Russell merely noted some of the factors affecting the occupance of flood plains.[3] J. Russell Smith called attention to the need for a different attack upon the Mississippi River problem following the flood of 1927[4] and various editorial writers[5] and public agencies[6] suggested after the 1936 and 1937 floods that a broader approach was desirable, but their suggestions have not found wide acceptance in practice. Today there are no studies or programs which meet the requirements outlined above.

This geographical approach to the flood problem appears to be more nearly national in scope, and more nearly sound from a social standpoint than the approaches which dominate prevailing public policy. The remainder of the dissertation states the evidence in support of this approach and shows its implications in public policy and in geographical research.

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[1]W. J. McGee, "The Flood Plains of Rivers," Forum, XI (1891), 221-234.

[2]Ellen Churchill Semple, Influence of Geographic Environment (New York: Henry Holt and Company, 1911), pp. 322-327, 363-370.

[3]J. Russell Smith, "Plan or Perish," Survey, LVIII (1927), 370-377.

[4]I. C. Russell, Rivers of North America (New York: G. P. Putman's Sons, 1898), p. 114.

[5]"A Modest Proposal for Flood Control," New Republic, May 19, 1937, p. 34.

[6]New York, Division of State Planning, A Common Sense View of the Flood Problem, Bulletin No. 28 (Albany, May, 1937). A similar view is taken by Allen Hazen in Flood Flows: A Study of Frequencies and Magnitudes (New York: John Wiley and Sons, 1930), pp. 2-3, 177-179.

CHAPTER II

ELEMENTS OF THE FLOOD PROBLEM

The flood problem has four basic elements. These are: (1) the flood hazard, (2) the environmental features of the flood plain, (3) the human occupance of the flood plain, and (4) the adjustment of human occupance to flood hazard. Each of these is present in some degree in every flood problem, whatever its nature. According to the comprehensive view outlined in the preceding chapter, each must be taken into account in arriving at a satisfactory solution of such problems.

For this reason, and because the terms describing these elements are used somewhat loosely in engineering and scientific literature, they are defined here prior to considering their interrelations in Chapters III and IV. Most of the following definitions coincide with those in standard nomenclature, but it has been necessary to suggest a few new terms for new concepts and to assign more nearly precise meanings to several old terms.

Floods

The term flood is used to mean any stream flow which greatly exceeds the average stream flow, whether or not it overtops the channel banks. The term has been used variously to mean "an unusually high flow of a stream,"[1] or "any flow equal to or greater than a designated basic flow."[2] In a stream channel having well-defined banks, any flow which overtops those natural curbs is, under the definition given above, a flood. In a channel lacking such banks, or containing a stream with an average daily flow reaching a height substantially less than bank-full capacity,

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[1] National Resources Planning Board, Hydrologic, Hydraulic, and Sanitary Nomenclature--Second Preliminary Draft (Washington: National Resources Planning Board, 1940), p. 117.

[2] Clarence S. Jarvis and others, Floods in the United States--Magnitude and Frequency, U. S. Geological Survey Water-supply Paper No. 771 (Washington: Government Printing Office, 1936), pp. 463-464.

a flood is any flow greatly in excess of the average. In short, the concept of flood centers upon the occurrence of flows markedly greater than the mean.

The components of extreme flows are defined in greater detail in the following terms, which are in relatively general use by hydrologists and engineers:

A flood event is a series of flows constituting a distinct, progressive rise, culminating in a peak, crest, or summit, together with the recession that follows the crest arbitrarily selected for consideration as a unit of flood occurrence.[1]

Flood stage is that elevation of the water surface--selected by local usage or by an investigator--above which the stream is considered to be in flood. Commonly, it is the stage at which damage begins.

Flood crest is the highest elevation reached by flood waters in a flood event.[2] It commonly is measured in feet above an accepted datum, such as flood stage.

Momentary flood peak is the maximum rate of flow attained during a flood event; usually this is the flow at the time flood crest is reached.[3] (It commonly is measured in cubic feet per second.)

Daily flood peak is the maximum daily flow during the flood event.[4]

Annual flood is the maximum daily flow during 12 consecutive months, that is, the highest daily flood peak for a year of record.[5]

Average annual flood is the mean of the annual floods during the period of record.[6]

From the standpoint of flood-plain occupance, the flood crest is in most instances the critical feature of the flood event, but inasmuch as streams commonly are measured on the basis of their flow rather than on that of their water surface, and inasmuch as

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[1] Ibid., p. 464.

[2] National Resources Planning Board, Hydrologic, Hydraulic, and Sanitary Nomenclature, Second Preliminary Draft (Washington: National Resources Planning Board, 1940), p. 61.

[3] Ibid., p. 118.

[4] Jarvis, op. cit., p. 462.

[5] Ibid., p. 463.

[6] Ibid.

protective works must be designed in terms of flow control as well as stage reduction, most computations of flood magnitude and frequency are in terms of daily flood peaks and of annual floods. The meaning of these terms is illustrated in part by a schematic hydrograph of stream flow and stage during one flood event (Fig. 1).

In designing flood-protection works and in forecasting floods, accuracy in the measurement of these quantities is highly important, but, in analyzing most other hydrologic aspects of the flood problem, it is rarely essential or practicable to describe the flood phenomena with equal precision. Therefore, the definition of flood is purposely broad so as to refer equally well to flood crest, momentary flood peak, average annual flood, or to any extreme departure from an arbitrary base.

The methods of analyzing data on stream flow and other hydrologic data so as to estimate the probable frequency of occurrence of a flood of a given magnitude for a given stream are numerous and intricate, and they are the subject of an extensive literature.[1] From this literature one concept may be drawn that is used repeatedly in dealing with flood problems. That is the concept of a flood of a given frequency. With the aid of adequate data on stream flow, precipitation, ground water, evaporation, soil characteristics, and vegetal cover, and with a sound method of probability analysis, it is possible to state, with varying degrees of accuracy, that a particular flood flow is, say, a "ten-year flood" or a "ten per cent chance flood" that is equalled or exceeded on the average of once in 10 years. Such frequency estimates are used often in engineering studies, and they may be accepted with three qualifications. (1) Their use does not imply any periodicity in flood occurrence. (2) It does not suggest that a "ten-year flood" is certain to occur during every ten-year period. (3) In all cases, such an estimate of frequency is only as reliable as are the basic study and data. Moreover, there are in use a large number of techniques of statistical analysis which yield widely divergent results. The possible range of such results is illustrated by the estimates prepared on the basis of relatively

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[1] Ibid., pp. 28-67.
National Research Council, American Geophysical Union Transactions of 1939, II, 143-218.

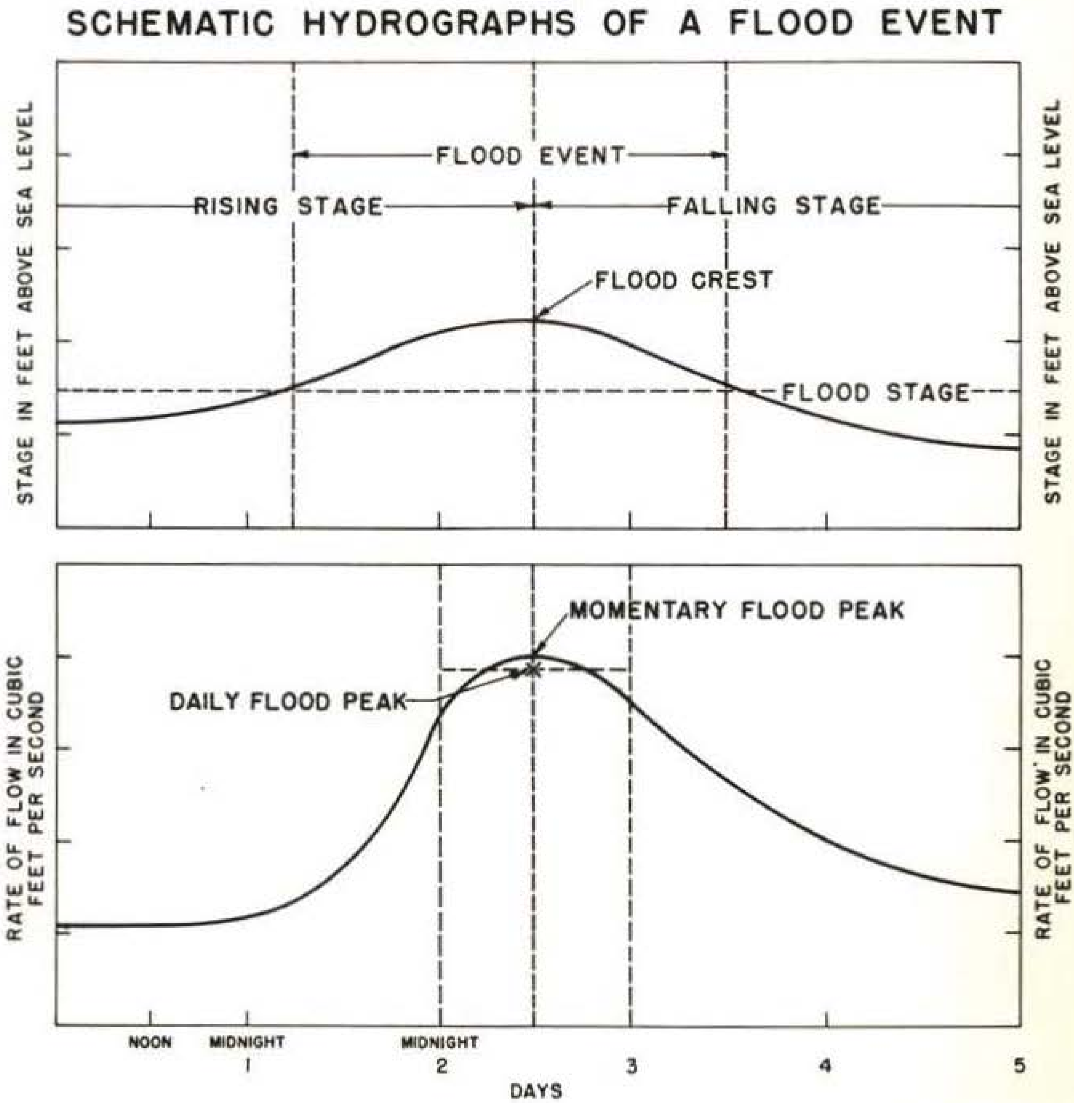

Fig. 1.--Schematic hydrographs of a flood event

satisfactory stream-flow records for the Tennessee River at Chattanooga, where divergencies of as much as 400 per cent in the estimated amounts of highly infrequent flows were obtained by Saville, Slade, and other investigators (Fig. 2).

Either through frequency analysis or the so-called "rational" analysis of hydrologic data, it also is possible to estimate the magnitude of the probable maximum flood, which is the maximum flow expected to occur on a given stream during a designated period or during an infinite period. Engineers cautiously designate such estimates as "project floods" or "1,000 year floods" or "probable limiting flood," but all may be grouped under the general definition given above, and all are used with the understanding that they involve numerous assumptions as to the continuation of present climates and the chance combination of physical conditions favorable to floods. The term "project flood" also is used to mean a flood, less than the probable maximum flood, for which projects are designed.

The significant features of flood events, from the standpoint of human adjustment to them, other than the probable frequency of their occurrence, are (1) season of occurrence, (2) rate of rise and fall, (3) velocity and (4) sediment load. Taking into account only the drainage areas in excess of 500 square miles for streams causing the greater part of the mean annual flood losses in the United States, and neglecting the cloudburst type of flood affecting smaller drainage areas, three outstanding forms of seasonal occurrence may be recognized in the United States.

First, there are areas in which infrequent great floods as well as frequent floods of lesser magnitude occur only during well-defined seasons. In the wet, mesothermal climatic province of the Pacific Northwest and in the semiarid and arid microthermal provinces of the Great Basin and Rocky Mountain, where floods occur chiefly as a result of spring snow melt from the mountains, and in the semiarid, mesothermal areas of the Southern California coast, where winter rains cause floods, it is possible to predict their season of occurrence with high accuracy.

Second, there are areas lacking any pronounced season of flood occurrence. These lie principally in the humid, mesothermal climatic provinces of the Southeastern and Gulf coasts.

Third, there are the areas in which a great flood may occur in any month of the year, but in which most floods occur

COMPARISON OF FLOOD-ESTIMATING METHODS, TENNESSEE RIVER AT CHATTANOOGA, TENN.

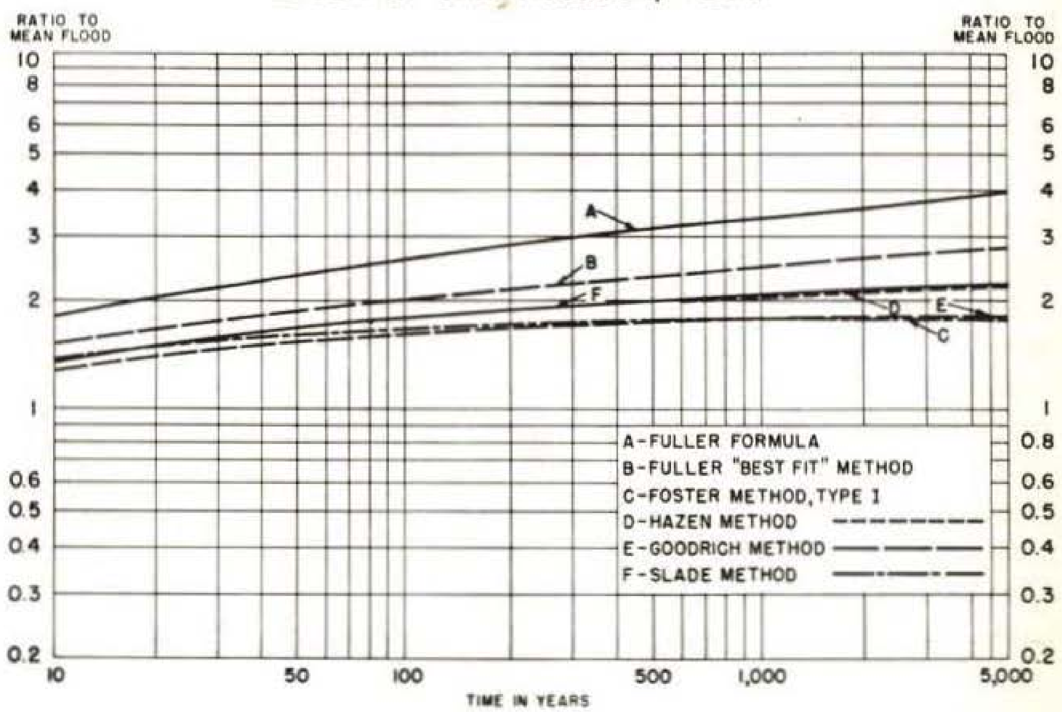

Fig. 2.--Comparison of methods used in estimating floods, Tennessee River at Chattanooga, Tennessee. This illustrates the general form of charting the relation of flood magnitude to frequency in connection with probability analysis. It also shows the divergent results from analysis of the same, relatively full body of data concerning past flood flows. The "ratio to mean flood" is in terms of discharge rather than stage. (From Geological Survey, Water-supply Paper No. 771.)

during a fairly well defined season. These are the humid and subhumid, microthermal climatic provinces of the Northeastern states and of the upper Ohio and Mississippi basins. Floods in those provinces are most frequent in winter and spring, and, inasmuch as most Lower Mississippi floods involve substantial contributions from the Ohio and Upper Mississippi basins, that stream is likely to have its greater floods during winter and spring.

This threefold classification is intended only to suggest a broad difference in season of flood occurrence. In future, as more stream-flow data are analyzed in detail, it should be possible to distinguish regional variations with provisions, always recognizing that cloudburst storms over relatively small drainage areas may cause sharp flood crests in almost any section of the country at any season.

The cloudburst type of flood is one extreme in the possible rate of rise and fall of water during a flood event. As illustrated in the South Concho River flood of September, 1936, near San Angelo, Texas (Fig. 3), the crest occurs within a few hours after the rise begins, and falls off below flood stage rapidly, although the sharp crest may be repeated shortly thereafter. Such events, occurring in less than 48 to 70 hours, may be termed <u>sharp-crested floods</u>. At the other extreme are the great flows of large rivers that continue for more than 70 hours and may be termed <u>broad-crested floods</u>. The Lower Mississippi has sometimes exceeded flood stage for as long as 30 days. The 1936 flood of the Connecticut River at Holyoke, Massachusetts, is more nearly typical of such floods (Fig. 3). For some sharp-crested floods, the momentary peak discharge may exceed the maximum daily flow for the same flood event by as much as 1,660 per cent.[1]

Sharp-crested floods are characterized, in general, by greater water <u>velocities</u> than broad-crested floods, but velocity is primarily a function of stream-bed gradient and of channel configuration and resistance, rather than of rate of rise and fall. The amount and mechanical composition of <u>sediment</u> carried in suspension and as bed load is a function of those two conditions and also of upstream land use, season of flood occurrence,

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[1] Jarvis, <u>op. cit.</u>, p. 108. This flow occurred in the Vermejo River near Dawson, New Mexico on June 30, 1934. The maximum daily flow was 62 c.f.s. and the momentary peak was 1,090 c.f.s.

TYPICAL FLOOD HYDROGRAPHS

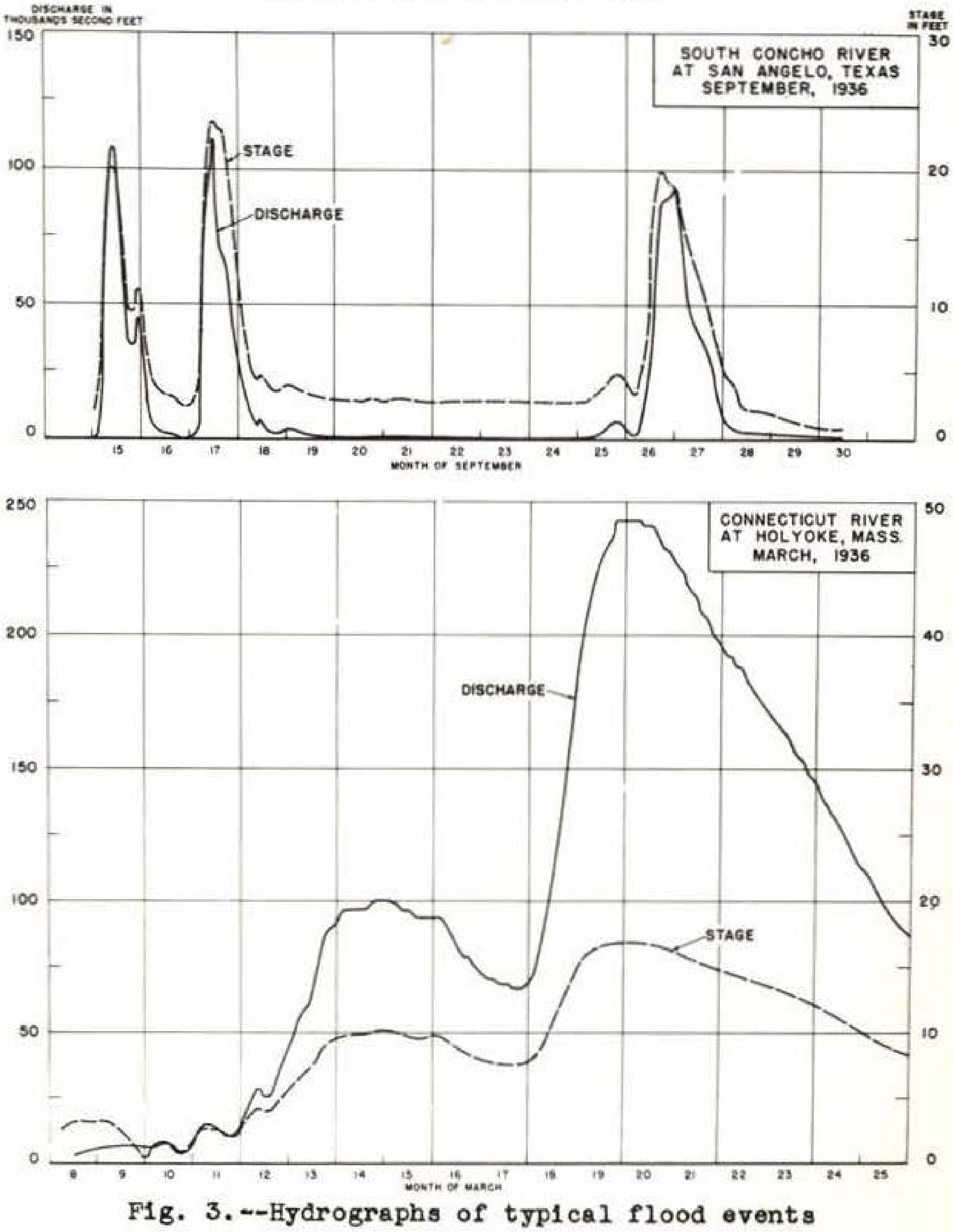

Fig. 3.--Hydrographs of typical flood events

character of underlying rock, ground-water level, local base level of stream erosion, and related conditions. Although it is convenient to distinguish between high and low velocities and between large and small loads of sediment, and also to characterize the sediment according to its size (silt, sand, gravel, boulders), there do not appear to be any especially important classifications of the two characteristics.

Flood Plains

The term flood plain is used to mean that land outside of a stream channel described by the perimeter of the probable limiting flood. It is land which is not covered by the stream at low flow or average flow, but which has been flooded in the past or may be flooded in future. It has no other essential feature; it may be broad or narrow, frequently flooded or rarely flooded. In this sense, every stream which has floods also has a flood plain.

Any flood plain may be considered to be subdivided into flood zones, all the land in each of which is subject to floods of approximately the same frequency, the zones of most frequent flooding lying at the lowest elevation, and nearest to the channel, except where there are natural levees or other obstacles to overflow.

This definition of flood plain differs from that commonly employed by geomorphologists, who use it to mean the alluvial floor of a valley. Inasmuch as the perimeter of the probable maximum flood in some valleys exceeds the limit of alluvial deposition, particularly in the valleys of streams which have not reached grade, and in other valleys falls far short of covering the alluvial fill, as in old valleys having shifting meander belts, the area actually subject to flood does not correspond in detail with the geomorphic flood plain. Indeed, none of the common geological classifications of streams or valleys is of special significance in a broad approach to the flood problem.[1] From the stand-

[1] Clyde Mallot in The Valley Form and Its Development, Indiana University Studies, XV (1928), 26-31, suggests a two-fold classification: Initial or primary flood plains which are of restricted width, shallow depth of alluvial deposits, and are developed by deposition by a shifting channel supplemented by a veneer of finer materials, and Final or cumulative plains which are developed chiefly by accretions from on top so as to form alluvium of considerable width and also exceeding the stream channel in depth.

point of human adjustment to flood hazard, it makes little difference whether a segment of a stream valley is consequent or subsequent, mature or old, rejuvenated or drowned. The significant physical features are the width of the plain, its slope, its underlying materials, and its position in the stream system.

On the basis of relative width, it is convenient to make following classification, taking as the criterion the average width of the flood plain on one side of the stream:

> Narrow flood plains are those having an average width of less than 120 feet.
>
> Medium-width flood plains are those having an average width of more than 120 feet and less than one-half mile.
>
> Broad flood plains are those having an average width of more than one-half mile.

Most flood plains have approximately the same average width on both sides of the stream but over long reaches in some cases and over short reaches in most cases they are much wider on one side than on the other. It is important, therefore, to characterize the two sides separately.[1]

A further distinction of value in dealing with flood plains relates to their underlying materials. Alluvial flood plains in which the surface materials are water-laid deposits of recent origin and which flank actively aggrading streams stand in contrast to non-alluvial flood plains in which downward erosion or diastrophism is the dominant process.[2]

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[1]The upper limit of 120 feet for narrow flood plains is the average width of the necessary right of way for a single-tract railroad together with a two-lane highway, and it also coincides roughly with the minimum width of fields for effective cultivation in many parts of the United States. One-half mile is selected as a convenient limit diversion between medium and broad flood plains of urban occupancy adjacent to a highway and a railway, or for a square-shaped farm having an area of 160 acres.

[2]A complete classification of alluvial plains is suggested in Frank A. Melton, "An Empirical Classification of Flood-plain Streams," Geographical Review, XXVI (1936), 593-609. Alluvial deposits are classified in great detail by Stafford C. Happ, Gordon Rittenhouse, and G. C. Dobson in Some Principles of Accelerated Stream and Valley Sedimentation, U. S. Department of Agriculture Technical Bulletin No. 695 (Washington: Government Printing Office, 1940), pp. 22-31, and delta deposits are reviewed by Richard Joel Russell in "Physiography of the Lower Mississippi River Delta," Lower Mississippi River Delta--Reports on the Geology of Plaquemines and St. Bernard Parishes, Geological Bulletin No. 8 (New Orleans: Department of Conservation, Louisiana Geological Survey, 1936), pp. 3-199.

The nomenclature of valley forms is fairly well developed, of course, and no new definitions are suggested here.

Flood-plain Occupance

The term occupance is used to mean the human process of occupying or living in an area, and the transformations of the initial landscape which result. It comprises all of the adjustments made by man--rationally or irrationally--to the natural and social environment of an area, and all of the landscape features involved therein.[1]

Occupance is classified according to the more common functions performed. On a simplified basis, there are the following principal types:

- Agricultural
- Residential
- Commercial
- Manufactural
- Transportational
- Recreational
- Governmental

Other classifications--for example, those based upon landscape forms, or upon pattern of operating units, or upon relative success or failure of occupance--are considered unnecessary. A systematic geography of flood-plain occupance would explore, however, the significance of such classes of occupance in relation to other landscape distributions and to cultural conditions.

Human Adjustment to Floods

The term adjustment is used to mean an ordering of occupance. Adjustment to floods therefore means an ordering of occupance to floods and to the flood hazard. The ordering may be systematic or unsystematic, rational or irrational, conscious or unconscious, but it comprises an observable arrangement of occupance in relation to floods. It may result in transformation of the landscape of other areas as well as that of a flood plain. Under this definition, all occupancy of flood plains involves one or more adjustments to floods; all adjustments to ..oods exist only

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[1]In this and other pertinent respects, definitions have been drawn wherever practicable from Preston E. James, "The Terminology of Regional Description," Annals of the Association of American Geographers, XXIV (1934), 78-86.

in occupance or lack of occupance.

Adjustments to floods may be divided usefully into eight major classes, as follows:

Land elevation. The elevation (up-building) of the surface of a flood plain so as to render it less susceptible to flooding.

Flood abatement. The application of land-management meassures upstream from a flood plain to prevent the accumulation of all or part of a flood flow in a stream channel.

Flood protection. The use of levees, channel improvements, cut-offs, floodways, reservoirs, and other engineering devices to reduce flood crests in a stream channel or to prevent floods from overflowing flood plains.

Emergency measures. The temporary removal or protection of property and persons, and the temporary re-scheduling of human activities.

Structural. The arrangement of physical structures, such as buildings, roads, and communication systems, and of institutional structures, such as production schedules and marketing procedures.

Land use. The arrangement of the pattern of land use of a flood plain.

Relief. The granting or loaning of private or public assistance to flood sufferers.

Insurance. The accumulation of premium payments from property owners in order to compensate them for losses resulting from floods.

These classes embrace, with few exceptions, the major adjustments that have been made to floods in the United States. In most flood plains two or more adjustments are likely to be found in combination.

These classes are distinguished by the action taken by people in the process of adjustment. Other classifications might be based upon (1) relative success or failure of adjustment, (2) stability of adjustment, (3) historical sequence, and (4) landscape transformations, but analysis of them appropriately may be left to other investigators of the systematic geography of flood plains.

Under these definitions readjustment, or the reordering of occupance, takes place wherever prior adjustments, such as land-use patterns, are altered, or wherever new adjustments, such as flood protection, are made.

Any readjustment incurs some social cost in the rearrangement which it entails. Such cost may range from slight property damage to severe impairment of public health or morale. Readjustment also may yield and frequently does yield some social benefit, which likewise may accrue in a variety of ways. Given a framework of social values for appraising costs and benefits, and assuming that the appraisal is complete, it follows that the ratio of costs to benefits is a partial measure of the social desirability of readjustment. It is clear, however, that the direct costs and direct benefits of readjusting occupance are only two of the factors involved.

Factors Affecting Human Adjustment to Floods

The term factor is used to mean any physical or cultural attribute which has had or may have an effect upon an adjustment. From the standpoint of the attributes involved, the principal factors may be classified as follows:

- Floods
- Surface configuration
- Drainage and ground water
- Soils
- Surface waters
- Minerals
- Climate
- Costs and benefits of readjustment
- Vegetation
- Corridor facilities
- Social institutions

The prevailing combination of adjustments in any flood plain may be considered as the function of a human decision--conscious or unconscious--taking into account all or some of the factors which have affected past adjustments or might affect prospective adjustments.

It is apparent that each factor which is operative in a given flood plain either bears an advantageous or disadvantageous relation to the form of adjustment which is made there at a given time, or else is insignificant.

As will be shown in following pages, the degree to which any one factor bears a significant relationship to a given adjustment is influenced in large measure by accidents of human disposition, reason, and technology, so that no hard and fast generalizations can be made with respect to their quantitative importance. It is sufficient here to recognize that floods, flood plains, human occupance, adjustments, and factors affecting adjustment compose in their mutual relations, one with another, the elements of the flood problem in any valley.

CHAPTER III

MAJOR FACTORS AFFECTING ADJUSTMENT TO FLOODS

The heavy annual toll of flood losses in the United States is a payment which nature capriciously exacts from man in return for his occupation of her flood plains. This rental charge is collected erratically and mercilessly and it tends to discourage such occupation. It is offset, wholly or in part, by the special advantages of slope, drainage, soil, surface waters, minerals, corridor facilities, climate, vegetation, and social institutions which are available or creatable in some flood plains. It is a charge that can be avoided by staying out of the flood plain, or one that can be reduced if not eliminated by readjusting human occupance to the flood hazard.

Whatever the form of adjustment made, the factors affecting the adjustment may be considered to fall into two major groups, revealing, like a balance sheet, the relative advantages and disadvantages of occupance. On the liability side of the ledger are the items of flood hazards causing social loss. With these may be included other factors of social expense resulting from disadvantageous features, such as poor drainage. On the asset side of the ledger are the advantages afforded by floods as well as by other factors of social benefit, such, in some instances, as suitable surface water supply and fertile alluvial soils.

Without setting up a definite ledger account of this form for the flood plains of the United States, this chapter seeks to indicate the major items that would enter into such an account, and to point out the conditions of flood-plain environment and occupance for which each factor has been important or is likely to be important. By qualitative rather than quantitative analysis the processes by which each factor may affect an adjustment to floods are examined, and flood plains are cited where such effects are known to have occurred.

This review reveals on a broad scale the character of the rental charge that man is paying for the use of flood plains, and the character of the income or assets he enjoys in return.

In addition to these sets of entries there are, of course, factors of liability and asset that apply, in the unit area in which a flood plain is located, equally well to the lands above and below the flow line of the probable maximum flood. While the latter regional factors may be of basic importance in the development of the occupance of an area, they do not directly affect adjustments to floods, and they are excluded from consideration here.

The distinctive costs and benefits involved in readjusting flood-plain occupance also are omitted from analysis in this chapter and they are considered in Chapter IV in connection with the specific adjustments with which they are associated.

Floods--Liabilities and Assets

Flood is the most important single factor affecting human adjustment in many flood plains, and it is the only factor present to an important degree in all flood plains. It is not everywhere recognized, and, although it has deep potential impacts upon society, its full effects, both advantageous and disadvantageous, are understood incompletely.

The flood hazard is underestimated by most flood-plain dwellers because of the infrequency of major floods, the frailties of human memory, and the reluctance of some people, for economic reasons or from sheer obstinacy, to admit that past floods may be repeated or exceeded. In the public mind, quite apart from the facts of the hydrologic record, there are "remembered floods" and "forgotten floods," and the latter are assigned no weight by the citizenry of flood plains. As a general rule, the flood hazard tends to wax and wane in the public mind in direct relation to the occurrence of high water. Immediately after a flood, losses are exaggerated and distorted. The almost invariable experience of men who survey flood damages is that early estimates appearing in newspaper headlines are far too high, that later estimates by local organizations are also high but less exaggerated, and that detailed surveys yield totals substantially less than anticipated by the flood sufferers. So long as there are no other floods, the memory of the last one grows progressively dimmer. Its scars disappear, public interest in preparedness or protection weakens, and at length its ravages are forgotten. In time, indeed, there may develop a pronounced aversion to public mention of past flood disasters. Unscrupulous land subdividers, false inflators of municipal reputation, and speculative promoters of drainage enterprises seek to eliminate the hazard simply by ignoring it. Thus, average past or prospective losses from floods as given in estimates of competent engineers, may appear unreliable to the people involved. They are inclined to be exceedingly active in seeking protection works immediately after a flood, and then to grow correspondingly indifferent to them.

Another discrepancy between concept and reality in dealing with floods exists in the tendency of laymen and technicians alike to assume that the highest flood of record will never be exceeded. In virtually all flood plains of the United States, occupance has been arranged, where any account is taken of the flood hazard, in the tacit belief that the largest flood of record also is the probable maximum flood. The West End generating station of the Cincinnati Gas and Electric Company at Cincinnati was designed and constructed to operate at a flood stage one foot above the highest recorded flood of 1884, but in 1937 it was forced to halt operations by a crest that reached seven feet higher. All along the Ohio River during the same flood, similar disappointments occurred. Following the Brady Creek flood of 1930, which had a momentary peak discharge of 48,400 second-feet, the city of Brady, Texas built a masonry wall to protect the business district. In 1935, the wall was overtopped by a slightly larger flood. With the aid of Work Projects Administration funds the city then constructed an earth levee three feet higher to protect the business section, but this was overtopped in 1938 by a flood having a momentary peak discharge of 86,000 second-feet. A year later, studies by the Corps of Engineers revealed that a floodway improvement costing $825,000 would be required if the probable maximum flood of 206,000 second-feet in that reach of Brady Creek was to be curbed.[1] Such discrepancies are not necessarily the result of miscalculation. In many flood plains evidence left by great floods in the soil, rock, or vegetation had been obliterated before human settlement began. Moreover, the records of river stages and discharges are lamentably short and incomplete. Estimates of

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[1] 76th Cong., 1st Sess., Brady Creek, Texas, House Doc. No. 441 (Washington: Government Printing Office, 1939), pp. 10-23.

the magnitude of infrequent floods have made notable advances in recent years through the development of analytical techniques and through the accumulation of basic data.[1] Almost without exception, recent efforts have been in the direction of higher estimates of the probable maximum flood.[2]

Sources of Flood-loss Data

Because the systems for collecting data with respect to the amount and character of flood losses in the United States are incomplete, inaccurate and inconsistent, it is impossible to estimate with accuracy the full extent of such losses. While precise measurements of the flow and peak of floods have been instituted with meticulous care under the guidance of the U. S. Geological Survey, the social impacts of those events have been canvassed lamely and inadequately.

Loss statistics are prepared by two Federal agencies, the Weather Bureau and the Corps of Engineers. The only nation-wide system has been maintained by the Weather Bureau since 1902.[3] The Bureau has published estimates of the damage caused by each flood, basing them chiefly upon the returns from questionnaires sent to county agents, county and city engineers, postmasters, mayors, and river observers. Individual letters are sent to industries and to railways. Officials in charge of district centers of the Weather Bureau sometimes check the returns from the questionnaires by reference to newspapers and to estimates of other agencies, such as the Corps of Engineers. Occasionally they make field inspections.

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[1]LeRoy K. Sherman, "Recent Advances in Applied Hydrology with Reference to Flood-forecasting," American Geophysical Union Transactions of 1939, Part II, pp. 174-176.

[2]Gail A. Hathaway, "Estimating Maximum Flood-flow as a Basis for the Design of Protective Works," American Geophysical Union Transactions of 1939, Part II, p. 203.

[3]Statements of floods and flood losses are published monthly in the Monthly Weather Review. Summaries of flood losses in the United States have been reported annually in the Review since 1932, and monthly prior to 1932. A compilation of Flood losses for 1924-1937 was included in the hearings on Comprehensive Flood Control by the House Committee on Flood Control, 1938, and was revised as of 1941 in the Weather Bureau bulletin on The River and Flood Forecasting Service of the Weather Bureau (Washington: Weather Bureau, 1941).

The questionnaires now in use were introduced in 1934, and request information on losses of: "(1) Tangible property totally or partially destroyed, such as buildings, fences, factories, highways, bridges, railroads, etc.; (2) farm property including (a) matured crops, (b) prospective crops, giving acreage involved, if possible, and (c) livestock and other movable property; (3) suspension of business, including wages of employees." The questionnaire also requests an estimate of "Money value of property saved by flood-warnings." These items are not defined in any more detail than given above, and the district centers or persons to whom the questionnaires are addressed are not supplied with any additional instructions. In 1936 and 1937 more detailed questionnaires on agricultural losses and highway losses were distributed through the Department of Agriculture's Extension Service and Bureau of Public Roads, respectively. The Weather Bureau personnel rarely make detailed inspection of flooded areas; the Bureau operates at long distance by correspondence with voluntary observers.

The other major source of data is the surveys of the Corps of Engineers. In connection with its authorized flood-control or "308" surveys, the Corps has canvassed all available data on past flood damage in most drainage areas of the United States, and has made independent surveys of damage after floods in those areas which experienced floods during the time that an examination, a survey, or a review of a previous survey was in progress. It currently collects any data with respect to unusual flood events which it believes would be of value in prospective studies.

The Corps does not have standard definitions of flood-loss or of survey-procedure for recording loss; responsibility for classification and evaluation of loss rests with appropriate district engineers of the Corps. Some of the studies, notably those by the Memphis and Rock Island district offices, are outstanding for completeness and for innovations in technique.[1]

Frequently the Corps has found it necessary to rely upon Weather Bureau records and upon old newspaper files and historical records for information on past losses.

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[1] 75th Cong., 1st Sess., Arkansas River and Tributaries, House Doc. No. 308 (Washington: Government Printing Office, 1937).
U. S. Engineer Office, Report on Flood Damages on Rock River, Illinois and Wisconsin, During Spring and Summer of 1937 (Rock Island, 1938).

The Department of Agriculture, working through the Bureau of Agricultural Economics primarily, collects some data on flood losses in connection with its flood-control surveys. A suggested procedure for collecting data on damages has been prepared by the Department and has been released in tentative form.[1]

The Division of Disaster Relief of the American Red Cross collects and publishes statistics on the losses experienced by family or individual cases registering for emergency-aid following floods, and on the expenditures made for those cases which are aided. These data are not intended to be complete, inasmuch as they exclude all losses to persons not requiring or applying for relief.[2]

In addition to agencies having national coverage, a few Federal, state, and local agencies collect flood-loss data in areas of restricted scope or for special types of losses. State highway-departments make inventories of damages to roads, culverts, and bridges; state health departments canvass the damages to waterworks and sewers; municipal, county, and state governments occasionally make independent estimates of losses in their respective areas; the Bureau of Reclamation records losses to irrigation districts and municipalities in some of the western drainage basins; and the Tennessee Valley Authority surveys losses within the Tennessee Valley and adjacent areas.

Under these circumstances there is no assurance that all flood losses will be canvassed in detail each year, inasmuch as field surveys are made in only a few areas and questionnaires do not yield returns from the remainder of the country in every instance. Moreover, even if all areas experiencing flood loss were covered by surveys of some type, the questionnaire method of appraisal used by the Weather Bureau is dependent upon the judgment of so many individuals working under such vague instructions and with criteria so lacking in precision and uniformity that the accuracy of the results would be open to grave doubt, particularly because the Weather Bureau makes no systematic provision for veri-

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[1] "Tentative Memorandum for Bureau of Agricultural Economics Flood Control Survey Representatives," March 9, 1939. (Mimeographed.)

[2] For example, see: Spring Floods and Tornadoes, 1936: Official Report of Relief Operations (Washington: American Red Cross, 1938).

fying the returns. These weaknesses relating to coverage and to accuracy can be corrected in large measure by administrative changes aided by additional funds. However, new personnel, better organization, and larger funds might not result in an adequate data-collection system. That can come only as sound criteria for evaluating losses are generally adopted.

For example, after the 1937 flood on the Ohio River, the Corps of Engineers estimated the flood losses at Paducah, Kentucky, to be $25,500,000.[1] A field party from the Tennessee Valley Authority working in the same area at the same time, concluded that the losses amounted to $13,167,692, or 51 per cent of the Army figures.[2] The difference apparently arose from the fact that the two agencies used different methods for evaluating the same losses and started with divergent assumptions as to the impact of flooding upon a community. Inevitably, the studies ended far apart in their findings. Similar differences are possible wherever losses are evaluated, and statistics on losses will remain inconsistent as long as relatively uniform criteria are not adopted. Until they are adopted, it will be fruitless to attempt to compare numerical estimates of flood losses for one area with those for other areas.

Social Impacts of Flood Losses

A basis for a relatively uniform appraisal of flood losses from a national standpoint was suggested by a subcommittee of the National Resources Committee in 1939,[3] but much confusion remains among investigators, in part because of faulty techniques and in part because of differences in basic assumptions as noted above.

The Subcommittee's suggestions, together with the few detailed studies of flood losses which have been made since 1938, provide a basis for outlining a tentative theory as to the social

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[1] 75th Cong., 1st Sess., Levees and Flood Walls, Ohio River Basin, Hearings before the House Committee on Flood Control on H.R. 7393 and H.R. 7647 (Washington: Government Printing Office, 1937), p. 28.

[2] Tennessee Valley Authority, "Report on Flood Damage at Paducah, Kentucky," 1938. (Unpublished.)

[3] National Resources Committee, Report of the Subcommittee on Flood-damage Data (Washington: National Resources Committee, 1939), pp. 1-6.

impacts of floods.

When a flood strikes, it deals four types of blows upon a community. First and most obvious, it damages physical property by killing crops, washing away soil, injuring or destroying structures, soaking household belongings and causing property deterioration in numerous other ways. Second, it interrupts the production of goods and services--industrial plants are shut down, telephone systems are broken, commercial transactions are halted, railroad transportation is delayed. Third, it destroys or impairs human life. Fourth, it forces the community and perhaps neighboring communities to attempt to minimize losses by removal or other emergency measures as the flood approaches and to reoccupy the flood plain after the waters have receded.

The first of these impacts--damage to physical property--is most widespread and most readily measured. Involving all forms of property, including land itself, these losses lend themselves to appraisal by the usual methods of property valuation.[1]

Social impacts resulting from interrupting the production of goods and services are commonly and loosely grouped under the inclusive names of "business interruption" or "indirect loss." They may be considered to involve either a complete elimination of production or a delay in production. In either case the effect is to waste labor, management, equipment, supplies, and land in so far as they are not used with normal efficiency during the period of time that flood effects are felt. If the opportunity to produce such goods or services is permanently lost and not merely suspended, the total of goods and services wasted may be counted as flood loss. This is chiefly the case with production which meets day-to-day market needs, ranging all the way from power generation for

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[1]The problems of evaluating such impacts resemble other problems of property evaluation, the chief difference being that decrease in productivity is measured rather than increase of productivity. The techniques of evaluation are thus those which have been reviewed at length by Bonbright and Clark. See James C. Bonbright, The Valuation of Property: A Treatise on the Appraisal of Property for Different Legal Purposes (New York: McGraw-Hill Book Co., 1937), I, 10-39, 113-266, and John Maurice Clark, Preface to Social Economics: Essays on Economic Theory and Social Problems (New York: Farrar and Rinehart, Inc., 1936), particularly pp. 48-60.

For a special review of valuation problem relating to flood losses see Reginald C. Price, "Valuation of Benefits and Costs of Flood Control Measures" (Unpublished Master's thesis, American University).

domestic illumination to personal services, or production which is effective only during a specified season of the year. The flooding of Kentucky strawberry fields in May or of a textbook-manufacturing plant in summer shortly before autumn school deliveries are required, works damage that is irreparable in this sense. If, however, the opportunity to produce marketable services or goods is merely deferred, the production losses, apart from the direct property losses, may consist of the depreciation while production is stopped, and of whatever increased costs attach to delayed or overtime production thereafter. Such losses apply to many production activities outside of the flood plains directly affected. The failure of a water system or a power supply may cut off production as effectively as if the plant had been flooded.

This concept of the loss resulting from interruption of production of goods and services from a strictly local point of view may be written, algebraically, as:

$$(A-B) - (C-D) + (E-F) - G - H + I \qquad (1)$$

where,

A - Probable value of goods and services which would have been produced under normal operating conditions had there been no flood. This is the normal production.

B - Value of goods and services actually produced during the period of the flood. This is the actual production.

C - Direct cost of probable normal production, including labor costs.

D - Direct cost of actual production, including labor costs.

E - Value of goods and services the production of which is delayed until after the flood. This is the delayed production.

F - Direct cost of delayed production, including labor costs.

G - Savings resulting from reduced overhead expense during the flood.

H - Savings resulting from reduced overhead expense during the period of delayed production.

I - Depreciation, if any, in value of productive equipment and supplies during the flood.

Under this view, which is subject to several weaknesses noted below, the net impact of production losses could not be expressed by loss in sales or loss in wages, or by any other measure which neglected the factors of direct costs and overhead costs, and the savings and excess costs of delayed production. Sales losses are likely to be an important index in themselves only if the business affected supplies a market that in time of flood cannot be extended beyond a day or two, as is the case with the production of perishable foodstuffs. Likewise, loss in wages would be significant chiefly for businesses which cannot engage in delayed production. As will be noted in the following section, the place given to losses in wages in calculating net loss depends upon the basic assumptions made with respect to the area affected.

Whatever the role assigned to wage losses, the concept seems to apply equally well to agricultural, manufactural, and commercial activities. Such application is largely a matter of theory at present. Notwithstanding the numerous inventories that have been made of flood losses in the United States, there has not been, to the writer's knowledge, any thorough and searching analysis of losses resulting from interruption of production. As detailed studies are made, it will be possible to test out this theory, but, meanwhile, a few generalizations can be made concerning it.

The concept, as expressed in this formula (1), does not adequately cover all cases of loss resulting from interruption of production. What of the inconvenience caused a railroad passenger who, during the Upper Ohio flood of 1936 lost a working day in attempting to get from Chicago to Baltimore by means of trains crawling over an emergency route through Buffalo? What of the disruption of telephone and postal communications? It is possible to estimate the extra cost of re-routing telephone calls and the mail, but only by highly arbitrary means is it possible to evaluate failures to transmit personal messages, or to obtain important business information. What, too, of good will lost through business disruption? In these respects, monetary evaluation becomes either fruitless or misleading, and yet to refrain from attempting to set a value may in effect assign to those impacts a value of zero in the analysis of flood losses.

Some investigators have sought to bridge this quicksand of "intangibles" by expressing production losses as ratios of the losses to physical property. By somewhat similar techniques, or by direct appraisal of losses in production, other investigators have attempted to establish ratios between property loss and production loss. A few of these attempts are summarized in Table 4, not to indicate a basis for such estimates in like areas, because the process of estimation was faulty in most of the surveys for reasons which will be indicated later, but rather to show the

TABLE 4

ESTIMATES OF RATIO OF LOSS IN PRODUCTION OF GOODS AND SERVICES TO PROPERTY LOSS CONTAINED IN FLOOD CONTROL REPORTS BY CORPS OF ENGINEERS, 1930-40

Drainage Basin and Class of Occupance (Source)	Estimated Ratio of Loss in Production of Goods and Services, of Property Loss Percentage	Period of Study	Remarks
Connecticut Basin (75th Cong., 2d Sess., H.Doc. 455)			
Urban................	114	1936	Based upon 1,215 individual returns to questionnaires. Includes emergency losses and cost of capital needed to replace direct losses.
Industrial...........	114		
Highway..............	50		
Railroad.............	70		
Rural................	10		
Belle Fourche Basin, Wyo. and S.D. (Unfavorable report of Chief of Engineers, June 30, 1941.			
All classes of occupance..............	20	1941	Rough estimate based upon experience in other parts of Missouri Basin.
Houston, Texas (74th Cong., 2d Sess., H.Doc. 378)			
All urban losses.....	13	1936	Interruption of transportation and utilities.
Sebewaing River, Mich. (76th Cong., 1st Sess., H.Doc. 286)			
All losses, chiefly urban..............	50	1939	No detailed field studies.
Pawtuxet Basin, R.I., (76th Cong., 3d Sess., H.Doc. 747)			
Residential..........	40	1940	Based upon samples of 1936 and 1938 losses in Providence Engineer District.
Commercial...........	70		
Industrial...........	120		
Utility..............	100		
Railroad.............	100		
Highway..............	100		
Agricultural.........	20		
Public...............	50		

TABLE 4 - Continued

Drainage Basin and Class of Occupance (Source)	Estimated Ratio of Loss in Production of Goods and Services, of Property Loss Percentage	Period of Study	Remarks
Neshamniny Creek, Pa. (Unfavorable report of Chief of Engineers, July 1, 1941)			
Residential..........	40	1941	Field survey.
Commercial...........	70		
Industrial...........	120		
Agricultural.........	20		
Marshy Hope Creek, Md. (75th Cong., 3d Sess., H.Doc. 708)			
Commercial and industrial uses in Federalsburg........	28	1938	Field survey.
Missisquoi River, Vt., (71st Cong., 2d Sess., H.Doc. 496)			
All losses............	15	1930	Field survey.
White River, Ark. (76th Cong., 1st Sess., H.Doc. 98)			
Agricultural..........	30	1940	Rough estimate.
Brazos River, Tex. (76th Cong., 1st Sess., H.Doc. 390)			
All losses............	50	1938	Rough field estimates.

variety in methods utilized and the range of results obtained.

On the whole, these investigators seem to have concluded that the ratio of production loss to property loss varies as a function of the intensity and complexity of human occupance in the flooded area. This general conclusion seems reasonable in part; the more intricate the production operations, the larger the numbers of business establishments, and the more widespread the business relations of those establishments, the greater is the probability that the impacts upon production will be large by comparison with property loss. It must be admitted, however, that under the concept stated above, size, complexity, and volume of business are not necessary criteria of the production losses to be expected. Ratios of direct to overhead costs and timeliness of demand for the goods produced are more likely to indicate the relative amount of loss to be expected.

If losses through interruption in production seem to defy measurement, encouragement may be gained from turning to the third and even more complicated class of losses, those resulting from loss or impairment of human life. By comparison, the production losses seem simple. Probably no phase of flood disasters has been more exaggerated and distorted than their menace to life and health. Lives are lost and health is endangered by some floods, of course, but the extent of these losses is relatively small. Since records of flood loss first were kept by the Weather Bureau in 1902, at least 3,186 deaths have been ascribed to floods.[1] They occurred at an average rate of 83 per year, or a little less than .3 per cent of the deaths from automobile accidents alone in the United States in 1930.

Alleged deaths from floods have never been studied in detail, and while it is possible to segregate their principal causes on all flood plains, the results of a canvass of deaths resulting, directly or indirectly, from the flood of January, 1937 in Kentucky are somewhat revealing.[2] Of the 363 deaths reported, 252 were due to pneumonia, 54 to influenza, 16 to drowning, 15 to explosion, 10 to exposure, 7 to heart disease, and 9 to other accidents. The flood period was one of severe weather conditions that included sleet, snow, and freezing temperatures. It seems likely that a substantial proportion of these deaths would have occurred had the flood been fully curbed. This conclusion is suggested by a review of the death rates and pneumonia rates for selected Ohio Valley cities for the years 1934-1938. The pneumonia mortality in lower Ohio Valley cities was abnormally high in the two weeks preceding the 1937 flood, and flood conditions could not have been

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[1]U. S. Weather Bureau, The River and Flood Forecasting Service of the Weather Bureau, p. 8, and 70th Cong., 2d Sess., Loss of Life and Property by Floods in the United States from 1902 to 1928, House Committee on Flood Control Document No. 29 (Washington: Government Printing Office), pp. 2-3.

The Red Cross estimates of deaths from flood during 1922-1941 are 2,029, with 9,133 others injured (see Table 13).

[2]J. F. Blackerby, "Mortality in Kentucky Attributed to the Flood," Public Health Reports, LII (April 2, 1937), 414-415.

responsible for increases of more than 60 or 70 per cent for a week or two.[1] Without discounting for a moment the serious hazard to life from floods and particularly from those of the sharp-crested cloudburst variety which sweep out canyon bottoms and arroyo floors in the semiarid and arid regions with sufficient energy to carry automobiles and houses with them, it seems probable that in flood plains where the crests are relatively broad, life is not greatly endangered, and that the hazard is only reduced in part by the construction of protective works. During the Los Angeles flood of 1938 a considerable part of the loss of life resulted from the collapse of bridges on which spectators had been allowed to crowd.

Contrary to the alarms of newspaper headlines, authoritative evidence suggests that public health does not suffer greatly in time of flood. Public-health records for Ohio Valley cities, such as Wheeling, during 1937, when weather conditions were severe and flooding was protracted, show that the death rates did not increase markedly over those for other years. Public-health services commonly are improved during flood emergencies, and special precautions are taken against epidemics. The hazard from water-borne diseases--notably typhoid--may even be reduced under certain extreme conditions, inasmuch as floods tremendously increase the dilution of streams. Typhoid nevertheless always is a menace at time of flood because high waters sweep out privy pits, refuse piles, and accumulations of sewage in channel pools, and deposit more or less polluted waste in wells and at the intakes of water works.[2] Less than 3 per cent of the water-borne outbreaks and of the typhoid deaths from that cause in the United States during 1920-1936, were associated with floods (see Table 5). The menace has been curbed in large measure by preventive work, discussed in Chapter IV, which, in addition to suppressing epidemics and reducing distress, may carry public health methods to populations not usually benefiting from them. Added protection from disease thus tends to offset increased hazard from flood, with a net loss of perhaps little more than the cost of concentrating special medical

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[1] Public Health Reports, Vols. XXXXIX-LII (1934-1938).

[2] Arthur E. Gorman and Abel Wolman, Water-borne Outbreaks in the United States and Canada and Their Significance (New York: American Water Works Association, 1939).

TABLE 5

WATER-BORNE OUTBREAKS IN UNITED STATES DUE PARTLY OR WHOLLY TO FLOODS, 1920-1936[a]

Outbreaks and Cases	Number of Out-breaks	Typhoid Cases	Typhoid Deaths	Diarrhea and Dysentery Cases
From all causes.......	399	12,585	862	103,032
Associated with floods	18	648	37	946
Percentage associated with floods.........	2.2	1.9	2.3	1.1

[a]Source: Arthur E. Gorman and Abel Wolman, Water-borne Outbreaks in the United States and Canada and Their Significance (New York: American Water Works Association, 1939).

and nursing services in the flood area.

Probably the most far-reaching loss inflicted by floods upon public health is that resulting from malnutrition due to destruction of food crops. Famine and flood do not go hand in hand in the United States as they frequently do in the North Chinese plain and the other great flood plains of Asia, but pellagra has been a prominent consequence of flood in sections of the South where single-crop cotton culture prevails. Following the lower Mississippi River flood of 1927, pellagra increased markedly in the overflow areas of Tennessee, Arkansas, and Mississippi as a result of decreases in milk production, losses of poultry and swine, and reduced production of vegetables.[1] These unfavorable dietary conditions were enforced by lowered income resulting from unprofitable cotton crops in 1925-1927, prices in the latter year reflecting flood losses as well as market depression.

According to LePrince, if overflow in the "malaria belt" occurs when temperatures reach 76° F. and if the water remains high for a period of 12 days or more, malaria-carrying mosquitoes multiply greatly.[2] This threat of malaria undoubtedly helps to

[1]Joseph Goldberger and Edgar Sydenstricker, "Pellagra in the Mississippi Flood Area," Public Health Reports, XXXXII (1927), 2706-2725.

[2]J. A. LePrince, "Malaria and the Mississippi Valley," Engineering News-Record, CVII (September 17, 1936), 404.

explain the sparsity of early settlement along swampy reaches of the Lower Mississippi and other Southeastern streams, such as the Pee Dee, where broad-crested floods inundate the lowlying zones for two weeks at a time.

Finally, the public-health impacts include mental disturbances resulting from disruption of living patterns and of individual security. To the extent that community life is dependent upon communications and transportation, as it is almost wholly in the contemporary city, any serious interruption in those services softens for a time the rigid pattern of life and tends to induce a new social attitude toward everyday affairs. These effects of flood crisis are discussed further in the section dealing with gains from floods.

It appears that loss of life may be severe in the case of sharp-crested floods, that damage to public health from medium- and broad-crested floods is small by comparison with other losses, that such damage may be most significant when associated with severe weather conditions and with dietary deficiencies, and that it tends to be offset by emergency public-health activities. The net loss is the sum of loss of life, increase in physical and mental disease, and cost of emergency medical and sanitary measures, from which must be subtracted the reduction in incidence of disease and the physical and mental benefits from emergency inoculations, physical examinations, and emotional releases.

The fourth type of impact is that experienced by private and public interests alike in evacuating the flooded area and in <u>reoccupying and rehabilitating</u> it later. These are losses quite apart from the losses accruing to property and production. They include, principally, the expense of moving populations out of the flood zone, caring for them during the flood, providing emergency police, fire, sanitary, and other social services, and cleaning up streets and private residences after the flood. Direct and indirect expenditures for labor and supplies may be used as a fairly reliable measure of such losses.

Problems of Loss Valuation

If loss data are used in estimating benefits they must be assigned some value, however rough. This valuation process is complicated in at least two major respects, each relating to the ends of social enterprise. It also is hampered by deficient techniques for defining losses and for allowing for obsolescence and deterioration.

The first major problem of valuation is whether the social group considered for the purposes of valuation is the affected group in the flood plain, the locality, the region, the nation, or some other unit. For example, production losses at a manufacturing plant, under the concept stated in formula (1), may be large in terms of the decrease in production for the year. The town in which the plant is located may not suffer as large a loss in net income for the year, because relief payments from outside sources may offset the decline in payrolls, so that retail trade declines only slightly. On a national scale, however, the loss may be considered as even smaller, inasmuch as competing plants, not flooded, may increase their production to satisfy demands that the flood-plain plant is unable to supply, and thus make the net loss to the nation the extra costs involved in the loss of production labor, in slowing up production in the flood plain, in speeding it up outside the flood plain, in facilitating temporary changes in market organization, and in providing necessary relief. Viewed thus, production losses would be least significant when measured in terms of national economy and most significant when measured solely in terms of flood-plain economy. Where the loss is irreparable within reasonable time, as threatened by the near flooding of the great Mt. Wilson lens during its second year of cooling at the Corning glass works at Binghampton, during the flood of 1935, the national and local losses may coincide, but otherwise, according to this view, they are not the same.

In most fields of manufacturing heavy decreases can take place in production without materially affecting national production for the year. If, however, it is assumed that there is no idle labor and no idle productive capacity, except on an overtime basis, as during a period of emergency war production, any event which reduces production involves an equivalent loss to national production as well as to local production. This is the second major problem of valuation.

Flood losses in the United States customarily are valuated on the theory that employment is full and that the local point of view prevails. This procedure, although unrealistic and conducive to very liberal estimates of losses, has the advantage of being relatively easy to apply on a uniform basis. Moreover, once an estimate has been made, it can be corrected by deletion far more readily than by extension. Without attempting to suggest economic solutions of these two problems, it should be pointed out that some assumption is necessary under any procedure, and the amount of loss, especially loss in production, will be large or small according to the assumptions made. It also should be noted that the justification for preventing production losses is greater during periods of war production than at any other time. Then every production loss is a net loss from a national standpoint.

Two minor problems of valuation procedure may be noted with less reservation, inasmuch as their solution is clear regardless of the basic social assumptions.

Most common of these problems is the practice of duplicate counting of the same losses, particularly where production losses are involved. In a number of instances,[1] depreciation of property value due to flood has been taken as a loss in addition to all the regularly-appraised property losses.

The use of an estimate of depreciation of property value has been defended by some investigators on the ground that it alone could adequately measure the effects of loss of life and community disruption which are experienced by the flood-plain dwellers. These effects are believed by such investigators to include decreased sales value of property, permanent loss of business and good will, restriction of new industrial development, abandonment of the flood plain by residents and industries, decreased utility of productive property, higher rates of interest on new capital, and fear and mental distress. Depreciation is calculated upon the assumption that the value prevailing prior to a flood was a fair value, whereas it may, in fact, have been inflated through ignorance of the flood hazard, in which case the value assigned by the community following a flood represents the more reasonable one. There are other objections. It may well be that new industrial development should be curtailed and that an exodus of existing industries should be promoted. In so far as property values reflect the utility of land, and in so far as they decrease because of experienced damages to that property, it is

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[1] 76th Cong., 2d Sess., Pawtuxet River, Rhode Island, House Doc. No. 747 (Washington: Government Printing Office, 1940), pp. 25-26.

misleading and inaccurate to count both property damage and property depreciation at the same time for the same place. Either one might be satisfactory. Both would be certain to result in a duplication by approximately the amount of the property damages.

Duplication occurs in other respects. Not uncommonly the item of "loss of wages" by laborers is counted as an "indirect" loss along with "loss in revenue" by producers.[1] Under the formula suggested for calculating production losses (1), both of these items would contribute to such losses, but they are not mutually exclusive. For example, in manufacturing processes having high labor costs, the labor costs would exceed profits, and, in any event, profits are not in themselves a reliable index of loss in productivity. Another confusing distinction is between "property loss" and the cost of "repairs and rehabilitation." Obviously, unless care is taken, the two items for the same area might easily overlap. In several instances this actually has occurred in estimating the value of flood protection.[2]

Less readily identified but no less important is the practice of failing to make allowance for depreciation and obsolescence. As noted previously, there are many methods for calculating depreciation and obsolescence, but often they are neglected. So long as losses are regarded as impacts upon social organization, the use of the cost-of-replacement or original cost methods of valuation is inappropriate. Society loses by flood the productive capacity of goods or services, not the entire original investment. Capitalized income, capitalized earnings, and market value are

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[1] 76th Cong., 1st Sess., Hoosic River, N. Y., Mass. and Vt., House Doc. No. 182 (Washington: Government Printing Office, 1939), p. 21.

[2] For example, the review report of the Chief of Engineers on Ohio River, Reevesville, Illinois, December 24, 1941, applies an increase of 21 per cent to the direct flood losses in order to allow for the "unallocated relief expenditures" for the area.

The obverse of this difficulty is illustrated by the unfavorable report of the Chief of Engineers on Whitewater River, Minn., September 25, 1941. There, it is said, "In view of the character of the direct urban damages sustained in this valley it is concluded that indirect damages resulting therefrom would be largely offset by expenditures for reconstruction and replacement of the properties damaged. For this reason no allowance are made for indirect urban flood damages." Under this theory, the larger the costs of reconstruction in proportion to gross loss, the smaller would be the net losses.

measures of such loss in capacity, and replacement costs or original costs may be used with validity only if due deductions are made for depreciation and obsolescence. Inasmuch as a person unskilled in appraisal methods is likely to think of value in terms of replacement cost, and inasmuch as the U. S. Weather Bureau and engineering estimators operated for at least three decades without the advantage of advice on appraisal techniques, the data for the United States probably are exaggerated in that respect. It also follows that because the market price is used more readily as a measure of the value of private property than of public property, the public property losses have been subject to the greater distortion.

Considering all these possible discrepancies, a rough balance can be seen in available means of measuring flood losses. On the one hand, property losses and costs of evacuation and reoccupation are understood with moderate precision, but the methods of measuring them are subject to such misuse that they tend to be inflated. On the other hand, production losses and public-health losses are recognized with less precision, and so tend to be underestimated. The extent to which these divergencies cancel out is a matter of speculation, but some light is thrown upon the problem by examining the recorded data on flood losses.

Total Flood Losses in the United States

The average annual rental charges which floods exact in the United States are at least $75,000,000 and are more probably in excess of $95,000,000 in property losses alone. Precise averages cannot be calculated because, as already noted, statistics on flood losses are incomplete and highly inaccurate.[1]

The accompanying chart and maps, based upon Weather Bureau data, show the amount of loss reported in each major drainage basin for each year during the 39-year period, 1902-41, and for the period as a whole. From these a few outstanding characteristics

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[1] In arriving at this estimate the Weather Bureau data have been compared with a compilation of the estimates made in Corps of Engineers reports. Without allowing for "indirect" losses or for losses on the Ohio River and certain other areas the latter reports show a total average annual loss exceeding $66,000,000.

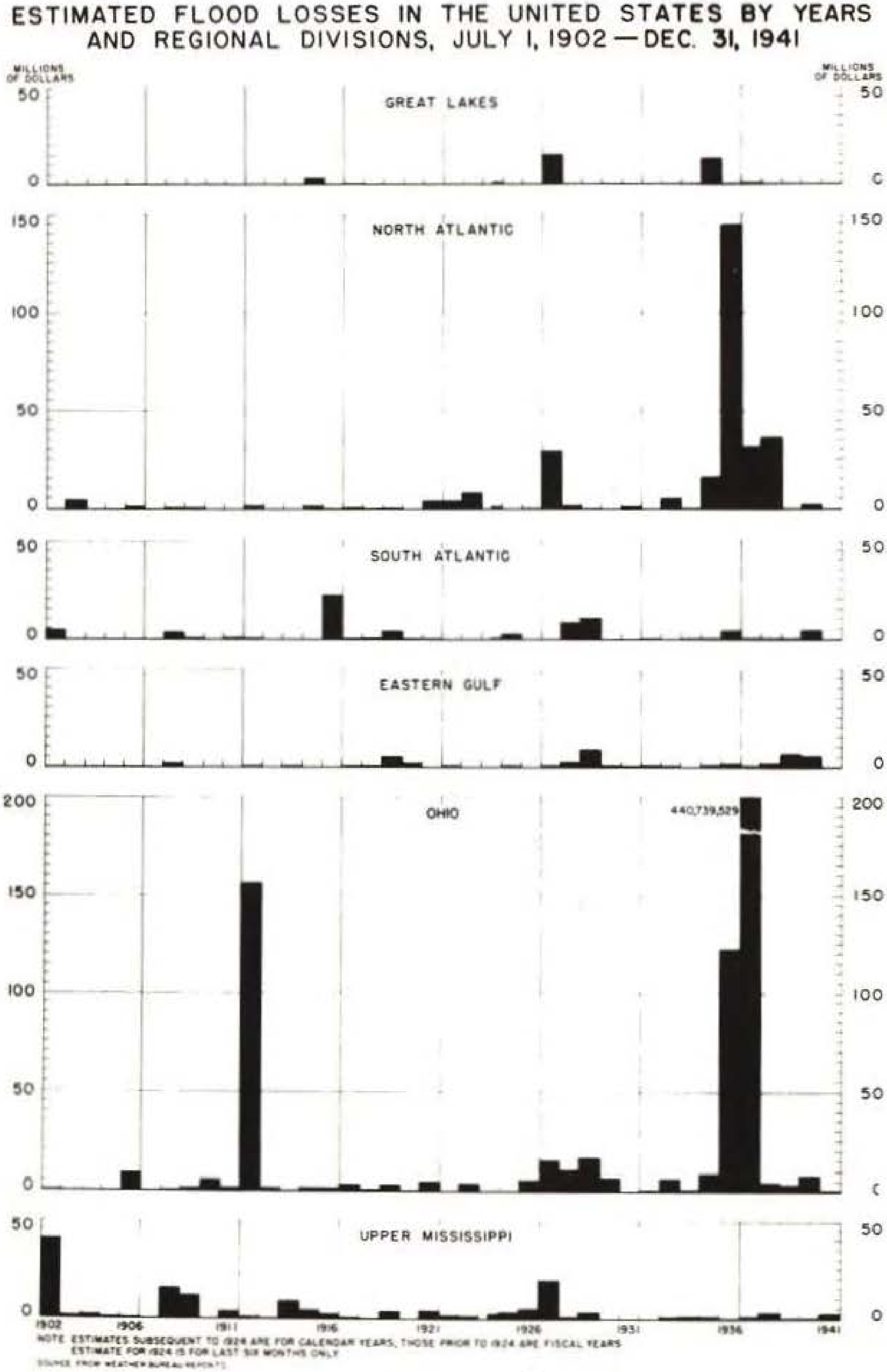

Fig. 4a.--Estimated flood losses in the United States by years and regional divisions, July 1, 1902--December 31, 1941 (Part I). The bar showing the 1937 losses in the Ohio Basin is interrupted.

ESTIMATED FLOOD LOSSES IN THE UNITED STATES BY YEARS AND REGIONAL DIVISIONS, JULY 1, 1902—DEC. 31, 1941

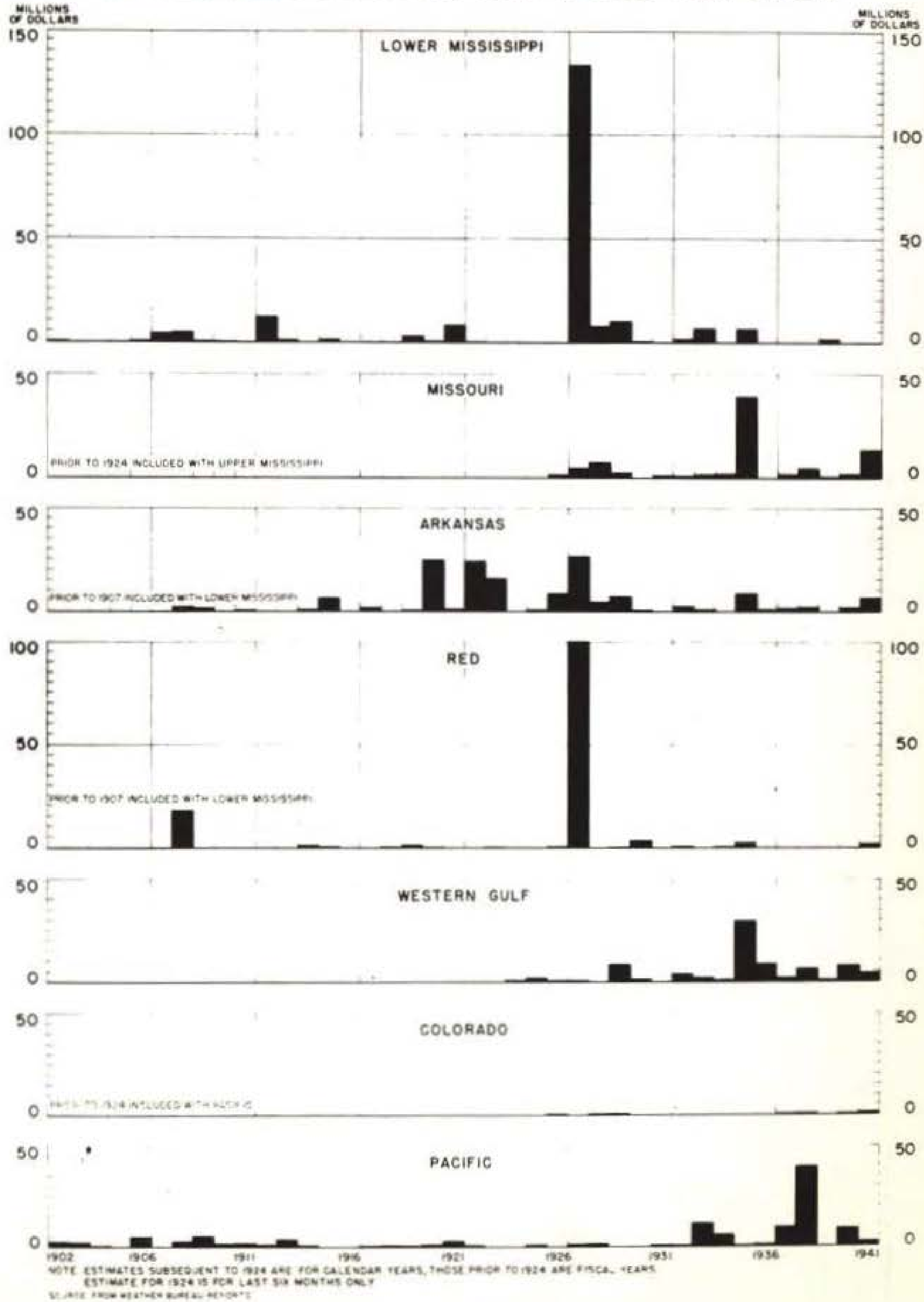

Fig. 4b.--Estimated flood losses in the United States by years and regional divisions, July 1, 1902--December 31, 1941 (Part II).

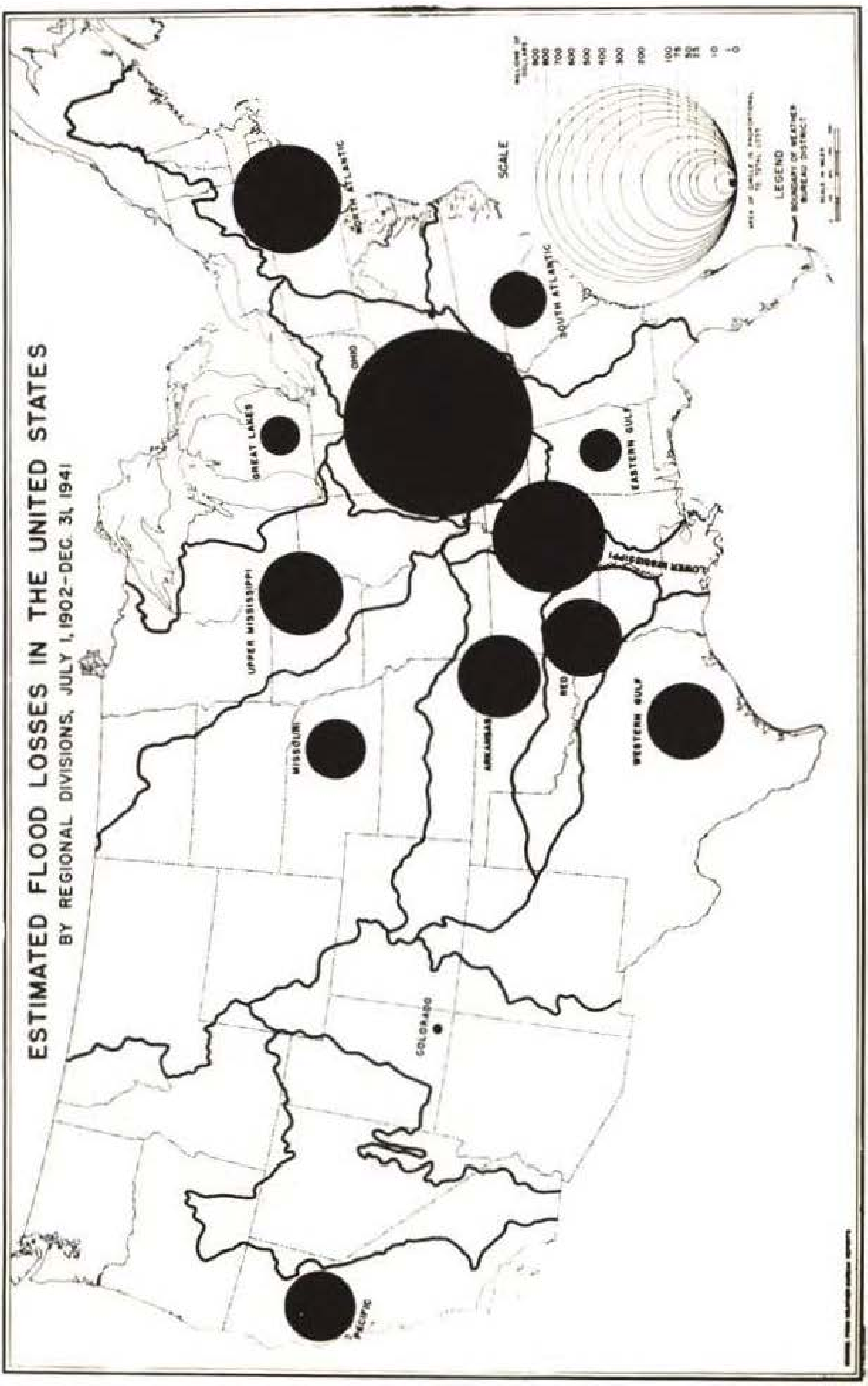

Fig. 5.--Distribution of estimated flood losses in the United States, by regional divisions, July 1, 1902--December 31, 1941.

of flood experience in the United States may be noted.[1]

During that period damages in excess of two billion dollars were recorded. The minimum annual loss of $400,000 occurred in 1905-06. The maximum of $432,000,000 was caused by the great Ohio and Lower Mississippi river floods of 1937 (see Fig. 4).

One-fifth of all loss during the period occurred in 1937, and approximately one-half was experienced in the three years 1937, 1927, and 1936. Slightly less than two-thirds of the loss occurred in five of the years of record (1912-1913, 1927, 1935, 1936, and 1937).

Although total losses have been greater in recent years than in the early years, there is no pronounced periodicity. (The question of whether or not floods have become more frequent and severe is raised by these data, and is discussed in Chapter IV.)

Some loss was reported every year in one or more regional divisions, and every regional division experienced some loss in at least one year. The Eastern Gulf, Red Basin, Colorado Basin, and Pacific divisions showed the smaller losses, the Colorado Basin, in particular, reporting only slight losses. The Ohio and North Atlantic divisions together accounted for more than 74 per cent of the total losses for the period 1934-1941 (see Fig. 5).

From the standpoint of size of loss during the period of record, the flood problem in the United States clearly was most important in two broad bands of territory. One band, roughly corresponding to the Northeastern manufacturing belt, stretches from Kansas City to Boston, and lies south of the Great Lakes and St. Lawrence River and north of the Tennessee and James drainage basins. The other meets the first transversely and lies due south along the axis of the Lower Mississippi River, including the lower reaches of its tributaries.

The larger part of the recorded losses resulted from a few great floods. Estimated economic dislocations from all the small floods of record totalled less than those from the Ohio flood of 1937 alone.[2]

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[1]These data were first published by the author in the "Symposium on Floods," American Geophysical Union Transactions of 1939, Part II, pp. 221-224, and have since been revised.

[2]Some persons hold that the economic significance of relatively frequent floods of small magnitude has been underestimated in the collection of Weather Bureau data. This contention probably

At least half the losses in all years since 1933, and as much as 92 per cent of the losses in some years (1936) were tangible property losses in urban areas or to transportation facilities. Agricultural losses amounted to as much as one-half in a few years but in some other years were less than 10 per cent of the total (Fig. 6).

Thus, in terms of severity of past damage, the flood problem is localized in large measure in the urbanized northeastern quadrant of the United States and in the Lower Mississippi Valley. Damage is most in connection with a few great and infrequent floods in those areas.

Range of Flood Losses

Social impacts from floods differ in importance according to the class of occupance affected, the season of occurrence, and other characteristics of the flood event quite apart from any influence that human preparations or evacuation efforts may have. In order to understand those effects more concretely, the major types of losses, classified according to occupance, will be examined in this section with a view to (1) defining them, (2) indicating the conditions under which they are significant, and (3) noting suitable appraisal techniques where available.

In practice, flood losses are collected and reported in terms of the occupance affected rather than in terms of the nature of their social impact, and, accordingly, the range of possible losses from flood will be considered upon that basis.

Agricultural losses.--Direct physical losses from floods in agricultural areas relate to growing crops, stored crops, orchards, farm timber, livestock and livestock products, farm houses, household furnishings, personal belongings, other farmstead buildings and equipment, fences and other outdoor improvements, drainage and irrigation works, and the land itself. In addition, there are losses in crop production.

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is true, but from the statistics now in hand it seems unlikely that losses from the minor floods would be of sufficient volume in the aggregate to alter the above-mentioned proportions materially. E. N. Munns suggests that such losses may equal the losses from the major floods. 75th Cong., 1st Sess., Levees and Flood Walls, Ohio River Basin, Hearings before the House Committee on Flood Control on H.R. 7393 and H.R. 7647 (Washington: Government Printing Office, 1937), p. 244.

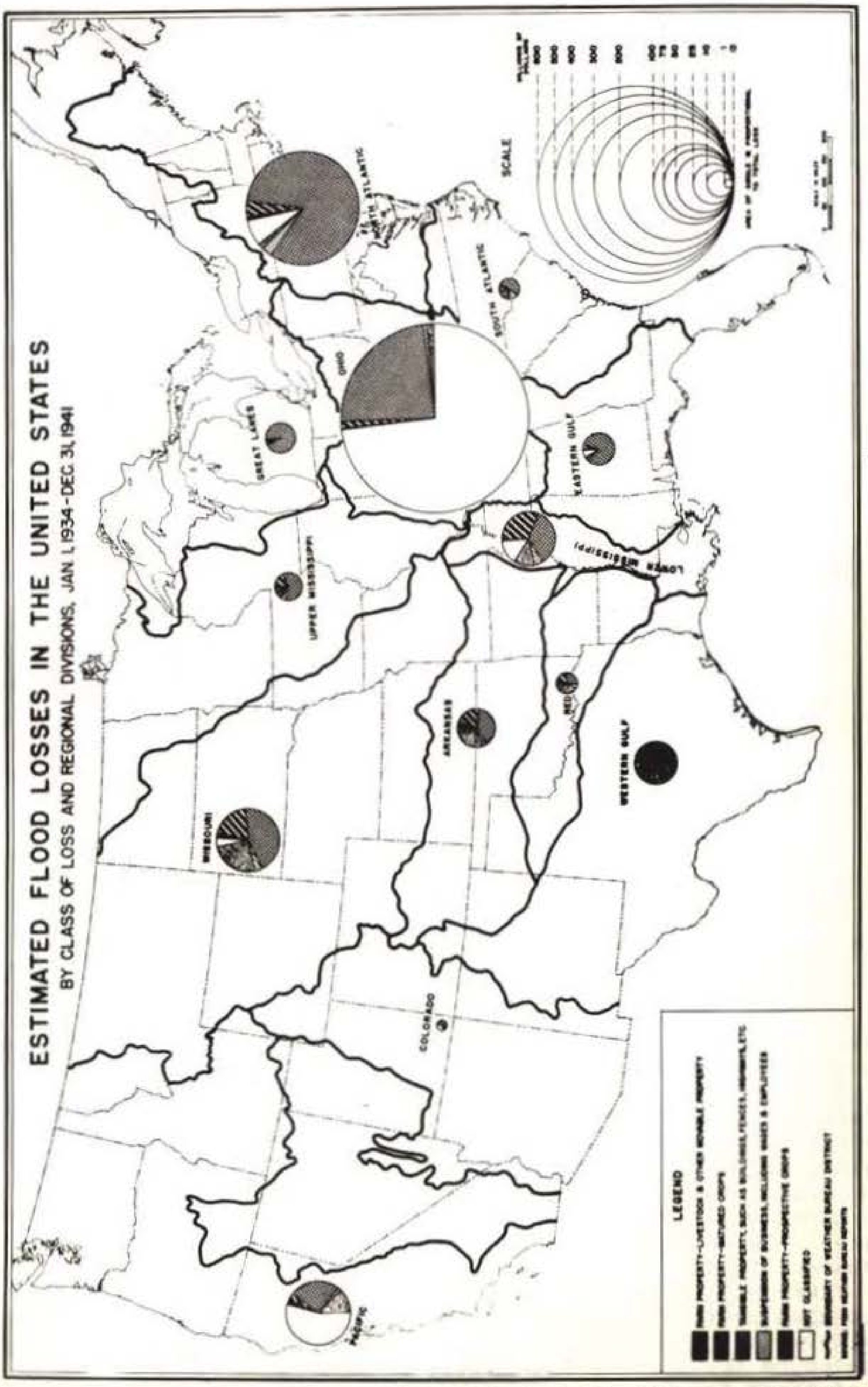

Fig. 6.--Distribution of estimated flood losses in the United States by class of loss and regional divisions, January 1 1934-December 31, 1941.

Crop losses--both in property and in production--are the most important group, accounting in 1934-1941 for more than 92 per cent of all agricultural losses reported in the United States (see Table 6). Under the theory of production losses stated above, decrease in the value of crops as property at time of harvest may involve a complete destruction of unharvested crops, in which case the net loss is the value of the crop had it been harvested, less the direct cash expenses not incurred in harvesting. To this must be added the value of unused family and other farm labor which would have been used in making the crop and the charges on unused workstock and farm equipment, for which there are no alternative uses during the crop season. Direct crop loss also may involve a partial reduction in yield or quality of growing crops, and this differential is readily measured by comparison with the yield of crops on nearby land free from flood. If perennial crops are so damaged as to require reseeding, the resulting loss is conveniently gauged by the cost of the reseeding operation plus the depreciation in crop yield.

Production losses result either from failure to plant crops, in which case the normal value of the anticipated crop is a measure of loss, or from the increased expense of planting or preparing land a second time. In the latter case, the net loss is obtained by subtracting from that added expense the value of substitute crops, if any, the value of crops the planting of which is delayed, and savings through non-use of equipment, materials, and hired labor.[1]

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[1]It is recognized that any such estimates are subject to the same weaknesses as any estimates of farm production costs. Merrill K. Bennett has called attention to these, saying: "Statistics of money costs of production are inherently untrustworthy. Money cost data can be compiled only by the adoption of certain arbitrary rules of accounting procedure. It is impossible by any method definitely to separate charges for interest from charges for rent of land, and certain elements of cost, notably interest on growing crops and wages of management are usually omitted because calculation is in effect impossible. Joint products are so numerous in agriculture that allocation of costs becomes a serious problem; yet allocation must be made on some arbitrary basis. Non-cash cost items predominate in agriculture, and valuations have to be made on uncertain bases. These difficulties of accounting procedure are so numerous and significant that practically no farm cost study can be found to which reasonable objection cannot be raised regarding the accuracy of the data. . . . ." _Farm Cost Studies in the United States, Their Development, Applications, and Limitations_ (Stanford University: Food Research Institute, 1928), pp. 260-261.

TABLE 6

ESTIMATED FLOOD LOSSES IN THE UNITED STATES, 1934-1941[a]

(000's Omitted)

Area	Not Classified	Tangible Property	Matured Crops	Prospective Crops	Livestock and Other Moveable Farm Property	Suspension of Business	Total
St. Lawrence............	$ 119	$ 13,312	$ 57	$ 592	$ 54	$ 87	$ 14,223
North Atlantic Slope....	14,760	170,817	8,789	3,251	2,599	6,427	206,646
South Atlantic Slope....	...	4,214	307	1,629	469	1,279	7,899
East Gulf of Mexico.....	3,545	2,886	2,093	6,157	530	980	16,194
Upper Mississippi Basin.	...	6,737	2,032	1,794	183	571	11,320
Missouri Basin..........	2,087	27,820	12,474	15,816	1,556	2,194	62,668
Ohio Basin..............	413,553	131,752	6,564	6,663	1,191	2,975	562,701
Arkansas Basin..........	65	7,879	5,073	6,615	635	773	21,040
Red River Basin.........	82	1,959	1,636	3,088	260	458	7,485
Lower Mississippi Basin.	6,485	15,442	13,823	5,756	449	2,369	44,328
West Gulf of Mexico.....	1,000	8,597	4,430	12,787	1,203	626	28,645
Colorado Basin..........	500	844	2	190	3	100	1,641
Pacific Slope...........	36,256	16,639	2,314	8,080	1,514	927	65,733
Total..............	$479,174	$408,903	$59,599	$72,426	$10,651	$19,772	$1,050,528

[a]Source: U. S. Weather Bureau.

To a large degree, the loss for a given crop is a function of the season and the duration of flooding, and estimates of past crop losses may be calculated with accuracy on the basis of relations which can be established between amount of loss, season, and duration. This general technique probably was used first by Meyer in the Minnesota Valley, and has since been applied widely with refinements.[1] Studies such as those of the Arkansas Valley reveal that depth of flooding and shape of the crest have relatively little effect upon the amount of crop loss.[2] It will be observed from the charts given in Figure 7 that for cotton, corn, and wheat in an Eastern Texas area the major losses occur during the growing season. Losses amounting to as much as 50 per cent of the total possible loss to such crops may develop, however, from winter floods. Those charts also indicate that whereas an inundation of a few hours will have little effect upon crop production, the seriousness of loss increases rapidly during the first 48 hours that water stands in the fields, and approaches a maximum at that time.

These factors are illustrated by the sample estimates of agricultural losses given in Table 7. Crop production losses are the outstanding items in estimates of growing season losses and mean annual losses. They take a place of equal or lesser importance with losses to buildings and other improvements during other periods.

In contrast, losses to livestock and other movable farm property, which averaged 8 per cent of the Weather Bureau estimates of agricultural losses for 1934-1941, are especially responsive to differences in depth of flooding and in the rapidity with which crest is reached. For them, the duration and season of flooding are relatively unimportant except in periods of severe winter weather when exhaustion and even freezing of livestock may be involved. Valuation of livestock losses, as of all the remaining types of farm losses other than those to drainage and irrigation

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[1] Minnesota Department of Drainage and Waters, First Biennial Report of the Commission of Drainage and Waters to his Excellency the Governor and the Legislature (E. V. Willard, Commissioner, 1921), pp. 44-48.

[2] 74th Cong., 1st Sess., Arkansas River and Tributaries, House Doc. No. 308 (Washington: Government Printing Office, 1936), I, 464-465.

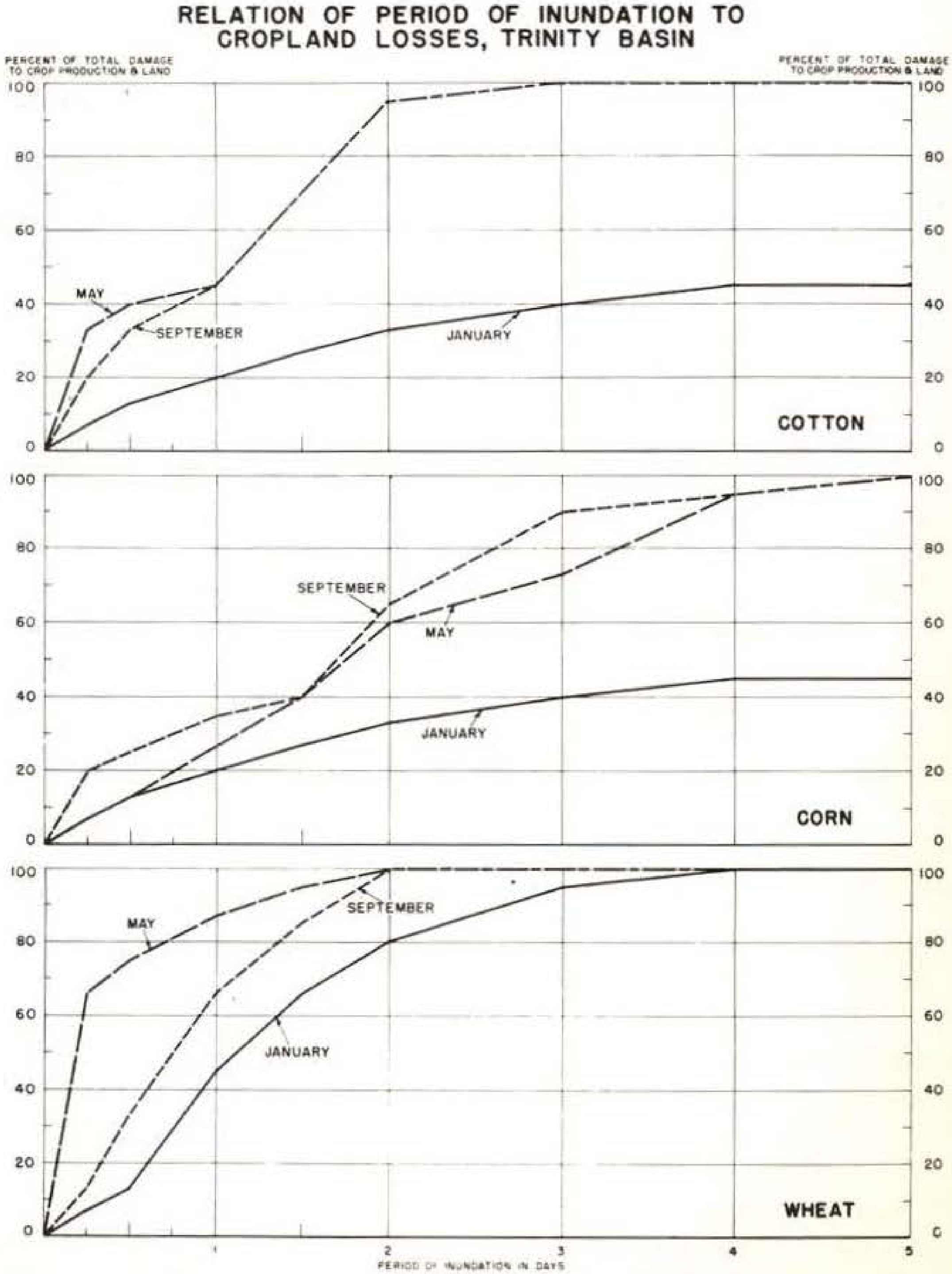

Fig. 7.--Relation of period of inundation to cropland losses for cotton, corn, and wheat crops in the months of January, May, and September, Trinity Basin, Texas (from Department of Agriculture Survey Report on Trinity Watershed, appendices, p. 173).

TABLE 7

ESTIMATED LOSSES FROM FLOODS IN SELECTED AGRICULTURAL AREAS

Loss	Percentage of Total Agricultural Loss			
	Trinity Basin, Texas[a] Mean Annual Loss	Arkansas Basin, Colo., Kan., Okla., and Ark.[b] (Corps of Engineers) Maximum Flood in Growing Season	Rock River, Ill.[c] (Corps of Engineers) Late Winter Flood	Central and Northern California[d] Early Winter Flood
Crop and pasture....	80	77	20	42
Land.........	12	14	3	?
Livestock....	2	..	1	14
Buildings and other farm improvements......	6	9	76	44
Total...	100	100	100	100

[a]U. S. Department of Agriculture Survey Report.

[b]75th Cong., 1st Sess., Arkansas River and Tributaries, House Doc. No. 308 (Washington: Government Printing Office, 1937).

[c]U. S. Engineer Office, Report on Flood Damages on Rock River, Illinois and Wisconsin, During Spring and Summer of 1937 (Rock Island, 1938).

[d]California, Report of the Department of Public Works to the Governor of California on Damages Resulting from Storm and Floods, December 10-13, 1937 (Sacramento: The Department, 1938).

works and to land, presents no outstanding difficulties and lends itself to the market value or capital income methods.

With drainage and irrigation works it is troublesome to distinguish between normal maintenance and repair work and that required wholly by flood destruction. The processes of silt deposition in ditches, of bank caving, and of deterioration of concrete and wooden structures, are accelerated by floods, but are normal in many regions, and are taken into account in estimating the maintenance and depreciation costs of drainage and irrigation enterprises. Inasmuch as many such enterprises are located in flood plains to take advantage of alluvial soils and gentle slopes, it follows that they are designed to bear occasional flood losses as part of the operating expense and that these losses may have quite a different economic effect, therefore, than those in areas which are unprepared.

Floods deplete land by scouring top soil; by depositing sand, gravel, clay, or other infertile debris; by washing away all or part of the soil profile; by clogging drainage channels so as to impede drainage; and by dissecting land so as to leave it in operating units of uneconomic size. Standard land-appraisal methods may be used to gauge these losses, but it is believed that land value alone may not be an entirely satisfactory measure of the total social impact in areas in which land damages require abandonment of farming. The expense of relocating the farmers who are permanently deprived of their land resource by floods is likely to be much greater than the value of the land itself, and public expenditures may be required to help effect a lasting readjustment. Rarely is enforced abandonment on a large scale, although it threatened to assume such proportions in the Republican valley after the flood of 1935, and it takes place in terms of a few farms here and there.

Urban residential losses.--Losses to urban residential occupance accrue largely to the improvements, decorations and furnishings of residences and to personal belongings. They may include, in addition, foundations and superstructures of residences; garages and other buildings; automobiles and other vehicles; grounds and improvements; and loss of income from rentals.

Height and velocity of flood waters determine to large degree the severity of damage to foundation and superstructure; it is only in rare instances that buildings are carried off their foundations and swept along with the current. Results of a few of the detailed damage surveys which are available (Table 8) indicate that these items constitute a relatively small part of the total residential damage in the areas studied. The chief losses result from soaking internal improvements, furnishings, and personal effects. Even in low-quality houses such losses amount to approximately half the total residential losses, and on higher-class properties they may amount to more than 70 per cent of the losses. Height of flooding is the major limiting condition for such losses. The higher the water velocity the greater is the hazard from floating objects which may batter out windows, carry away plaster and doors, and otherwise damage fixtures and decorations.

Loss of income is, on the whole, a very small part of residential losses because only in rare instances do homes remain unoccupied for more than a few days after a flood has receded.

Commercial losses.--The three major items of commercial loss are decorations, store furnishings, and stocks of merchandise. Other commercial losses attach to building foundations, superstructures, and improvements; equipment, such as freight-handling equipment and scales; outbuildings; vehicles; grounds; and business interruption.

TABLE 8

ESTIMATED LOSSES FROM FLOODS IN SELECTED URBAN RESIDENTIAL AREAS

Loss	Percentage of Total Loss for Building Unit			
	Paducah, Ky. (T.V.A.)	Passaic Valley, N. J., 1937		
		High Quality		Low Quality
		Frame	Brick	Frame or Brick
Building..............	42	29	35	46
Furniture and fixtures	56	71	65	54
Rents.................	2	..	..	..
Total............	100	100	100	100

Losses in merchandise accounted for more than 25 per cent of the total commercial losses in a few floods for which detailed data are available. These losses, although affected in large measure by height of flooding, are probably more directly a function of the character of crest profile than any other loss. They are readily transported, and storekeepers are accustomed to transporting them, so that removal can be accomplished with sufficient warning. As already suggested in connection with urban residential losses, the degree of loss in decorations and store furnishings is more nearly a function of height of flooding than of other conditions. Plate glass windows are one of the principal objects of damage in retail commercial areas; they become vulnerable as soon as the water is sufficiently high to carry floating objects against them. Decorations and furnishings amount to 50 or 75 per cent of the losses experienced by much commercial occupance.

Recorded statistics fail to distinguish among forms of business interruption, but three general forms may be identified upon the basis of the formula stated above. These are: (1) the value of goods and services which are not sold; (2) the net depreciation resulting from non-use of productive equipment; and (3) the excess cost of delayed sales. It is to be expected that the net decrease in sales of a given article or service will be relatively small unless the demand for the commodity is met by commercial concerns outside of the flooded area or unless a marked decline in production elsewhere in the flood plain causes decreases in agricultural, manufactural, or other payrolls. In so far as the commodities handled are staple food products, tobacco, and other items having little flexibility in daily consumption, the needs of the affected population will be met on a normal or reduced level during time of flood by purchase or donation from outside sources. Other normal purchases are deferred or are suspended with the result that the equivalent income is used in making repairs and replacements required by flood losses. This hypothesis is supported both by data on general business activity and by the experience of business men. The record of Federal Reserve Bank clearings for selected flood areas in recent years shows that commercial sales drop heavily during the period of high water and then rebound promptly as a community resumes its normal activity. If necessary repairs and replacements are financed from reserves, outside donations, or loans, renewed business activity may actually exceed normal, so that we find sections of the business community hailing a flood in such terms as these:

> A strong rebound after interruptions of this kind is natural. They block the shipment of goods on order and cause purchases to be deterred, and when business is resumed there is a rush to fill urgent needs, even those who experienced losses in the floods may for a time spend more than usual; they will buy less of some things but they have to replace household and personal goods destroyed, and the purchasing power to make these replacements will come out of savings, borrowings or relief contributions. The same is true of business concerns. The first necessity is to repair the damage to transportation facilities and plant equipment, and to clean up and get to work; and for the most part going concerns can find the money they need out of reserves or loans.
>
> Thus the floods will lead to a good deal of expenditure

on labor and methods not previously planned, and reports from the areas affected already show the stimulus.[1]

This view prevails among many business men, but there are some who recognize that any temporary stimulation in building and buying operations following a flood is at the expense of purchasing power which otherwise would be used later or elsewhere.[2] A canvass of available data on bank clearings, freight loadings, and similar indices of business activity in selected flood-plain communities fails to reveal many marked changes during flood periods. Either the rehabilitation and repair activities obscure the flood impacts, or they are not sufficiently large to be distinguished from the normally operating factors affecting price fixing and rate of production.

In truth, there is little detailed evidence to support the somewhat popular belief that floods cause intense distress and disruption in a commercial community. Interruption of business may result, perhaps, in production damages in excess of property damages but business men are not inclined to place much emphasis upon the seriousness of business interruption. Until more data on the subject are collected and analyzed, it seems doubtful whether production losses should be counted as of the same magnitude in commercial areas as losses in merchandise and in store furnishings and decorations.

Manufactural losses.--Machinery and business interruption are the two outstanding types of losses experienced by manufacturing plants. Other important items are foundations, superstructures, improvements, and decorations of buildings; office furnishings and records; stocks of raw materials and finished goods; outbuildings; vehicles; and grounds and improvements.

Machinery losses commonly form a major part of the total losses to manufacturing. This is evident from reconnaissance studies of flooded areas and from the preoccupation of trade associations and plant executives in such areas with machinery problems. Silt and rust are the two enemies of machinery in time of flood. While water may not have sufficient velocity or debris load to cause heavy damage during a flood, it invariably leaves a

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[1] National City Bank of New York, General Business Conditions (New York: National City Bank of New York, March, 1937), p.1.

[2] Guaranty Survey (New York: Guaranty Trust Company of New York), XVI (1937), No. 11, p. 7.

coating of moisture and silt which works injury to electrical contacts, cutting and grinding surfaces, gears, and precision mechanisms. All flood water carries a sufficient load of fine sediment to cause some damage, and quite irrespective of the total load of sediment, machines suffer from it. Electric motors and steam boilers probably require more attention in rehabilitation work in order to remove silt than for any other purpose. In metal-working, railway, food-products, chemical, and textile shops, to name only a few, machinery losses are the major flood problem.

A survey of the experience of rock-products plants during the flood of 1937 in the Ohio Valley shows that even in this heavy and relatively simple processing work the chief losses resulted from damage to motors and electrical equipment, and from erosion of stockpiles of sand.[1] Floating equipment and heavy stationary equipment did not suffer greatly. Some office records were lost and certain riverside bins and pumphouses were undermined, but the only other large expenses were incurred in cleanup work, especially in washing stockpiles of sand and gravel.

Some manufacturing plants suffer solely from losses in production. Although located above the flood plain, they are dependent upon power or water or fuel obtained from facilities that are inundated. Thus, numerous plants in the Cincinnati area were forced to shut down during the 1937 flood until power houses, water systems, or railway lines could be placed in operation. Where perishable materials are preserved by refrigeration or where continuous chemical processes are used, a shutdown in power or water may be as serious as though the plant were partly under water.

The preceding discussion of interruption in commercial operations is applicable in principle to manufacturing operations, though on a simpler scale. Unless the process is necessarily of seasonal character, as with canning and women's clothing, or unless it employs a continuous process of production, as in the iron and steel and distilling industries, there is within our present economic system a strong possibility that any cessation of production will be offset by delayed activities. Total payrolls for the year as a whole may be no smaller and the total output of goods for the year may be no less than if a flood had not occurred.

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[1] Bror Nordberg, "River Plants Recovering from Flood Disaster," Rock Products, March, 1937, pp. 44-47.

The data on production in the Pittsburgh area during 1936 would seem to support this belief.[1] To date there have been no studies of manufactural activity in time of flood which would suggest the contrary.

It follows that the social impact of interrupting manufacturing operations tends to be greatest with seasonal and continuous process industries in any period, and with national-defense industries during war periods when full production is the order of the day. Under any circumstances, the duration of flooding is one of the more significant conditions limiting the amount of losses through business interruption, since the time period affects the chance of developing substitute production, and also determines in large measure the extra costs involved in readjusting production schedules to make up for lost time.

Efforts to measure the amount of business interruption in this field have been few and incomplete.[2] Machinery losses as well as other types of losses may be valuated readily on the basis either of repair cost or market price.

Public utility losses.--Gas, water, waste-disposal, electricity, telephone, and telegraph services suffer chiefly from damages to outdoor or underground equipment and from interruption of service. The first of these--the direct losses to transmission lines, sewers, water mains, and other equipment--is expressed in reparable losses and in the added maintenance cost of making minor repairs and keeping systems in operation during the flood. Analysis of sample distributions of losses of that character suggest

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[1] Pittsburgh Business Review, Vol. VI (February, 1937). Annual statistical supplement.

During the severe St. Patricks Day flood of 1936 in Pittsburgh, two blast furnaces were out of operation, electric power production was approximately 50 per cent of normal, carloadings dropped 38 per cent, and river shipments dropped 64 per cent. These indices of business activity made a quick recovery within a week or two. Ibid., VI (March 30, 1936), 3.

"A Business Survey of the Flood," Barron's, XVII (February 1, 1937), 9, suggests that the principal national industry affected by the Ohio River flood of 1937 was the distilling business more as a result of power shutdowns and because of interruption of shipments to retail stores than because of direct property damage.

[2] The principal attempt has been made by the Corps of Engineers in the Connecticut Basin. In this instance the ratios of "indirect" to "direct" losses were obtained by taking the means of such losses reported by merchants and manufacturers on questionnaires following the flood of 1936.

that height of water at the key generating and transmission points is the principal difficulty with electrical, telephone and telegraph systems, and that flooding of pumps and filter beds is mainly responsible for sanitary evils.

These losses seem of secondary importance by comparison with the inconvenience and interruptions of production resulting from breakdowns in any one of the systems. By calculating the costs of maintaining service in the face of flood or of initiating it thereafter, it is possible to estimate a small part of the losses from such interruption and this has been done in a few instances. The major losses rest, however, in the realm of the intangibles. For example, during the Louisville flood of 1937, most of the city was without electricity for 168 hours. At Cincinnati, in the same flood, the people lacked public water supply for 216 hours.[1] What is the real damage of the resulting interruption? One rough measure which may be applied but has not been widely used in estimating flood losses is the value of the service during the period of interruption, as gauged by its regular sales price. This is a meagre measure, at best, because the importance of being able to communicate from a flood-bound area with the outside world, or of being able to heat food when a home is isolated and the weather is severe, may be many times the value of the same service in normal times. Here is a case in which some arbitrary coefficient of increase in estimates of losses seems justified.

On the whole, damage to electricity and gas service seems to be of greater general significance than the others. In time of flood, water can be obtained for essential industrial and domestic purposes if the necessary pumps and treatment facilities are available. Moreover, the dilution of the flow is such that stoppage of sewerage systems does not constitute an exceedingly difficult problem until the waters recede. Telephone and telegraph systems rarely suffer serious injury, in part because their lines commonly are strung above flood crest stage and in part because they are not susceptible to long interruption by water soaking alone. Unless a telephone exchange is inundated, the telephones generally remain in use.

As a matter of fact, the significance of floods in dis-

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[1]E. J. Tangerman, "A River Goes Wild," Power, LXXXI (1937), 172-174.

rupting communications in the United States has been exaggerated grossly. The flood of 1937 in the Ohio and Lower Mississippi valleys is a case in point. Telephonic and telegraphic communication was suspended only in parts of the flooded area.[1] At the height of flood, communications across the line of the flood and to most of the affected cities was possible. Delays came in considerable measure from the tremendous increase in volume of messages, particularly in toll calls, caused by flood-rescue and related work. Mails were affected only slightly. According to information obtained from the Post Office Department, the deliveries of first class mail between New York and Chicago were delayed a few hours, and those between Cleveland and points south of the Ohio River were delayed somewhat longer.[2] Deliveries were suspended, of course, in the flooded areas, but generally were resumed as soon as the waters receded. No important amount of mail was lost.

Transportational losses.--The same conditions noted with respect to communications apply to transportational activities. While traffic is suspended in and immediately adjacent to a flood zone, other freight and passenger movements continue. Interruption in railway or highway traffic affects chiefly the transportation within the flooded area, but it may retard transportation following routes crossing the flooded area. Probably the most severe traffic tie-up resulting from floods in the history of the United States was that in the Middle Atlantic States and New England during March, 1936. Then, the main line of the Pennsylvania Railroad between Pittsburgh and Harrisburg was closed, its tracks at the Harrisburg and Wheeling stations were under water 4 feet and 10 feet respectively, more than 500 miles of line were under water at some time during the flood, and 8,000 miles of track were exposed to flood conditions.[3] Approximately 75 miles of the main

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[1] Judson S. Bradley, "Meeting the Challenge of Sleet and Flood," Bell Telephone Quarterly, XVI (1937), 89-98.

[2] Even when the hurricanes and flood of 1938 cut the raillines between New York and Boston, the first class mail was delivered by chartered airplane, and the parcel post was handled by Navy vessels, without substantial delay. In fact, the Department often saves money during a flood, because it does not pay for the normal and frequent rail service, and pays instead for a less frequent and only slightly more costly alternative service.

[3] "Floods Ravage Railways in East," Railway Engineering and Maintenance, XXXII (1936), 226-229, 236.

lines of the Baltimore and Ohio Railway between Washington and Pittsburgh were under water, causing the line to be out of service for through traffic for 5 days. Most of the Pittsburgh terminal facilities of the Pittsburgh and Lake Erie Railway and at least 26 miles of its line were inundated. The New Haven and Boston and Albany systems were disrupted for a period of at least 5 days, the major interruptions occurring in the flood plain of the Connecticut River. It is, however, a great tribute to the efficiency of transportation agencies, dairymen, and public-health officials that during the flood which cut across the Northeastern dairying areas in many places, no serious interruption resulted in the perishable milk supply, which probably is the most delicately timed of the transportation services in those areas.

The Ohio River flood of 1937 caused less disruption than the New England flood because the flooded valleys parallel the major East-West trunk lines. The chief through rail crossings of the Ohio River below Steubenville, Ohio, were closed off, even though it was possible to maintain service over one line serving Cincinnati and another serving Louisville. Losses in railway equipment were relatively small inasmuch as currents in most places were not strong. The railways suffered expense from interruption of their business, from rehabilitating water and silt-soaked equipment, and from providing emergency services for evacuees. The main streams of North-South and East-West traffic were re-routed without undue delay or expense.[1]

Interruptions in transportation can be measured in at least two ways. First, the value of the normal commercial traffic on the highways and railways can be estimated from records of comparable periods, and a certain percentage can be taken as the loss, making due allowance for transportational services which are delayed, and for the costs of re-routing traffic. In the Connecticut Basin the estimated cost of delay and detouring was calculated by assuming a value of one dollar for each hour that a highway vehicle was delayed, using prior traffic counts as a basis for calculating the number of vehicle hours. The same esti-

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[1]J. J. Pelley, "Railroads Help in Flood Emergency," Railway Age, CII (February 20, 1937), 321-322, 328.

"Service Restored Rapidly as Ohio Recedes," Railway Age, CII (February 6, 1937), 248-253.

mates attacked the question of losses in railroad traffic by adding the loss in revenues during the period of the flood to the increase in operating costs. In studying the Fourche bottoms along the Arkansas River immediately below Little Rock, Arkansas, the Corps of Engineers estimated that indirect losses, due largely to interruption on main highway and railway arteries, appeared to be three times the property losses.[1]

Second, the extra costs of operation for a period approximately longer than the flood can be taken as a rough gauge of losses. This procedure is more readily applied, but is less accurate than the first one because it fails to account for traffic movements which are permanently abandoned. A number of railroad officials have said that their losses in traffic depended largely upon whether or not the same territory was served by a competing railroad which was not subject to flood. Perhaps no other phase of flood experience illustrates so well as transportation the difficulty of attempting to express production losses as a ratio of property losses. Washouts of a highway costing $50,000 may result in no other loss or in tremendous loss, depending upon the location of the highway which is otherwise untouched by high water. Similarly, the effects of damages to other productive equipment in commerce and manufacturing is more a function of the volumes and quality of business handled than of the amount of physical loss.

A review of property losses for representative transportation services shows that culverts, bridges, and roadbeds are the outstanding items among the number which includes buildings, outdoor terminal equipment, rolling stock, goods in transit, and the cost of maintaining emergency service. Losses to production and to human life and health are relatively small. During the past seven years the railway train accidents resulting from floods and washouts have amounted to only four-tenths of one per cent of the total number of accidents and have not changed notably in incidence, as shown in Table 9. During that period, 74 people lost their lives due to such accidents, and 53 of these lives were lost in one wreck caused by the undermining of a bridge during a cloudburst flow in Custer Creek, Montana.[2] More than 84 per cent of

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[1]76th Cong., 3d Sess., <u>Arkansas River, Little Rock to Pine Bluff, Ark.</u>, House Doc. No. 718 (Washington: Government Printing Office, 1940), p. 44.

[2]U. S. Interstate Commerce Commission, <u>Accident Investi-</u>

TABLE 9

TRAIN ACCIDENTS DUE TO WASHOUTS, 1934-1940[a]

Year	Train Accidents				Persons Killed		Persons Injured	
	All Causes	Bridge Wash-outs	Road-bed Wash-outs	Total Wash-outs	All Causes	Due to Wash-outs	All Causes	Due to Wash-outs
1934	6,023	7	13	20	256	8	1,000	15
1935	6,551	4	22	26	239	3	1,056	34
1936	8,286	3	27	30	277	5	1,547	22
1937	8,412	2	19	21	310	..	1,367	30
1938	5,682	8	35	43	293	53	1,073	90
1939	6,074	4	14	18	214	3	1,422	53
1940	7,106	1	22	23	342	2	1,550	40
Total	48,134	29	152	181	1,931	74	8,965	284

[a]Source: U. S. Interstate Commerce Commission, Summary and Analysis of Accidents on Steam Railways in the United States Subject to the Interstate Commerce Act, Accident Bulletin, 1934 to 1940.

the train accidents attributed to floods resulted from injury to roadbed, and 16 per cent resulted from loss of culverts or bridges. Roadbed maintenance in narrow floodplains probably has been the major cause of trouble on railways at flood time.

Serious highway accidents due to floods and washouts are few in number, and result for the most part from sharp-crested floods in arroyos and canyons of the semiarid and arid regions. No fatal accidents caused by road defects of this character were reported in 1940,[1] but an examination of newspaper clippings shows that no year has passed since 1934 without at least one such accident.

Other losses.--Two major types of loss apply to all occupancy classes. The first is cost of public evacuation and relief operations, which will be analyzed in Chapter IV.

gation Reports, No. 76 (1938), pp. 31-34.

[1]Accident Facts, 1941 Edition (Chicago: National Safety Council, Inc., 1941), p. 93.

The second is fire. Floods promote fire by dislodging tanks and spreading oil and gasoline, by hampering the work of fire-fighting units, by closing down water pumps, by damaging electrical and heating systems which sometimes are repaired too hastily for safety after the flood, and by disrupting sprinkler systems. The most serious of such fires in recent years occurred in the Mill Creek section of Cincinnati during the Ohio River flood of 1937, and resulted in damage in excess of $1,400,000.[1] Because buildings in flooded areas commonly are abandoned temporarily, the fire hazard tends to be decreased somewhat, but at the same time the lack of personnel to watch for fires and the necessity for emergency heating and cooking arrangements for those people who remain, are likely to increase the hazard. A committee of the National Board of Fire Underwriters found in 1939 that floods bring special fire hazards but do not produce abnormally large flood losses.[2]

Two other groups of losses are linked so intimately with corollary profits that both losses and profits are discussed together. These are (1) psychic losses and profits to the community, and (2) effects upon the natural landscape.

Psychic Losses and Profits

Floods bring sensations of fear and distress to a community, but they also stimulate and exhilarate. Kutak has noted in connection with a sociological appraisal of the Louisville flood of 1937 that a flood disaster is typically a crisis situation characterized by suddenness and by an intoxicating loosening of the mores of the community.[3] As the onrushing waters threaten life and property, every effort is bent to organize all human resources to meet the attack. Flood-fighting and evacuation measures require new organizations into which all citizens, regardless of income and social position, can enter shoulder to shoulder. The old pattern of living is broken for the time, ultimate aims yield to immediate demands, confusion is widespread, and to many

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[1] Factory Mutual Record, XIV (1937), Nos. 3 and 4, 9-12.

[2] National Board of Fire Underwriters, The Flood Problem in Fire Prevention and Protection (n.p., 1939), pp. 94-97.

[3] Robert I. Kutak, "The Sociology of Crises: The Louisville Flood of 1937," Social Forces, XVII (1938), 66-67.

a person there comes a refreshing sense of release from humdrum obligations and tasks. It is a solemn and serious business for the men on the levees and the women in the relief stations, but it also seems to be an intensely satisfying one.

These sensations are pleasing at the moment, and they also promote mutual interest and helpfulness among the people of a community, thereby stimulating civic improvement. The experiences of caring for evacuees and of battling together against an evil natural element, even though the battle be shared vicariously through a radio announcer, inspires good will and provides the setting for new ideas with respect to municipal planning and development. These profits pass in time and probably they are embraced with particular enthusiasm by persons in the upper income groups who realize that any levelling effects will be merely temporary.

It seems probable, however, that in certain flood plains, such as the alluvial valley of the Mississippi River, there are groups in the lower income brackets who have profited in a different way from public-relief activities accompanying floods. For the first time, perhaps, those people have experienced adequate diet, adequate medical care, and association with others who enjoy higher wage rates and better working conditions. As suggested by Bernard, this undoubtedly was the case following the flood of 1927 in the Lower Mississippi,[1] and while it hardly could be considered a justification for repetition of that disaster, it certainly offset some of the inconvenience and hardship that did result.

While sorrow and frustration also follow the path of lost lives, broken families and disrupted economy that is etched by floods, these losses are balanced against psychic profits. Few communities can be more drab than a town already near the verge of economic bankruptcy which has suffered a crippling blow from floods. Yet it seems likely that in a few such towns a flood has made short work of what otherwise might have been prolonged deterioration, and that the flood has stimulated new and drastic action. The Shawneetown and Leavenworth examples, discussed in Chapter IV, bear out this idea in part.

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[1]Bernard, op. cit., p. 193.

Floods as Agents of Landscape Change

The losses defined in preceding pages are those which accrue to the cultural landscape of a flood plain as a result of flood, and in discussing them it has been assumed tacitly that other conditions remain constant. Actually, the flood plain itself changes more during the flood event than at any other time. Then it is that lateral and vertical erosion is most pronounced, and then it is that most sediment is deposited. Some of these changes cause lasting loss to the occupants of a flood plain. Others result in net gains.

The process of flood plain development is a combined action of channel cutting and valley-flat filling. In a young valley having a valley flat the stream cuts down into materials having a veneer of alluvium of lesser thickness than the channel depth and at the same time moves across the valley flat by erosion on the outside of bends and deposition on the inside of the bends. In old valleys, downward erosion is slight and deposition of sediment is the dominant process, but there may be a wide lateral shifting of the stream channel in its bed of alluvium.

With one exception, all phases of cutting and filling are more active during and immediately after a flood than at any other time. Downward erosion is largely a flood phenomenon, and it is known that for many streams, such as the Missouri River, which is continually changing its bed elevation, the greatest scouring occurs during high water when volume is large, velocity is high, turbulence is high, and the carrying capacity of the stream is, therefore, relatively great.[1] In the Finger Lakes Region of New York, it has been estimated that as much lateral erosion occurs during floods having a frequency of once in 100 years, as during all the intervening years without such floods.[2] Lateral bank cut-

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[1] 73d Cong., 2d Sess., Missouri River, House Doc. No. 238 (1935), pp. 1150-1152, 1163-1165.

For a general review of the literature on this subject as of 1932, see William H. Twenhofel, Treatise on Sedimentation (Baltimore: Williams and Wilkins Co., 1932), pp. 37-44. Also, John B. Leighly, Toward a Theory of the Morphologic Significance of Turbulence in the Flow of Water in Streams, University of California Publications in Geography No. 6 (Berkeley: University of California Press, 1932), pp. 1-22.

[2] O. D. VonEngeln, "Flood Erosion," Abstract, Proceedings

ting is pronounced during peak discharge or on the receding stages of floods. Large-scale shifts in channel, including meander cut-offs and sudden changes from an old bed to a new one, take place as the flood approaches or passes its crest. The less rapid process of lateral movement exemplified in bank caving of streams in alluvial valleys, accelerates as the flood recedes. During rising flood stages, the swifter currents tend to shift toward the center of the channel and do not return to the concave shore until the water begins its fall. This leads to erosion on the concave shore, a process which is promoted by the saturation of the stream banks at crest or near crest, so that "slip planes" are created along which the bank material slumps or slides as the pressure of water is withdrawn.[1] In the alluvial valley of the Miami, Kilchis and Tillamook rivers on the Oregon coast, the damage from bank cutting caused by annual floods exceeds the direct damages to property, and the cutting is most pronounced on falling stages of the flood event when the streams are at approximately two-thirds bankful capacity. The net change resulting from these floods is a gain in the amount of alluvial fill in the valley area, but the immediate effect is a decrease in the old fills and an increase in fresh deposits of sediment.[2]

In this connection it may be noted that navigation improvements on streams flowing in meander belts through alluvial valleys are likely to encourage further encroachment upon the flood plains because measures that curb lateral erosion by such streams reduce the hazard of loss through bank cutting. This was the case along the Missouri between Sioux City and Kansas City when revetments and other channel-stabilization works were installed and lateral erosion was curbed. Between 1930, when the river works were begun, and 1938, the amount of cleared land in the flood plain

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<u>of the Geological Society of America for 1935</u>, p. 115.

W. Storrs Cole, "Modification of Incised Meanders by Flood," <u>Journal of Geology</u>, XLV (1937), 648-654.

[1]Gerard H. Matthes, "Basic Aspects of Stream-meanders," <u>American Geophysical Union Transactions of 1941</u> (Washington: National Research Council), p. 634.

[2]Unfavorable report of the Chief of Engineers on "Miami, Kilchis, Wilson, Trask, and Tillamook Rivers, Oregon," July 1, 1941. (Unpublished.)

increased by 40 per cent.[1]

Sediments are deposited chiefly during floods, either by sideward filling or as top-delivered veneer. It is here, however, that there is the principal exception to the statement that the processes of change are greatest at flood time. Although sediment is actually spread over the flood plain by flood waters, it reaches the plain in many instances by processes which are accelerated at other times. Thus, it may be observed in many young valleys that tributaries tend to build up small deltas on the valley flat in periods of moderately high water when the flow of the main stream is inadequate to transport the sediments. Unless floods of large magnitude wipe out these deltas and move their contents down or across the stream they will continue to block the main channel and to cause shifts in it.[2] Similarly, sediments accumulate in a stream channel at times of low flow, and are deposited at places where the gradient is low, where the flow diminishes, or where there is a specially large obstruction by reason of bed materials or of a tributary carrying a heavy debris load. The debris deposits become compacted with colloidal and organic material and grow until cut out by flood flows.[3] Indeed, in some streams, such as the Lower Rio Grande, the elimination of major flood flows (through the construction of Elephant Butte Dam) has facilitated accumulation of sediment and growth of vegetation with the result that the carrying capacity of the downstream channel for relatively frequent floods is reduced materially.[4] Because streams normally reach their greatest efficiency with the maximum of tractive force

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[1] 76th Cong., 3d Sess., Missouri River--Sioux City to Kansas City, Iowa and Missouri, House Doc. No. 821 (1940), pp. 16-17.

[2] Gerard H. Matthes, "Floods and Their Economic Significance," American Geophysical Union Transactions of 1934, Part II, pp. 427-432.

[3] Stafford C. Happ, Gordon Rittenhouse, and G. C. Dobson, Some Principles of Accelerated Stream and Valley Sedimentation, U.S. Department of Agriculture Technical Bulletin, No. 695 (1940), pp. 71-74.

In parts of the arid southwest, sediment transportation takes place only during floods. J. C. Stevens, "The Silt Problem," Transactions of the American Society of Civil Engineers, CI (1936), 240-244.

[4] A. L. Sonderegger, "Modifying the Physiographical Balance by Conservation Measures," Transactions of the American Society of Civil Engineers, C (1935), 291-295.

This situation is being remedied by channel works constructed by the International Boundary Commission.

and turbulence at bank-full flows, lesser flows may be incapable of scouring out accumulated channel deposits. All the foregoing statements concerning stream and debris dynamics recognize the tremendous diversity among streams in these matters. Many phases of the basic theory are still in controversy. In a sense, each case is unique and the streams of the United States lend themselves only to the broadest type of generalization.

Just as reduction of stream flow causes changes in valley-forming processes, so changes in the load of sediment effect the same processes, but inasmuch as they result primarily from land use outside of the flood plain they are not discussed here.

Certain changes in landscape which accompany floods have outstanding significance in human occupancy. Most dramatic but least frequent are major channel shifts of the type which, along the Lower Mississippi River, change overnight the location of a Vicksburg from the main channel to backwater, or shift the navigable channel away from terminal facilities, or leave a waterworks intake standing high and dry, or desert a bridge crossing. Such shifts are likely to be accompanied by large losses of land through bank cutting. Lateral cutting and filling also may cause losses to sewerage and land drainage systems by clogging the outlets or by removing the channel to such a distance that the decreased gradient prevents successful operation of the systems.

To the extent that such changes require special remedial works or enlarged maintenance costs for dwellers along a river bank, their costs can be computed fairly accurately. It is far more difficult to assign some reasonable value to the action of floods in flushing out accumulations of debris that otherwise would cause channel shifts and affect flowlines and drainage systems. With respect to most valleys it is safe to say that without the cleansing action of great floods the moderate-sized floods would have higher flowlines. A partial index of the benefits from such floods therefore would be given by the added cost of increasing the design of protective works in order to cope with the heightened flowline. Once channel-flow relationships have been modified, the effects are likely to grow and spread, and to take on larger significance than is represented by the need for protective works.

Floods further affect to some extent the vegetative succession on flood plains by crushing vegetation, including standing timber, and by spreading seeds.[1] Timber losses result chiefly from (1) shutting off a supply of oxygen at the roots during floods of long duration, and (2) uprooting or girdling by water and ice action. McKenzie also reports losses in Massachusetts through deposits of fuel oil on leaves and branches. Floods may eradicate wildlife associations which are not able to retreat to high ground, and they may spread the eggs and larvae of insect pests such as the buffalo gnat.[2] There is little detailed evidence concerning the net effects of high water upon plant and animal associations. Floods are notorious in agricultural areas as carriers of weeds and of certain diseases, such as brown rot fungi in citrus orchards,[3] but individual floods apparently do not cause marked changes for more than a year unless water stands on the ground for several months or unless severe scouring results in destruction of the soil profile and in the establishment of pioneer associations. This conclusion is supported by the efforts to use irrigation water to control certain plant pests by regulated flooding. Few of them have been successful.[4]

Floods may cause heavy losses in the population of larger animals, as along the Wolf River, Wisconsin, where June floods sometimes drown young muskrats in the bordering marshlands.[5]

Sediment Deposition

For the country as a whole, the most important gain from floods, in addition to their action in cleansing stream channels, is in alluvial deposits. Floods bear fruit as well as blight, and, as in geological time, they are responsible for soils of high fertility; in a single year they may carry rich rewards to cultivators of the soil. These rewards accrue in two ways.

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[1] Malcolm A. McKenzie, "Flood Injury to Trees," Science (new series), LVIII (1936), 412-413.

[2] "Savage Fly Outbreaks Threaten as Aftermath of Floods," Engineering News Record, CXVIII (1937), 738.

[3] Harold E. Wahlberg, "Handling Flood Problems in the Orchard," California Cultivator, LXXXV (1938), 262.

[4] Lloyd N. Brown, "Flooding to Control Root-knot Nematodes," Journal of Agricultural Research, XXXXVII (1933), 883-888.

[5] 72d Cong., 1st Sess., Wolf River, Wisconsin, House Doc. No. 276 (1932), p. 25.

(1) Plant nutrients in the soil are increased by deposition of solids and by precipitation of available bases. Little is known concerning the full effects of recent floods upon the soil profile but there is scattered evidence which suggests that, viewed solely from the standpoint of flood-plain occupancy, gains from deposition outweigh or at least equal losses from scouring and sanding.

A survey of the rural areas in Vermont affected by the flood of March, 1936, showed that approximately 317 acres of farm land were lost outright by stream cutting and channeling, and that 274 acres were covered with gravel and sand deposits which were too deep and too infertile to reclaim. An additional 1,700 acres were covered with deposits more than 6 inches deep which were reclaimed with difficulty. However, 2,245 acres, or approximately half the total area affected, were covered with shallow deposits that were reclaimed easily. The deposits varied in alkalinity from 6 to 8 pH and in calcium similarly. They lacked nitrates and magnesium, showed traces of potash, and carried medium high amounts of phosphorus.[1] They could not, therefore, have increased soil fertility notably, but their adverse effects lasted for less than a year. Inasmuch as channel degradation is a much more dominant process in the narrow and medium-width Vermont valleys than in most flood plains of the country, these results may be taken as representative of the less favorable conditions of sediment deposition.

There are no precise data relative to silting from streams in old age which move in meander belts, but local experience borne out by records of fertilizer requirements and crop yields for the Yazoo Delta indicate that the lands subject to Mississippi River floods in that area are more productive and have required applications of fertilizer less soon than have comparable soils that were protected from flood.

An intermediate situation is found in the Ohio Valley, where Soil Conservation Service made 200 cross-section surveys of deposition and soil removal following the 1937 flood. The unpublished results, summarized in Table 10, reveal that in the wide

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[1] D. E. Dunklee and A. R. Midgley, The Effect of 1936 Flood Deposits on Vermont Farm Lands, Vermont Agricultural Experiment Station Bulletin, No. 445 (1939), pp. 1-16.

TABLE 10

SEDIMENT DEPOSITION AND REMOVAL DURING THE OHIO VALLEY FLOOD OF 1937[a]

Effect on Land	Area		Volume
	Acres	Per Cent	Tons
Valley lands			
Area damaged:			
Urban deposits.......	89,093	11.0	+ 3,835,200
Rural sand deposits..	26,726	3.3	+16,858,651
Removals............	69,567	8.5	-12,312,777
Total..........	185,386	22.8	
Area benefited.........	304,066	37.4	+30,222,457
Area unaffected........	323,384	39.8	.....
Total..........	812,836	100.0	+38,603,531
Tributary backwater lands	763,949	.....	8,429,306

[a]Source: Brown and Brown, "Sedimentation Survey Following the Ohio River Flood of January, 1937."

flood plains along the valley, deposits of relatively fertile silt were made to an average depth of one-half inch, the deeper deposits occurring in low sags back from the river bank.[1] Backwaters caused relatively uniform deposits of 2-3 inches in the lower valleys of tributary streams. In the gorge-like reaches of the valley below Cincinnati there was extensive bank-cutting associated with heavy deposits of sterile sand below the cuts. There also was widespread erosion of cultivated fields, amounting to as much as 6 inches. Approximately 69,500 acres of rural land were damaged seriously by soil removal, and 26,700 acres were damaged by sand deposits. At the same time, 304,000 acres of valley land and 764,000 acres of land at the mouths of tributaries were benefited by deposition. Slightly less than 40 per cent of the entire valley was not affected either by removal or by deposition. In terms

[1]Carl B. Brown and Mark H. Brown, "Sedimentation Survey Following the Ohio River Flood of January, 1937," Unpublished report of the Soil Conservation Service.

of acreage affected, the Ohio Valley gained at the expense of upstream valleys. In terms of net change in productivity, it is impracticable to generalize; there is no evidence as to the amount of damage or amount of benefit on the affected lands. It seems clear, however, that the net effect in the valley as a whole was more beneficial than detrimental.

Robinson has ascribed the higher silica-sesquioxide ratio of soils of unconsolidated water-laid sediments in Wales to the precipitation of silicic acid from river waters.[1] While the effect has not been investigated in the United States, it may be assumed for certain valleys having somewhat similar debris characteristics.

(2) The second gain to soil from floods results from increase in soil moisture. This is well recognized in the arid and semi-arid regions, particularly in the Southwest, where water-spreading devices are being expanded actively under public auspices. On the Great Plains spring floods form a definite part of the agricultural schedule. Thus, in the Missouri Plateau of Montana, North Dakota, and Wyoming annual spring-flood flows are regarded as beneficial because the moisture deposited by them promotes the growth of forage crops.[2] Such gains are relatively easy to measure by comparing the yields of flood plains with those of adjacent lands.

Flood Plains--Advantages and Disadvantages

Most of the entries for floods on a balance-sheet for flood-plain adjustment belong on the red side of the ledger. On the whole, floods in the United States cause greater loss than gain in human occupance. A few items, such as channel cleansing and some of the deposits of sediment are proper entries as assets on the black side. It is obvious that there are compensating factors for the losses from floods; otherwise, flood plains would not continue to be occupied. These factors, as suggested, may be

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[1]G. W. Robinson, "The Nature of Clay and Its Significance in the Weathering Cycle," Nature, CXXI (1928), 903.

[2]73d Cong., 2d Sess., Missouri River, House Doc. No. 238 (1935), pp. 318-319, 326-327, 310 and 303.
Unfavorable report of the Chief of Engineers on "Belle Fourche River, Wyoming and South Dakota," June 30, 1941. (Unpublished.)

divided into two groups. The "regional factors," or those which apply to adjoining areas as well as to flood plains, can be determined only by comprehensive regional study, and, therefore, are not a part of this analysis. The "flood-plain factors," or those which apply only to flood plains, may be segregated by means of less comprehensive engineering and geographic studies, and are noted here briefly.

Slope and Contour

Rarely does a flood inundate a high-grade residential district in an American town or city. The lower-income groups in urban areas suffer proportionately more from floods than do those in higher brackets. For example, Garland shows that in the cities of the Ohio Valley between Huntington, West Virginia, and Maysville, Kentucky, the better residential areas are on terraces and valley bluffs above the reach of floods, and that new residential development is moving out of the flood plain, although the earliest occupance of that character first located upon ridges in the valley bottom.[1] Farther upstream at Pittsburgh, the urban areas flooded in 1936 were chiefly manufactural, commercial, and low-grade residential occupance. Six thousand four hundred nineteen dwellings out of a total of 153,810 in the city were under water. Prior to the flood, 22 per cent of the dwellings in the flooded area had been rated unfit for use, whereas only 3.8 per cent of all city dwellings had been so rated. At least 40 per cent of the flooded dwellings were without indoor water closets, in contrast with an average of 14 per cent for the entire city.[2] It seems to be a reasonable hypothesis that wherever a flood plain is narrow or of medium width, the better grade residential occupance seeks the upland. Flood plains lack the scenic views and the interrupted landscape that commonly go with hillside or upland location, and they also are more likely to be occupied by objectional commercial and manufactural forms. Aesthetic considerations therefore lead housing development, particularly higher-cost residences, out of many flood plains. There do not appear

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[1] John Henry Garland, Occupance of the Eastern Segment of the Middle Ohio Valley (Chicago: University of Chicago Libraries, 1940), pp. 105-106.

[2] Pittsburgh Business Review, VI (1936), No. 5, pp. 17-20.

to be any clear-cut savings to residential construction in flood plains as compared with construction on adjacent lands.[1]

In regions of rolling topography, flood plains may afford special advantages to commercial uses which place high premium upon flat yard space. Lumber yards, oil depots, amusement areas, and sand and gravel yards, are notable examples. Quite independently of the use of any available water-transportation facilities, these uses demand relatively level ground and are able to pay for it.

The same is true of heavy manufacturing activities which require large floor space, outdoor storage facilities, or extensive railroad sidings, particularly plants for which single-story shops afford economies in lighting, heating, foundations for heavy machinery, reduction of vibrations, floor construction, and handling of materials.[2] Steel-rolling mills and oil refineries are among the types of plants that have been located on flood plains in part to take advantage of the lower construction and operation costs made possible by the terrain. A glance at the topographic maps for the Kentucky Mountains[3] and for the Allegheny Plateau section of Pennsylvania and West Virginia indicates that the valley bottoms afford the only relatively flat terrain accessible to the potential lines of cheap transportation movement. This seems to have been the case in the vicinity of Johnstown, Pennsylvania, where plants of the Bethlehem Steel Corporation and of the Lorain Steel Company occupy a large part of the flood plain and provide work for more than half the industrial laborers there. This small strip of bottom land on one of the main routes between Philadelphia and Pittsburgh attracted agricultural settlers in 1800, and became a busy terminal on tne western branch of the Pennsyl-

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[1]Inasmuch as foundation costs account for as little as 1.5 per cent of the total cost of residential building, and rarely exceed 15 per cent for large structures, such as apartment buildings, the net differential in cost between the two locations is unlikely to be a significant factor in selecting the location of new buildings. H. E. Pulver, Construction Estimates and Costs (New York: McGraw-Hill Book Co., Inc., 1940), pp. 482-484.

[2]Milo S. Ketchum, The Design of Steel Buildings and the Calculation of Stresses in Framed Structures (New York: McGraw-Hill Book Co., Inc., 1932), pp. 361-362.

[3]D. H. Davis, "Urban Development in the Kentucky Mountains," Annals of the Association of American Geographers, XV (1925), 94.

vania Canal in 1834. Iron ore deposits in the nearby upland were developed shortly thereafter, and an iron industry grew up to use those supplies as well as local coal supplies. Today, the manufacturing plants utilize the bottom land with its nearly level terrain, its water supply and access to rail transportation, while the commercial core of the city occupies the site of the original village. Other uses have been forced into the intervening sections of bottom land, or have developed on adjacent slopes and uplands.[1] Virtually all of the bottom land was flooded in 1936.

Mining activities recognize a similar situation in many valleys, where tipples, shaft houses, switching yards, screening and milling equipment, and storage facilities are on nearly level land, even though at some distance from the mine mouth.

In mining, as with most heavy manufacturing, the attraction of a lowland terrain, whether great or small, is exercised indirectly in many instances, through the effect of slope and contour on transportation facilities. Where the railway and highway go, commerce and manufacturing also go, and thus these classes of use tend to concentrate in association one with another on flood plains rather than on adjacent uplands. For example, some recent manufacturing developments in the Middle Ohio Valley were located so as to be near the valley-bottom railway rather than the river itself.[2]

The situation affecting agricultural land use is quite different. From the standpoint of farm operations, most flood plains afford two great advantages. One is ease of tillage; the other, lack of susceptibility to soil erosion. Ease of tillage tends to be a major factor only where the crops to be cultivated may be handled with profit with tractors and large-size machinery. Thus, in the Cotton Belt the prospects for continued prosperity in the large alluvial valleys are brighter than on the uplands or in the small alluvial valleys because the flood plains, in addition to being fertile, are better suited to mechanical cotton picking and cotton chopping. Experiments with machinery in the

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[1]Raymond E. Murphy, The Geography of Johnstown, Pa., an Industrial Center, Pennsylvania State College Bulletin, Mineral Industries Experiment Station No. 13 (1934) (State College: School of Mineral Industries), pp. 1-51.

[2]Garland, op. cit., pp. 81-82.

Yazoo Delta of Mississippi in the early 1930's indicate that the costs of farm operations using machinery, something which is practicable upon the lowlands, were appreciably lower than on farms not using such machinery. As farm technology improves, the differential in costs probably will widen.[1]

A further reason why the alluvial valley of the Mississippi holds hopeful prospects for permanent agriculture is that the menace of soil erosion is minimized by the gentle slopes.

Along stream valleys having sufficient bottom width to accommodate highways, surface relief affects in modest degree the design of low-density roads. As a general rule, fuel consumption by a modern automobile does not increase appreciably until grades of 7 1/2 per cent or more are encountered.[2] Few streams have a grade of more than 5-7 1/2 per cent and few highways which parallel their courses require special grading to reduce motor operation costs. Moreover, grading expense is not a controlling factor for all types of highways. Expenditures for grading may amount to as much as 68 per cent of the total construction costs on an average dirt road, whereas they may be as little as 9 per cent for bituminous or concrete surfaces.[3] Surface grade is relatively important in affecting the location and cost of a soft-surface, low traffic density type of highway, and is relatively unimportant for a hard-surfaced, arterial highway. Unlike railways, the most economical location of which is largely a matter of finding long, low grades, the modern highway is designed to fit surface configuration only in so far as necessary to minimize the cost of exca-

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[1] Lewis E. Long, Farm-power in the Yazoo-Mississippi Delta, Mississippi Agricultural Experiment Station Bulletin, No. 295 (1931), pp. 20-30.

M. G. Varden, J. O. Smith, and W. E. Ayres, Making Cotton Cheaper, Mississippi Agricultural Experiment Station Bulletin, No. 290 (1931), pp. 20-24.

[2] H. B. Shaw, "Highway Grades and Motor Vehicle Costs," Proceedings of Twelfth Annual Meeting of Highway Research Board, 1932, p. 91.

John A. Oakey, "Operating Characteristics of Cars on Grades," Civil Engineering, VII (1937), 396.

John H. Bateman in Introduction to Highway Engineering (New York: John Wiley & Sons, 1939), p. 330, suggests 5 per cent as the maximum grade for gently-rolling country.

[3] Sigvald Johannesson, Highway Economics (New York: McGraw-Hill Book Co., Inc., 1931), p. 26.

vation and to avoid unstable subsurface conditions.[1]

Considerations of traffic flow, alignment, curvature, and underlying subsoil and rock, play on the whole a much larger role than does the grade factor in affecting the placement of new or relocated highways. With increasing development of high-speed, hard-surfaced highways, requiring low curvatures, new locations in areas of low or medium relief are likely to be in available flood plains more on account of the prior location there of dirt highways, railways, and towns than on account of any advantages afforded by the flood-plain configuration. The exception, of course, is in areas of high relative relief, such as the mountain valleys of the Middle Rockies in Colorado, where valley bottoms or lower valley walls afford the only practicable locations for highways.

Drainage and Ground Water

In so far as flood plains, by virtue of low gradient, immature drainage, and high water table, are poorly drained, they have two major disadvantages for human occupance. Poor drainage makes difficult the construction of building foundations and road beds and impedes tillage. It favors the breeding of pest and malaria-carrying insects. These are deterrent factors in the settlement of many flood plains. In few instances have good drainage conditions been an incentive to more intensive use of flood plains.

The drainage of soil moisture is a function of soil texture, soil depth, underlying rock, climate, and land form. In many flood plains these combine to produce slow drainage and a high ground-water table. Many alluvial valleys with relatively thick alluvium and flat surface are swampy or marshy. All of the great alluvial valleys of the United States--the lower Mississippi, the Sacramento, and the larger streams of the Southeast--are characterized by swampy areas. The cost of urban occupancy in such areas is substantially higher than on nearby uplands. Building construction is more expensive because of the pumping necessary to keep excavations dry. Roads, bridges, and other structures,

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[1]Arthur G. Bruce, Highway Design and Construction (Scranton: International Textbook Co., 1937), p. 66.

as well as buildings and public utilities, require special treatment to cope with a high water table.

The cost of rural occupancy of such areas also is materially higher than that of upland areas because of the expense of land drainage which invariably is essential and also because of the heavier farm equipment or delayed tillage operations that sometimes are involved. Drainage expenses ranging from $20 to $100 per acre are common in alluvial flood plains, the cost depending in part upon the amount of flood protection, if any, that is combined with the drainage works. Most cultivated lands in the large alluvial valleys of the United States are in organized drainage districts. As a result of speculative expansion in the decade 1910-1920 and subsequently deflated crop prices, and because of faulty engineering design in some instances, a large proportion of these districts were in financial distress by the 1930's.[1]

Increased demand for farm land in the South, Federal aid in rehabilitating distressed districts, and a gradual sifting out of unwise ventures had made a good many of the enterprises solvent by 1940. Their present degree of solvency indicates that notwithstanding losses from floods and heavy additional expense required for effective drainage, these lands were sufficiently productive to support a profitable agriculture. Neither floods nor poor drainage structures had outbalanced the advantages of soil and landform afforded by the flood plains.

One aspect of poor drainage which did, however, retard the agricultural occupation of some flood plains for many years was the mosquito problem. Because the malaria-bearing mosquito (anopheles) and several other pest mosquitoes breed in fresh standing water or damp places, they are abundant in swampy terrain. The lower portions of the Yazoo Delta in Mississippi were avoided for many years, even though their better-drained soils were highly fertile for cotton culture, on account of the difficulty of drainage and the fear of mosquitoes and the accompanying "fever." Settlers in the Middle Illinois Valley commonly avoided the flood plain for the same reason.[2] Mosquitoes no longer are the menace

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[1]Emil Schram, Speech before American Society of Agricultural Engineers, June 18, 1934.

[2]Harlan H. Barrows, Geography of the Middle Illinois Valley, Illinois State Geological Survey, Bulletin No. 15 (Urbana: University of Illinois, 1910), pp. 76-77.

which they constituted in earlier days. Breeding-control measures and house screening have been so perfected that inconvenience and the menace to health can be eliminated or reduced at relatively modest cost.

Early settlers preferred flood-plain locations in some regions because of the abundance there of ground water. In the peopling of the Illinois prairies, water supply was one of the several factors which tended to restrict many initial settlements to the borders between wooded hillsides and adjoining grasslands.[1] As Meinzer points out in his ground-water hydrology of the United States, there are several regions, including valley fills of the Western states and alluvial valleys of the Great Plains and Texas coastal drainages, in which ground water is generally more plentiful in valley bottoms than in interstream areas and in which the bottoms therefore are likely to be an attraction to agricultural occupance.[2] In the Basin and Range Province of the Southwest the flood plains of valley floors and of mountain pediments have offered to early pueblos as well as modern settlers the advantage of natural subsurface irrigation and some running water.[3] In other sections, the association of valley relief with the occurrence of springs at lower levels and of low-lying terrain with a high ground-water table is well recognized, and need not be elaborated.

Soil

Most flood-plain soils are alluvial in origin or receive occasional increments of top soil. Most of them therefore are azonal in character. Their soil profiles are immature and have an erratic areal distribution. In so far as a flood plain soil has not been water-laid or no longer receives water-borne deposits,

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[1] Derwent Whittlesey, "Early Geography of Northern Illinois," Science (new series), LXXXI (1935), 228.

[2] Oscar Edward Meinzer, The Occurrence of Ground Water in the United States, with a Discussion of Principles, Geological Survey Water Supply Paper, No. 489 (Washington: Government Printing Office, 1923), pp. 192, 291-298, and 303-306.

[3] Carl Sauer and Donald Brand, Pueblo Sites in Southeastern Arizona, University of California Publications in Geography, III (Berkeley: University of California Press, 1930), 419-437.

it tends to develop a mature profile consonant with the climate of the region and with its physiographic position. Such soils have zonal characteristics in common with other members of their own soil group and family, of course, and they have few characteristics, except those of drainage, not shared by other types in the same series outside of the flood plain.

Azonal soil types present bewildering variety, and it is not practicable to generalize as to their advantageous and disadvantageous features in so far as crop yields and tillage practices are concerned. It already has been noted that flood-plain soils are markedly less subject to erosion through sheet wash and gully formation than other major soil groups inasmuch as they underlie relatively flat slopes and, in many series, have a high colloidal content. It should be recognized, however, that the narrower the flood plain and the younger the valley, the greater is the likelihood that losses will result from scouring and from deposition of sand and gravel. Excluding those infrequent flood phenomena, it probably is safe to say that alluvial flood plains contain the only soils in the United States that may be considered permanently free from the danger of erosion.

Erosiveness does not attract or repel agricultural land occupance as do those features which affect immediate yields and tillage practices. Such alluvial soils as the Yolo[1] and Genesee[2] have a relatively high content of calcium and exchangeable bases, making fertilization or soil-building crop rotations less necessary to high yields of cotton and corn than they are for many other soils. Their suitability for crop production has been amply demonstrated by soil scientists and by geographers who have found concentrations of highly productive agricultural occupance centering upon flood-plain areas having those soils and located in such diverse sections as the irrigated valleys of the Gila Basin, Ari-

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[1]E. J. Carpenter and S. W. Cosby, Soil Survey of Contra Costa County, California, Bureau of Chemistry and Soils, Soil Survey (Washington: Government Printing Office, 1939), pp. 52-53, 65.

[2]C. S. Pearson, D. G. Greenleaf, H. R. Adams, and Winston Neely, Soil Survey of Wyoming County, New York, Bureau of Chemistry and Soils, Soil Survey (Washington: Government Printing Office, 1938), pp. 31-32, 34.

zona,[1] the Milk River Valley, Montana,[2] and the Wabash River bottoms of Southwestern Indiana.[3] There are likewise examples of relatively infertile deposits that are deficient in colloidal material or otherwise unsuited to general agriculture.[4]

As one should expect, there are pronounced dissimilarities among the soils of the flood plains of the most aggrading streams, the texture varying from the sandy loams of the natural levees and the boulder deposits of alluvial fans[5] to the poorly-drained phases of the tough clays which lie in the sloughs or "sags" back from the river channels.

Surface Waters

Water courses themselves attract certain land uses to their banks in defiance of the flood hazard. Principal among these attractive factors are water supply, waste-disposal facilities, water transportation, water power and recreational facilities. The early location of towns and cities on American flood

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[1]E. C. Eckmann, Mark Baldwin, and E. J. Carpenter, "Soil Survey of the Middle Gila Valley Area, Arizona," Field Operations of the Bureau of Soils, 1917, p. 18.

[2]William DeYoung, F. O. Youngs, and T. W. Glassey, Soil Survey of the Milk River Area, Montana, Bureau of Chemistry and Soils, Soil Survey (Washington: Government Printing Office, 1928), pp. 15-22, 33-35.

[3]T. M. Bushnell and W. E. Thorp, "Soil Survey of Gibson County, Indiana," Field Operations of the Bureau of Soils, 1922, pp. 1194-1199, 1214-1216.

[4]A good example is the overflow phase of the Hadley loamy fine sand in the Connecticut Valley. W. J. Latimer and L. R. Smith, Soil Survey of Hampden and Hampshire Counties, Massachusetts, Bureau of Chemistry and Soils, Soil Survey (Washington: Government Printing Office, 1928), p. 23.

G. L. Fuller and S. O. Perkins, Soil Survey of Wayne County, Georgia, Bureau of Chemistry and Soils, Soil Survey (Washington: Government Printing Office, 1926), pp. 33-34.

These statements are based upon a general summary of the range of alluvial soils in U. S. Department of Agriculture, Soils and Men, Yearbook of Agriculture, 1938 (Washington: Government Printing Office), pp. 1001, 1067-1068, 1133-1[illegible].

[5]Bouldery channels may be barriers to urban development on alluvial fans. Clifford M. Zierer, "San Fernando--A Type of Southern California Town," Annals of the Association of American Geographers, XXIV (1934), 5.

plains is to be explained largely in terms of one or more of these factors.

The towns which experience major flood losses along the Merrimack River in Massachusetts centered their most vigorous economic development around the generation of mechanical water power at falls in the river.[1] Technological limits to the transmission of energy during that first period of development after 1790 made it impracticable to locate textile mills beyond the reach of riverside canals, and so the mills of Lowell[2] and Lawrence and Manchester were congregated along the streams, contending for locations near the falls where low-head hydraulic turbines could be used. The perfection of electric transmittion made it feasible to use Merrimack power far beyond the reach of the creaking, cumbersome relays of pulleys and drive shafts that first fed energy into the noisy workrooms of the mills. But the mills remain. At strategic falls along the Thames, the Blackstone,[3] and the Connecticut, venerable mills of the same type crowd the narrow floodplains. They house industries many of which no longer use mechanical power, although they utilize water for cooling and processing. Most of the average annual damage experienced along the Thames River occurs at such places, of which Norwich is typical.[4] Those losses are payments made from time to time for advantages which have disappeared, and commercial and residential occupance continues to cluster around mills that, were it not for prior investment, could as well be located above the flood plain.

The accessibility of water for power purposes still is responsible for two types of flood-plain occupants. At scattered points along streams throughout the eastern states there remain small water mills which suffer occasional flood losses. In 1880

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[1] Victor S. Clark, History of Manufactures in the United States (New York: McGraw-Hill Book Co., for Carnegie Institution of Washington, 1929), I, 404-405, 409.

[2] Margaret Terrell Parker, "Lowell: A Study of Industrial Development" (Unpublished dissertation, University of Chicago, 1939), pp. 117-127.

[3] Preston E. James, "The Blackstone Valley: A Study in Chorography in Southern New England," Annals of the Association of American Geographers, XIX (1929), 77-81.

[4] 76th Cong., 3d Sess., Thames River, Mass., Conn., and R.I., House Doc. No. 885 (1940), pp. 2-3.

at least 8,482 mills developed water power in the United States. More than half of them were in the drainage basins of the Connecticut, Hudson, Delaware, Susquehanna and Potomac Rivers.[1] For the most part they seem to have been designed to withstand moderately high flood flows; machinery was well anchored, building construction was sturdy, and provision was made to store damageable goods above the reach of floods. There is no record of the number in operation today. An unknown proportion of them are located sufficiently above the flood line, being connected with the stream channels by small diversion canals so that they are free from damage. Probably at least two-thirds are in the paths of floods, and, of course, all have dams or headgates which may be damaged by floods and which are repaired and maintained so long as the costs are not excessive for the income received. Experience in one section of New York state is instructive in this connection. On Kayaderossas Creek, a tributary of Saratoga Lake, there were in the 1890's at least 50 mills engaged in manufacturing. They accounted, among other products, for more than 60 per cent of the paper-bag production in the United States. Today, only one of the 50 mills is operating, and the dams at the other mills have been destroyed by flood.[2] So long as business prospered, the dams were maintained against flood damage, but as soon as the need for them disappeared, the structures disintegrated rapidly.

The other major power users are the hydroelectric generating plants themselves. Their storage and diversion dams must occupy stream channels, and, except in rare instances, the turbines are closely associated. It has not always been easy to design these structures to withstand floods. The Holtwood plant of the Pennsylvania Water and Power Company on the Susquehanna River was built in the belief that it would be dry in the greatest flood, but in 1936 all of the electric motors for auxiliary pumps and compressors, the bearings for seven generating units, and several transformers were under water. Power operations were halted for

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[1]H. H. Bennett, "Utilization of Small Water Powers," <u>Transactions of the Third World Power Conference, 1936</u>, VII, 476-482.

[2]Unfavorable preliminary report of the Chief of Engineers on "Kayaderossas Creek--Fish Creek--Saratoga Lake Watershed, N.Y.," November 6, 1941, pp. 6 and 8. (Unpublished.)

four days.[1] Probably the plant would have been designed differently had a flood of that magnitude been expected, and, indeed, the companion plant at Safe Harbor upstream did prove to have been designed to withstand such a flood. Under some conditions it is not economically feasible to prepare for the anticipated maximum, and plants are built with the knowledge that they will be flooded at times.

In the United States today the need for harnessing water power is an incentive to flood plain use only in so far as small mechanical powers are feasible, or if it is unduly costly to design hydroelectric plants which will be free from damage.

A somewhat similar situation exists with respect to domestic and industrial water supply. So long as water could be diverted efficiently only by gravity, it was necessary for sizeable urban communities to remain relatively near adequate surface sources if the ground-water supplies were not sufficient to meet demands. Improvements in syphons and pumps have largely reduced this limitation until today that consideration is not likely to bulk large in any analysis of city relocation or readjustment. Apparently, it is only in certain manufacturing processes using large quantities of water that this factor remains highly important. Modern steam-condensing electric generating stations are a case in point, requiring approximately 90,000 gallons of water for each ton of coal.[2] For this reason and because of possible savings in handling coal where it can be shifted from water carrier direct to boiler-house bunkers, large fuel-electric power installations generally are made on stream or lake banks if factors of electric transmission permit. Speaking of steam-power stations, Gaffert says, "availability of condensing water is of greater importance than all the other factors governing station location."[3] In numerous cities and villages, such as Iowa City,

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[1] Ice and Floods: Holtwood and Safe Harbor, March, 1936 (n.p.: Pennsylvania Water & Power Co. and Safe Harbor Water Power Co., 1936), pp. 41-73.

[2] Alfred H. Lovell, Generating Stations: Economic Elements of Electrical Design (New York: McGraw-Hill Book Co., Inc., 1941), p. 272.

[3] Gustav Gaffert, Steam Power Stations (New York: McGraw-Hill Book Co., Inc., 1940), p. 470. He states that 0.6 to 1 gallon per minute of condensing water is required for one kilowatt of installed capacity.

Iowa, the waterworks have been located on a flood plain with full knowledge of the flood hazard in order to take advantage of low pumping costs.

A closely related problem is waste disposal. From the isolated farm house with its outhouse overhanging the convenient brook to the large paint-manufacturing plant which chooses a waterside site in order to dump tons of poisonous trade waste every day, a main objective of waste-disposal has been to get the waste into a public waterway as quickly, easily, and cheaply as possible, leaving to others downstream the task of coping with the polluted waters. Stream channels are natural sewers, and the closer a source of pollution can be situated to them the easier will be the task of disposing of that waste. Municipal sewerage did not develop until after 1855 and there was little incentive for early American towns to locate near watercourses as ready depositories for domestic waste.[1] Sewers for storm-water drainage, combined with cesspools or open pits, were the order of the day. To a minor degree, it now is advantageous from the standpoint of sewerage costs to locate municipal sewerage works as near as practicable to the receiving stream. A review of the technical literature on this subject indicates, however, that the flood hazard is a relatively unimportant factor in sewer and treatment-plant construction. The exceptions are the manufacturing plants that produce large quantities of objectionable waste. The more objectionable ones are paper mills, canneries, distilleries, textile mills, steel-pickling plants, oil refineries, and tanneries.[2] Even with these plants, flood-plain location is not especially desirable. Waste generally flows by gravity to the receiving water, and thus distance from a height above the water does not involve expense unduly greater than that for a waterside location.

The greatest single attraction of the river bank in many areas probably is the availability of water transportation. Certainly, water-transport facilities accounted for the early loca-

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[1]Leonard Metcalf and Harrison P. Eddy, American Sewerage Practice (New York: McGraw-Hill Book Co., 1914), I, 14-26.

[2]National Resources Planning Board, Water Pollution in the United States (Washington: Government Printing Office, 1939).

tion of many towns on the Ohio and Upper Mississippi river system.[1] Certainly, too, the dominant consideration leading to the multiplication of iron and steel plants along the Upper Ohio River in recent decades has been cheap water transportation. Engineers estimate that it costs 10-25 cents to collect and transport a ton of coal from Upper Ohio Valley mines to the river banks, 5 cents to load from tipple to barge, 5 cents to unload from barge to railroad car, 8 cents to unload from railway car to stock pile, and 38 cents to distribute by rail from a water terminal to stock piles away from water. Barge transport costs approximately 3 mills per ton mile, which would amount to 27 cents per ton for a haul from Point Pleasant, Ohio, to Portsmouth, Ohio, and 79 cents per ton for a haul from Point Pleasant to the Mouth of the Allegheny River.[2] Although the costs of loading coal from tipple to railway car and of unloading it to a stock pile are slightly smaller than the costs of loading to and from barges, because river tipples need to be heavier than land tipples in order to withstand floods, the consumers of coal can make substantial savings by arranging their plants so that direct shipment may be made from mine to receiving plant. The major costs are incurred in transshipment at both ends of the line, and it is this item, as much as savings in direct line haul by water, that is responsible for the clustering of commerce and processing that persists on some river banks in the face of repeated flood disasters.

If a commodity is handled in bulk, and if its transportation cost is a substantial part of its total cost, there is strong resistance to removing the storage or processing facilities far from a wharf. Theoretically there exists for every commodity an areal limit beyond which it cannot be transshipped economically from water carriers and still compete with deliveries by other carriers. From the standpoint of transport cost alone, storage or processing should take place as near as possible to the water's edge consistent with competing land uses and other cost factors. From the standpoint of flood losses, it should take place above the level of maximum floods, and the actual location tends to re-

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[1] Barrows, op. cit., pp. 76, 84-92, 99.

[2] 76th Cong., 1st Sess., Lake Erie and Ohio River Canal, House Doc. No. 178 (1939), pp. 293-298.

flect the resultant of these two forces.

With the increasing development of recreational facilities in the environs of urban areas in the United States in recent years, largely as a result of improved automobile transportation, flood plains in such localities have been utilized more intensively than formerly for summer cottages. From the Potomac Gorge near Washington, D. C., to the San Bernardino mountains above Los Angeles, cottagers have braved the risk of flood loss in order to be near water and to boat, swim and fish in scenic areas wherever practicable. Inasmuch as most of these recreational cottages are constructed and furnished inexpensively and are occupied only a part of the year, their owners or renters find it practicable to risk the chance of an occasional loss.

Corridor Facilities

Although the gradients of flood plains may not have special inducements for highway location, it has long been recognized that the floors of valleys in relatively rough terrain are particularly well suited to through routes of railway travel, and, in an earlier day, highway travel. The flood plain may not itself be attractive, but the valley bottom may be very much so. Perhaps the best demonstration is that the main lines of the Pennsylvania and Baltimore and Ohio railways cross the Appalachians in long valleys and are subject to heavy flood losses.

An early American railway builder advised his assistants, "first get into your heads the drainage, drainage, DRAINAGE. The drainage and location of the drainage is the framework on which you must hang your location!"[1] So he epitomized the guiding principle of railway location in the United States during the latter part of the nineteenth century. In seeking line locations which would yield the most favorable ratio of annual revenue to the cost of construction and operation, the builders attempted to find the easiest possible grades for the longest possible distances, and adjusted distance, curvature, and cut-and-fill operations over short distances to meet that primary requirement.[2]

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[1]Quoted by Clement C. Williams, The Design of Railway Location (New York: John Wiley & Sons, 1924), p. 388.

[2]Arthur Mellon Wellington, The Economic Theory of the Location of Railways (New York: John Wiley & Sons, 1891), p. 660.

Ruling gradients of more than 2 or 2 1/2 per cent were avoided, although a few "momentum grades" and "pusher grades" were allowed in order to traverse especially difficult terrain. The reason was simple. The operating efficiency of a modern freight train on a 1 per cent grade sinks to slightly more than one-tenth of that efficiency for a 2 per cent grade.[1] According to Wellington, on a 1 per cent grade the engine on an average freight train accounted for 14 per cent of the average paying weight of the train, on a 2 per cent grade it amounted to 26 per cent, and on a 4 per cent grade it amounted to 58 per cent.[2] It paid to cling to river valleys, which had more nearly uniform natural slopes than those on nearby uplands.

In addition to favorable grades, some river valleys had the advantages of relatively low curvature, comparatively large concentrations of settlement, and low cost cut-and-fill operations.[3] The leading analyst of railway location noted in 1890 that in locating valley lines it was difficult to make due allowance for the fact that in those locations "nature has made our fill," and that construction costs accordingly tended to be minimized in so far as rise and fall of surface were concerned.[4]

Valleys also have their disadvantages. They require more bridges and culverts than do ridge lines, and on the whole they are less favorable to making slight readjustments in ruling gradient so as to effect economies in operation.[5]

With such considerations tending to govern the location of railways, flood plains were attractive not so much because of minor variations in surface configuration as because of the long, low gradients which they made available. These corridor facilities were, then, especially significant for railways. Highways and urban occupance have developed flood-plain locations in many instances in order to be near some railway rather than because of any other advantages of the flood plain.[6]

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[1]Williams, op. cit. p. 388.

[2]Wellington, op. cit., p. 688.

[3]Williams, op. cit., p. 389.

[4]Wellington, op. cit., p. 850.

[5]Williams, op. cit., p. 389.

[6]San Bernardino, California is an example of a city which

On the whole, the flood hazard does not seem to have been a major deterring factor in the minds of railway builders. Wellington said:

> Without going to the length of saying that it is ordinarily justifiable, which would be going too far, it is an entirely safe statement that when the works endangered by such overflow are not of a very costly character, it is far better to risk the chances of overflow and damage at a few points every 8 or 10 or 15 years, or often still more frequently, than to sacrifice the advantage of easy gradients and light first cost to avoid the risk, especially as it is often impossible to avoid it without abandoning the valley altogether.[1]

The records of railway damage today bear clear testimony that this was a commonly-accepted practice, although it must be said that much of the loss seems to occur on lines which the early builders thought would be free from all or almost all floods. In their concern for economy in railway costs, they neglected the costs to the urban-land users who followed the railways into the valleys. It seems probable that in some locations, if the advantages and disadvantages of a flood plain for an entire community rather than for a railway alone had been computed, a different location would have been selected.

Social Institutions

To a large degree, factors of social organization and precedent affect adjustment to floods. Not only do they play an important role in encouraging encroachment upon flood plains, but they are responsible for the maintenance of certain occupance long after technological change has rendered it obsolete.

Institutional inertia.--Quite apart from accidents of human caprice and judgment which may lead to the establishment of a given form of flood-plain occupance, the attraction of a given type of occupance may lead to the location of related activities for no other reason than to be near the preceding settlement. Thus, residential land uses in Johnstown crowd into the Conemaugh and Stony Creek valleys chiefly to be near the steel mills which,

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developed partly on a flood plain because of corridor facilities offered for early wagon transportation. Railway and highway now traverse the same pass. H. F. Raup, San Bernardino, California: Settlement and Growth of a Pass-Site City, University of California Publications in Geography (Berkeley: University of California Press, 1940), pp. 11, 37, 44-46.

[2]Wellington, op. cit., pp. 783-784.

for reasons already stated, reap great advantages from flood-plain location.[1] There are innumerable examples of cities having large commercial functions that grew up around the use of river transportation as did the cotton and wholesale district of Memphis.[2] The commercial towns of the Mississippi delta are located primarily in relation to agricultural occupance, which capitalizes upon the rich alluvial soil and the relatively level terrain. Perhaps more generally important than the attractions of manufactural and commercial enterprises are the attractions of community facilities once they are established. Schools, streets, public-safety services, and public utilities are an incentive to new occupance that otherwise would find no special advantages in the flood plain; highways follow railways into valleys in order to traverse towns on the railways rather than because of any special advantages of the valleys.

It also has been noted in connection with factors of surface water that because of technological or landscape change many factors affecting the early settlement of flood plains in the United States are no longer significant. Just as Tennessee Valley farmers are reluctant to leave their lands in a reservoir area because of proximity to the old family burying ground, so much residential, commercial and manufactural use remains in flood plains today in order to be near relics of industry that have declined. At York, Pennsylvania, the first paper mill was located in 1800 on the banks of Codorus Creek to utilize the water power and water supply. Improvement of the creek for navigation made it the locus of commercial activities in the 1830's. Today the creek is no longer used either for power or navigation, its waters are polluted, and the city's water supply comes from a reservoir four miles upstream.[3] Now it is solely a liability, causing mean annual losses in excess of $100,000, and requiring a Federal expenditure of $4,115,000 for remedial channel-improvement and reser-

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[1]Murphy, <u>op. cit</u>.

[2]Rayburn Whitson Johnson, <u>Land Utilization in Memphis</u> (Chicago: University of Chicago Libraries, 1936), pp. 38 and 42.

[3]Raymond E. Murphy, <u>The Economic Geography of York, Pennsylvania, A City of Diversified Industries</u>, Pennsylvania State College Bulletin, Mineral Industries Experiment Station, No. 17 (1935) (State College, Pennsylvania: School of Mineral Industries), pp. 1-62.

voir construction in addition to local expenditures which have exceeded $500,000. In general, urban and rural occupance is characterized by resistance to any alterations, even for the better.

There is no ready means of measuring the force of these social factors. Yet they are of major, sometimes sole, importance in many flood plains in accounting for the continuation of occupance.

Riparian law as an inducement to encroachment.--The riparian doctrine as developed in English common law that a person holding property adjacent to a stream has a right to use any part of the stream bed to its center line so long as he does not impair the flow of water downstream or violate a power of the state to use and improve the stream has encouraged encroachment upon the flood plains of the United States.[1] Even in those states

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[1]The riparian doctrine has been stated in the case of U. S. v. Chandler-Dunbar Co., 229 U.S. 53, as follows:

"The technical title to the beds of navigable rivers of the United States is either in the States in which the rivers are situated, or in the riparian owners, depending upon the local law.

"The title of the riparian owner to the bed of a navigable stream is a qualified one, and subordinate to the public right of navigation and subject to the absolute power of Congress over the improvement of navigable rivers.

"Under the Constitution, Congress can adopt any means for the improvement of navigation that are not prohibited by that instrument itself.

"Commerce includes navigation and it is for Congress to determine when and to what extent its powers shall be brought into activity.

"The judgment of Congress as to whether a construction in or over a navigable river is or is not an obstruction to navigation is an exercise of legislative power and wholly within its control and beyond judicial review. . . . .

"Every structure in the water of a navigable river is subordinate to the right of navigation and must be removed, even if the owners sustain a loss thereby, if Congress, in assertion of its power over navigation so determines."

Again in the case of U. S. v. River Rough Co., 269 U.S. 411, the court ruled as follows:

"In the absence of a controlling local law, the right of the owner of riparian property on a navigable river to have access from the front of his land to the navigable part of the stream, and, when not forbidden by public law, to construct landings, wharves or piers for this purpose, is a property right incident to his ownership of the bank, which, though subject to the absolute power of Congress over the improvement of navigable rivers, may not be arbitrarily destroyed or impaired by legislation having no real or substantial relation to the control of navigation or appropriateness to that end."

which retain title in the stream beds, there is little administrative control over encroachment. Property owners have been induced to expand into a flood plain in many instances because there alone could they obtain additional and abutting space without public grant or private purchase. Familiar sights in commercial districts located on or near flood plains are the extensions of shops and office buildings back over the stream beds. Such extensions are convenient, and, for a short time, cheap.

In so far as the beds of navigable waters are concerned, the United States has ceded ownership for all such undisposed lands, as of the time the state was admitted to the Union, to the several states, which have either retained title or have granted it to riparian owners.[1] At present, most of the Western states and a number of other states such as Pennsylvania retain ownership in the land underlying navigable waters.[2] In the New England states and in some others ownership definitely is in the owners of adjacent lands.[3] There is great diversity among the states in their provisions with respect to the assertion of public ownership and with respect to the point--high water mark, low water mark, or thread of the stream--to which riparian ownership extends.[4] Both state and private ownership is, of course, subject to the paramount right of the United States to control commerce by regulating navigation or any works which might interfere with navigation.

The beds of fresh water non-navigable streams are the property of riparian owners in the thirteen original states and, with some exceptions, in the other states.[5] Texas, for example, recognizes the riparian doctrine for lands abutting non-navigable streams less than 30 feet wide, but retains title to part of the

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[1]Edward S. Bade, "Title, Points and Lines in Lakes and Streams," Minnesota Law Review, XXIV (1940), 316-318.

[2]Clesson S. Kinney, A Treatise on the Laws of Irrigation and Water Rights, and the Arid Region Doctrine of Appropriation of Waters (2d ed.; San Francisco: Bender-Moss Co., 1912), I, 533-546.

[3]Ibid., p. 534.

[4]Everett Fraser, "Title to the Soil Under Public Waters--A Question of Fact," Minnesota Law Review, II (1918), 313-338.

[5]Kinney, op. cit., pp. 925-926.

beds of wider streams.[1] The status of title to the beds of non-navigable streams adjoining lands granted by the Federal government to private persons seems to be open to question.[2] The Federal government has never sought successfully to claim title to such lands, and it has, under the Desert Land Act of 1877 (19 U.S. Stat. 377), reserved all non-navigable waters for public use under the laws of the respective states and territories.

Lacking any common law curb upon encroachment, it is difficult for state or municipal governments to exercise their potential authority to limit the assertion of property rights in stream beds unless a strong case can be made against encroachment on the ground that the public safety and welfare would be impaired. The possible ways of administering a regulatory program are discussed in Chapter IV.

Other Factors

Mineral deposits, climate, and natural vegetation are other factors which have affected human decisions to occupy flood plains. Although they do not have the same widespread significance as those factors previously mentioned, each of them has been outstanding in at least a few situations. A few examples may be cited.

Probably no other extractive or manufacturing industry is so widely exposed to the rush of flood waters as is the sand and gravel industry. The large share of the total cost of sand and gravel production which is involved in transportation makes it desirable, where water transport is available, to locate the sorting and washing facilities directly on a river bank, and, where such facilities are not available, to locate them as near as possible to the deposits. Moreover, in many regions the more accessible and suitable deposits are located in valley bottoms.[3] Thus

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[1]Wallace Hawkins, "Title to River Beds in Texas and Their Boundaries," Texas Law Review, VII (1929), 493-519.

[2]Bade, op. cit., p. 318.

[3]This is true in such diverse areas as Louisiana and Missouri.

T. P. Woodward and Albert J. Gueno, Jr., The Sand and Gravel Deposits of Louisiana, Geological Bulletin No. 19 (New Orleans: Department of Conservation, Louisiana Geological Survey, it is that sand and gravel producers take floods in their stride as a normal part of their production costs, and so organize their activities and equipment as to minimize losses.[1]

To a minor degree, some other mining operations are located in valley flats because the lower altitude affords more ready access to underlying deposits and to transportation facilities than do the adjoining uplands. Conspicuous examples of such localization within regions having fairly widespread deposits are the coal mines in the Appalachian bituminous field[2] and the flurospar mines in the Lower Ohio Valley.[3] In both instances, the mine mouths are within reach of floods. They could not have been located elsewhere without heavy additional expense for excavation or for transportation.

Lack of data on microclimates makes it difficult to specify those factors of drainage and wind velocity which have been significant in flood-plain occupance. It is fairly well established that in many Appalachian and Allegheny Plateau valleys, such as the Tennessee and the Upper Ohio, the valley bottoms have higher summer temperatures and humidity and more frequent frost and fog[4] than other areas and that the flood plains are less in demand for residential and airport purposes if the other compensating factors of surface configuration are assumed to be constant. Murphy states that higher-grade residential occupance in the Johnstown, Pennsylvania area recently has sought the nearby rolling uplands partly to avoid the smoke and fumes of the steel plants in the valley

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1941), pp. 26, 32-38.

C. L. Dake, The Sand and Gravel Resources of Missouri (Rolla: Missouri Bureau of Geology and Mines, 1918), pp. 46, 211-244.

[1]Nordberg, op. cit.

[2]In the Kanawha Basin of West Virginia and Virginia, the coal tipples and their tributary railways are located very largely in valley bottoms. 74th Cong., 1st Sess., Kanawha River, House Doc. No. 91 (1935), p. 64.

[3]The major producing mines in the flurospar field of Illinois and Kentucky are those located on faults nearest to the Ohio River on the Illinois side. These were forced to suspend operations for 6 weeks during and after the flood of 1937. H. C. Chellson, "Floods versus Flurospar," Engineering and Mining Journal, CXXXVIII (1937), 331-332.

[4]Robert G. Stone, "Fog in the United States and Adjacent Regions," Geographical Review, XXVI (1936), 118, 120.

bottom and to enjoy cooler summer temperatures.[1] Other factors, of course, have been the unsightliness of manufacturing plants, city noise and traffic, and the advantages of upland landforms.

In citrus-growing regions, the factor of air drainage may be of outstanding importance in connection with farm location and with the cropping system on Piedmont flood plains. Large sections of the Southern California citrus area and the Central Valley prune and grape-producing areas are notably vulnerable to flood in part because of the superior climate of the lower sections of the alluvial deposits and in part also because of the superior facilities for delivery of water.[2]

Whereas the climatic amenities of Eastern uplands has led residential occupance out of certain flood plains, protection from hot summer winds and cold winter winds has driven not a few Great Plains urban settlements into valleys, and so into the paths of floods, as in the Black Hills.[3]

The more conspicuous instances of vegetative factors are found where Southern Pine or grass are the climax association. The hardwoods which were well developed only on the flood plains of the Lower Mississippi and of the Gulf and South Atlantic drainages have been utilized by a specialized lumber industry that has been forced to cope with occasional floods in order to obtain those species of trees. The industry has not been responsible, however, for the development of more than a few towns which have lingered in the paths of floods after the resources were exhausted. Other natural factors being unfavorable to continued occupance, the permanent processing plants have tended to develop at upland points, such as Memphis, near to river wharves but slightly above the reach of floods.[4]

In the Central Prairies and Great Plains, the cottonwood

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[1] Murphy, op. cit.

[2] Charles C. Colby, "The California Raisin Industry: A Study in Geographic Interpretation," Annals of the Association of American Geographers, XIV (1924), 60.

Edward A. Ackerman, "Influences of Climate on the Cultivation of Citrus Fruits," Geographical Review, XXVIII (1933), 294-95.

[3] Otto E. Guthe, The Black Hills of South Dakota and Wyoming, Papers of the Michigan Academy of Science, Acts and Letters, XX (1934), 364, 369-371, 374.

[4] Johnson, op. cit., pp. 22-23.

and other woody vegetation which lined the stream courses was an attraction to early settlement because of the fuel supply it provided, but the development of cheap rail transportation soon eliminated the importance of local vegetative cover.

Summary of Flood-plain Factors

The examples that have been given merely illustrate how factors of environment and of social institutions have played a large role in attracting or repelling the occupance of flood plains in the United States. It cannot be said that any factor is everywhere and always advantageous or invariably disadvantageous, nor is it possible to claim a particular degree of importance for any one of them.

On the basis of the regional studies which have been examined, and of the techniques for land utilization which have beer shown to be related to each factor, a few of the clearly advantageous and disadvantageous implications may be distinguished by arranging some of the major factors as shown in Table 11. That table suggests the probable range of entries which may warrant appraisal in drawing up a balance sheet for human adjustment in an American flood plain. Floods, while a prominent factor, are not of sole or even primary importance in many instances, and under a favorable combination of circumstances any one of the other factors may be predominant.

Encouraged by a legal doctrine which permitted invasion even of stream channels, man has encroached upon the flood plains of the United States in the face of recurring and increasing flood losses. Part of this encroachment has been in ignorance of the flood hazard. In much larger measure, it has sought to utilize resources of terrain, soil, and water. Commercial and residential occupance have tended to follow agriculture, manufacturing, and railways into the flood zones, and through inertia both types have hung on even after the factors which were attractive lost importance.

Viewed in this light, a satisfactory solution of the flood problem in any flood plain is seen to require consideration of the factors which have been important and those which are likely to be important in relation to the occupance of the area. Certain occupance, such as that of the steel plants and sand and gravel plants of the Upper Ohio Valley, has prospered notwithstanding floods be-

TABLE 11

SUMMARY OF SOME MAJOR FACTORS AFFECTING ADJUSTMENT TO FLOODS

Factor	Occupance					
	Agri-cultural	Urban Resi-dential	Commer-cial	Manufac-tural	Trans-porta-tional	Mining
Flood height	O	D	D	D	D	D
Flood duration......	AD	O	D	D	D	O
Flood crest shape.....	O	D	D	D	D	O
Flood velocity..	D	D	D	O	D	O
Flood debris load......	AD	D	D	D	O	O
Slope.......	A	D	A	A	A	O
Drainage....	D	D	O	O	O	O
Ground water.....	A	A	O	O	O	D
Soil........	AD	O	O	O	O	O
Surface waters....	A	A	A	A	A	A
Corridor facilities	O	O	A	A	A	O
Institutional inertia	O	A	A	A	A	A
Riparian law	O	A	A	A	O	O
Minerals....	O	O	O	A	A	A
Climate.....	A	DA	O	O	O	O
Vegetation..	O	A	O	O	O	O

A = Advantageous to occupance in many flood plains.

D = Disadvantageous to occupance in many flood plains.

O = Not generally significant.

cause of its riverine location. Other occupance, such as that represented by the manufacturers along Codorus Creek, has continued long after once-great advantages of the flood-plain location disappeared. Still other occupance, of which the low-grade residential use of the lower Cincinnati flood plain is an example, has never been suited to the site, and derives no advantage from continuation there. Full and definite solution of the flood problem for each such area requires, still further, consideration of possible readjustments and of their costs and benefits.

Sound appraisal of possible readjustments in each situation is aided in two ways by analysis of the factors involved. Analysis reveals, first, the degree to which the particular flood plain affords advantages, such as fertile soils and cheap water supply, which should be utilized on a continuing basis if otherwise practicable. It reveals, second, the critical factors, such as prospective machinery losses in manufacturing plants or the significance of prevailing grade in railway location, around which effective readjustments can be designed. The greater the range of readjustments considered, the more important is an analysis of all these relevant factors.

CHAPTER IV

ADJUSTMENTS TO FLOODS

While public action toward floods in the United States has been confined to regulation of flood waters and protection against floods, to forecasting floods, and to cushioning the impacts of floods, many occupants of flood plains have worked privately to develop a much wider range of adjustments. Along the Mississippi River bottoms in Western Tennessee they have learned to follow Mark Twain's advice to "skedaddle" in house boats when floods come. They have changed land use to avoid or minimize damage, they have accumulated reserves, and they have altered structures or the layout of structures with a view to reducing possible losses.

It will be recalled that the major forms of adjustment which are common in the United States today are: (1) land elevation, (2) flood abatement, (3) flood protection, (4) emergency measures, (5) structural adjustments, (6) land use, (7) relief, and (8) insurance.

Under the view of the flood problem that has been outlined, the economic and social desirability of these adjustments in a flood plain, singly or in combination, is determined by the advantages and disadvantages of the site for suitable purposes and by the costs and benefits of making the requisite readjustment. For example, the desirability of loss reduction through altering the structure and arrangement of a freight warehouse subject to flood depends upon the cost of making the alterations and upon the benefits which would accrue from reducing prospective losses to stored freight. It also depends in part upon the relative advantages and disadvantages of the location of the warehouse on the flood plain by comparison with nearby sites above the level of the probable maximum flood. If the riverside location is a net advantage and conforms with a reasonable plan of urban development, and if the benefits from the alterations exceed the costs, the readjustments are feasible. If the flood-plain location is no longer an advantage, and involves, as at Cincinnati,[1] extra costs not shared by an alternative location at a new railway freight terminal, the justification for readjustment on the present site is in doubt, and a change in land use may be indicated.

These relations of factors affecting the feasibility of a single adjustment can be written in this general form:

$$\text{Economic justification} = \frac{\text{Advantages of site + benefit from readjustment}}{\text{Disadvantages of site + cost of readjustment}} \qquad (2)$$

This formula applies generally to all adjustments. It states in simple, perhaps over-simplified form, a relationship which is believed to be basic to all human adjustments to floods.

Two qualifications attach to the use of such a formula. In the first place, the relation applies equally well to all types of adjustments, and it has real significance only when used simultaneously for all possible adjustments in a flood plain. A structural change of the type suggested above for a riverside warehouse may be justified if viewed alone, but it may be far less desirable if compared with a plan for land-use change or for emergency measures.

In the second place, the formula adopts a much broader view than is commonly applied to the readjustments now receiving public attention. A general formula for most estimates used in the past in determining the feasibility of flood protection would be written:

$$\text{Economic justification} = \frac{\text{Benefits from protection}}{\text{Costs of protection}} \qquad (3)$$

Thus it ignores the question of whether or not a given location had real advantages for present or prospective uses. From the standpoint of the individual property owner concerned, that question may seem irrelevant because it may be argued that the only issue for him is whether or not he will prosper in his present location. From the broad standpoint of rational utilization of the resources of the flood plain, the prosperity of the individual is not an entirely reliable index, inasmuch as it may be developed at the cost of public subsidy for relief and protection.

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[1] E. A. Kraemer, The Cincinnati Waterfront: Its Problems and Recommended Future Utilization (Cincinnati: Cincinnati City Planning Commission, 1937), p. 16.

Both qualifications apply to each of the eight forms of adjustment reviewed in the following pages.

Land Elevation

Mound-building aborigines in the alluvial valley of the Lower Mississippi River had simple, even if laborious, ways of remaining above flood waters that their civilized successors now have trouble in adopting. Not being able to keep the Mississippi in check, they resorted to the obvious expedient of building a haven beyond the reach of the more frequent floods. For ceremonial and burial purposes originating in part without consideration of flood conditions, the Indians found land elevation a fairly successful adjustment to the whims of the Mississippi and the Tennessee.[1] The settlers did not follow the practice. They could not do so readily in view of the heavy construction cost and the difficulties of changing levels once a settlement had started, although for a time the early houses of New Orleans were placed upon cedar posts. One property owner in a city is not likely to change floor elevation unless his neighbors join him. Here and there a few city founders were wise enough to elevate their lands before subdividing them. Otherwise, the adjustment rarely was made, and were it not for the possibility of applying it to roadways, to groups of new farmsteads, or to new manufacturing plants in some favorable areas, it would not deserve mention.

Highways and railways show a more widespread use of the land elevation technique than displayed by any other class of occupance. Following the flood of 1929 along the Savannah River in South Carolina, the State Highway between Hardeeville and Tillman was relocated and reconstructed at the time flood losses were repaired. The new roadway was designed to rest 1.8 feet above the 1929 flood crest, and to prevent such waters from flowing over an area of approximately 163,000 acres that had been under water

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[1] Cyrus Thomas, "Report on the Mound Explorations of the Bureau of Ethnology," 12th Annual Report of the Bureau of Ethnology, 1890-1891 (Washington: Government Printing Office, 1894), pp. 625-627, 650-656.

Walter B. Jones, "Geology of the Pickwick Basin in Adjacent Parts of Tennessee, Mississippi, and Alabama," Smithsonian Institution, Bureau of Ethnology Bulletin, No. 129 (1942), pp. 334-335.

in 1929.[1] Thus, repairs were used to place a main traffic artery out of reach of floods and to prevent flood losses on adjacent lands. These possibilities are large wherever highways are reconstructed in flood plains. Similarly, the grade of the Chicago, Burlington, and Quincy Railroad in the Republican Valley of Nebraska was raised at critical sections following the disastrous flood of 1935. Flood-damage repairs that year amounted to $1,483,700, and grade elevation cost $1,000,000.[2]

Some towns have missed excellent opportunities to prevent flood losses in the course of land elevation. Reedsport, Oregon, is built in part upon a sand fill pumped from the river bed, but the fill was completed at a low grade which permits flooding due to combinations of heavy stream discharge, high winds, and tide.[3]

Nine hundred acres of the marsh borders of the District of Columbia were subject to frequent flooding prior to their development by district officials. At that time the district had the foresight to provide for land filling in advance of laying out the revised sewer and street systems and in preference to building levees to protect areas reserved for residential and commercial use. The levels established were several feet below the crest of certain great floods that were to follow, but in all other years the area has been free from high water.[4]

The same device has been used in some other cities where flood plains had special advantages of location. The city plan for Dubuque, Iowa contemplated elevation of the land surface of a nearby island in the Mississippi River in order to make that area useful for manufacturing, airport, and recreational purposes.[5]

Unless flood waters can be used to build up the land, as in the tidal marshes in the Po Valley of Italy, the costs of elevation appear to be prohibitive in rural areas. The cost of ele-

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[1]74th Cong., 1st Sess., Savannah River, Ga., S.C. and N.C., House Doc. No. 64 (1935), p. 47.

[2]76th Cong., 3d Sess., Republican River, Kansas and Nebraska, House Doc. No. 842 (1940), p. 18.

[3]76th Cong., 3d Sess., Umpqua River, Oregon, House Doc. No. 684 (1940), p. 13.

[4]Metcalf and Eddy, op. cit., I, 38.

[5]Comprehensive City Plan Prepared for City of Dubuque, Iowa (Planning and Zoning Commission, 1936), pp. 33-34.

vating the lands around farmsteads may be as great as that of the buildings themselves, and it is only where new buildings are being constructed in sufficient numbers to warrant the use of large-scale earth-moving machinery that this form of adjustment holds promise of aid in readjustment. Land elevation in cities would be more costly, would require high expenses in utility relocation on developed land, and in many flood plains would be seriously handicapped by lack of suitable earth for the fill. It does lend itself to use in undeveloped urban areas prior to the installation of utilities. Thus, in the New Creek area on Staten Island, New York, a flood-protection project which the Corps of Engineers found to be justified by using the traditional formula (3) for determining justification, was deferred at the request of municipal authorities who planned to raise street levels and sidewalk levels in preparing the area for subdivision.[1]

The distinctive costs of making such a readjustment are those of obtaining fill materials and of making any necessary changes in the existing pattern of urban occupance. Its distinctive benefits are in reduction of flood losses and enhanced drainage facilities. Probably it holds little promise in many flood plains, but it may prove useful in wide flood plains like the backwater areas of the Lower Mississippi where new farmstead construction is planned on a large scale, or in any city which is permitting the subdivision of an undeveloped flood plain and can adopt such a plan without impairing channel capacity.

Flood Abatement

The idea that land-use measures may prevent water from accumulating in channels sufficiently to produce flood flows caught the public imagination during the first Conservation Crusade about 1910 and has been nourished chiefly by warm public interest since that time. Little evidence to support its widespread adoption as an adjustment to floods has come from subsequent hydrologic and agronomic research. Neither has there been sufficient research to prove or disprove conclusively for most sections of the country the frequent contention that floods may be eliminated by human action upstream. Abatement has been demonstrated

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[1]Unfavorable report of the Chief of Engineers on "New Creek, New York," December, 1941.

to be a practical form of adjustment in a few drainage areas, and it has been shown to be a hopeless mirage in other drainage areas such as the lower Ohio Basin. It flourishes in the public fancy as a measure having widespread value, it is belatedly recognized by engineers as an important supplementary measure to engineering works, and it affords an economic solution to a few flood problems.

By "flood abatement" is meant any measure taken outside of stream channels with the effect of reducing the crest of flood flows or changing the debris load for a flood event. Inasmuch as flood peaks and the damaging effects of floods may be increased greatly by large loads of debris, the alteration in certain areas of debris flows may be as important or more important than water-flow reduction. By protection is meant those measures taken in stream channels with the effect of reducing the inundated area by a flood flow. They comprise restriction of overflow by levees and flood walls, its reduction by channel improvement, its diversion by floodways, and the delay and reduction of flood peaks in reservoirs. Abatement always involves measures taken outside of the flood plain affected, such as cropping practices, terracing, gully control, bank stabilization, forest fire control, revegetation, water spreading, and forest planting. Protection may be located on the flood plain or it may extend far upstream in the form of reservoirs and channel improvements.

Established Effects of Land Use Upon Floods

The number of factors determining the amount and the rate of flow of surface runoff in any flood event is so numerous and they are so inter-related as to render their measurement exceedingly difficult. Hydrologists have been sorely tried in attempting to assign quantitative values to such items as temperature, evaporation, rate of precipitation, vegetal cover, slope, soil profile, infiltration rate, moisture content of the soil, underlying rock, drainage pattern, and stream gradient in explaining the genesis of a single flood event in a small drainage area. It is far more difficult to sort out these items for a larger drainage area, and the technique of applying the results of plot experiments to large areas in these matters is still far from satisfactory. A review of the extensive literature on the subject indicates clearly that no generalization concerning the relative importance of any of those factors for the country as a whole or even for large drainage areas is warranted at this time. To be sound, such conclusions must await much more intensive research in the field. There are a few facts, however, which seem definitely established and which suggest the limits of applicability of flood-abatement measures of the types here under discussion. These are as follows:

(1) There is no evidence that the magnitude of great or infrequent floods on major rivers has increased markedly since the lands of their drainage areas were settled.

(2) There is no evidence that such great floods have become more frequent during the period of human settlement.

(3) The debris load of the flood flow of a stream in the Wasatch Mountain piedmont of Utah has been shown to have been increased as a result of overgrazing in the upper drainage area of the stream.[1]

(4) The debris load and the flood flow of several streams in the Los Angeles basin, California, has been shown to have increased for at least several years as a result of the burning of the forest cover in their mountain drainage areas.[2]

(5) A combination of sheet erosion, gullying, and ditching operations for drainage purposes in the upper Yazoo Basin, Mississippi, is known to have caused an accelerated aggradation of stream beds and consequent elevation of the crests of flood flows.[3]

(6) Large-scale drainage operations in the nearly flat drainage area of the Sebewaing River, Michigan, have increased the frequency and magnitude of floods in the lower reaches of that stream.[4]

(7) The rate of silting in several reservoirs has been shown to have been accelerated by uncontrolled erosion induced by human occupance of their tributary areas.[5]

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[1]Reed W. Bailey, C. L. Forsling, and R. J. Becraft, Floods and Accelerated Erosion in Northern Utah, U. S. Department of Agriculture Misc. Publ. 196, 1934.

[2]W. G. Hoyt and H. C. Troxell, Transactions of the American Society of Civil Engineers, LXXXXIX (1934), 1-111.

[3]Happ, Rittenhouse, and Dobson, op. cit.

[4]76th Cong., 1st Sess., Sebewaing River, Michigan, House Doc. No. 286.

[5]Henry M. Eakin and Carl B. Brown, Silting of Reservoirs, U. S. Department of Agriculture Technical Bulletin No. 524, 1939.

(8) The frequency of some floods of less magnitude than the probable maximum flood in the Trinity Basin, Texas, could be reduced by the accomplishment of certain cropping, terracing, grazing and forestry practices in critical areas of the basin, thus obtaining a substantial reduction in mean annual flood losses.[1]

(9) In no instance has it yet been demonstrated that any changes in land-use practices will certainly cause an observable reduction in the crests of great floods under all possible weather conditions.

(10) In no instance has it been demonstrated that any changes in land-use practices will have sufficiently reliable effect upon the crests of great floods to warrant the alteration of the design of engineering works which have been planned to afford protection against or to pass great floods.

All of these statements are believed to be well supported by hydrologic evidence, and while reference might be made to scores of doubtful hypotheses and to a dozen or two apparent myths relating to the interrelations of soil, vegetal cover, cropping practices, and flood flows, these indicate the physical range of possibilities for flood abatement by land management.

The situation can be summed up in this fashion. Most floods in most sections of the United States are not caused by man. To the extent that they are man-made there are feasible means for abating them. To the extent that they are natural, and this includes even some floods in areas where human occupance has increased floods, they can be abated only in part by changes in land use. No such abatement is known to be fully reliable under all circumstances. Changes in land use may be imperative in the interest of maintaining the soil and vegetal cover, but they cannot be considered as essential, primary, and reliable lines of defense against floods. They nevertheless may be essential elements of protective works in that they serve to prevent debris movement that would injure or impair the life of those works. In short, land-use practices cannot be considered as substitutes for engineering structures designed to control, curb, or pass major floods. Flood abatement through land-use practices is to be regarded as an adjustment having important application to a few sec-

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[1]Department of Agriculture, Survey Report on Trinity River Watershed, 1941.

tions of the country where heightened flood or debris flows are the result of misuse of the land. It unquestionably is an important supplementary measure to preserve the efficiency and lengthen the life of channel improvements, reservoirs, and other engineering works which are affected by accelerated silting or more frequent minor floods. As surveys by the Department of Agriculture initiated pursuant to the Flood Control Act of 1936 are advanced, there will be further information to support conclusions as to the feasibility or infeasibility of flood-abatement works in other sections of the country. Meanwhile, experience with the Department's flood-control surveys suggests some of the problems which lie ahead in carrying out those works.

Lessons from Agriculture's Surveys

The principal programs which to date have been prepared by the Department of Agriculture relate to the Los Angeles, Trinity, Codorus Creek, Buffalo Creek, and Washita drainage areas (see Table 12). They call for a variety of corrective measures, ranging from bank stabilization works to shifts in crop rotations. It is not claimed that any of them, if carried out fully, will reduce the crests of great floods notably, but all of them are intended to reduce somewhat the magnitude of the more frequent floods and to change the debris characteristics of the streams involved. In the Los Angeles Basin, the debris load of the mountain streams will be reduced and the hazard of heavy flows of water and debris from burned-over areas will be minimized. In the Trinity Basin, flood losses, particularly from floods less than the probable maximum, on tributaries not affected by the reservoirs planned by the Corps of Engineers will be reduced, and a small amount of silting in the main channel will be eliminated. On Buffalo Creek, the silting of Buffalo Harbor will be reduced materially, the cost of maintaining state roads subject to erosion and silting in time of flood will be cut, and a small amount of flood losses will be prevented. In the Codorus Creek Basin, as with all the others, the principal benefit will accrue to owners and operators of the treated lands in terms of increased farm income made possible by improved farming practices.

The surveys leading to the recommendation of these programs have overcome serious obstacles in the coordination of the services of three technical agencies (the Bureau of Agricultural Eco-

TABLE 12

LAND-IMPROVEMENT PROGRAMS RECOMMENDED BY DEPARTMENT OF AGRICULTURE IN REPORTS UNDER AUTHORITY OF FLOOD-CONTROL ACTS

Basin	Characteristics	Benefits[a]
Buffalo Creek, N.Y.	Physiography: 80% in Allegheny Plateau; 20% in Ontario plain; glacial till. Occupance: Outside of the Buffalo urban area, 75% land is used for farming, chiefly dairy and general farms. 437 square miles.	Flood damage reduction $212,000. Increased farm income $3,041,000. Silt reduction $1,765,000. Savings in road maintenance $515,000.
Trinity River, Texas	Physiography: Rises in high plains and flows through blackland prairies onto the coastal plain of the Gulf. Occupance: 87% of land is used for farming; 45% of land is cultivated; row-crop cotton farms, 40% of area; general farms 20%; pasture farms 12%; ranches, 12% 12,900 square miles.	Annual basis. Flood damage reduction $598,000. Increased farm income from changes in flood-plain use $757,000. Silt reduction $82,000. Increased farm income $14,134,000. Gain in income in purchase area $227,000.
Codorus Creek, Pa. and Md.	Physiography: Rolling to hilly. Occupance: Almost wholly in farms; 72% of land is cultivated; prosperous general farms. 277 square miles.	Increased farm income $1,386,000.
Los Angeles River, Calif.	Physiography: 43% foothills and mountains; 57% benchland and valleys. Occupance: 35% is built-up section of Los Angeles: 22% is agriculture and grazing: 43% is brush and woodland. 839 square miles.	Reduction of water and debris damage $15,671,000. Silt reduction $6,217,000. Water conservation $1,207,000. Increased farm income $15,911,000. Forest-fire loss reduction $1,577,000. Savings in road maintenance $711,000. Aid to mountain recreation $736,000.

[a]Benefits for the Trinity Basin are computed upon an annual basis; those for the other basins are computed upon the basis of present value.

TABLE 12 - Continued

Recommended Program				
Measures	Total Cost During Period of Instal-lation	Public	Private	Benefit-Cost Ratio
Farm-land treatment (80% participation by farmers).	$ 1,274,000	$ 487,000	$ 787,000	
Treatment of 10,800 acres of submarginal land to be purchased.............	117,000	117,000	...	
Streambank stabilization..	1,618,000	1,618,000	...	
Total................	3,009,000	2,223,000	787,000	1.84
Farm-land treatment.......	53,829,000	27,172,000	26,657,000	
Treatment of land proposed for public purchase.....................	2,857,000	2,583,000	274,000	
Public purchase of land...	2,068,000	2,068,000	...	
Fire control..............	196,000	196,000	...	
Total................	58,952,000	32,020,000	26,931,000	2.88
Farm-land treatment (65% participation by farmers)................	510,000	To be divided upon basis of current Soil Conservation District programs.		2.71
Farm-land treatment.......	10,978,320	991,820	9,986,500	
Fire control..............	17,975,981	17,975,981	...	
Cover improvement.........	82,100	82,100	...	
Road improvement..........	1,238,275	1,187,594	50,681	
Mountain channel improvement.....................	3,850,000	3,850,000	...	
Debris basins and minor channel improvements and contingencies............	2,055,493	2,055,493	...	
Total................	$36,180,169	$26,142,988	$10,037,181	

nomics, the Forest Service, and the Soil Conservation Service), and they have required the development of new methods for hydrologic analysis of factors related to infiltration rates. Profiting from the early difficulties of the Corps of Engineers in estimating flood-protection benefits, the investigators of the Department of Agriculture have adopted more nearly uniform means for computing the present worth of each of the benefits to be derived. The survey results have established definitely the practicability and necessity of land-use measures as a corollary of engineering works in certain drainage areas where silting is a significant problem. All of these developments have been forward steps.

More important than any of the foregoing lessons, the surveys by Agriculture have shown the disadvantages and difficulties of considering land-use practices chiefly in terms of flood-loss reduction or of considering such flood-abatement measures without regard to the alternative forms of adjustment to floods. The early field investigations by the Department were directed primarily at reducing flood losses and at controlling menaces to flood-protection structures by means of work on the land upstream. Flood control provided a symbol, a banner, for an attack upon erosion and waterflow and other land-use and misuse problems of the areas specified in the Flood Control Act of 1936. Now that the campaign is well advanced and a few strategic positions have been taken, it is doubtful whether or not the primary emphasis should continue to be upon flood abatement. The surveys thus far completed show in each area a greater benefit accruing to the income of farmers than to any other purpose. They also make it abundantly clear that remedial programs can be effective only if designed and carried out in such a way that they will have the participation of the farmers, ranchers, and timber operators permanently concerned. Such participation in turn can be gained only if the program yields substantial returns to the operator. Where the operator does not stand to gain from improvements in the interest of meritorious downstream benefits, public subsidy or public land acquisition probably is necessary to bring about the changed practices, as in the case of sections of the Upper Trinity Basin. Just as one engineering project on a stream system may set in motion a series of readjustments affecting reaches above and below it, so flood-abatement measures are likely to have profound effects upon the agricultural economy of the upstream drainage areas.

For example, the heavy silt deposits reported above to have occurred during the Ohio Valley flood of 1937 raise the question as to the corollary effects which that movement of sediment had upon the welfare of the upstream farms, woodlands, and stream channels from which it came. Such evaluation raises the basic problem of whether benefits shall be considered from the standpoint of the landowner or of the nation. Under the flood-control banner there has been attained for the first time a procedure for analyzing all aspects of land use in a drainage area. This must be improved and extended as an integral part of finding the most effective use of all of the nation's resources, but it properly should carry the banners of farm income, navigation and other uses of water, and forest and soil conservation as well as or more than that of flood control.

Furthermore, it has become apparent that such comprehensive surveys, however labelled, can be effective only if related carefully to engineering studies for flood protection and for multiple uses of water. The ideal regional survey envisaged by pioneering members of the Waterways Commission in 1918 and by the Mississippi Valley Committee in 1934 has not yet been realized in the United States, but the development of sound study techniques by the Department of Agriculture has gone far toward making such investigations possible and practicable.

Flood abatement is an adjustment, then, which holds some hope of assistance in the reduction of flood losses, particularly from the more frequent floods, in suitable areas. The full potentialities of the land-management measures which it includes cannot be developed except in the course of a more comprehensive consideration of the occupance of the upstream lands affected and of related engineering works for water use and control in the same drainage areas.

Flood Protection

Four major types of engineering works are in use for flood protection. They are (1) levees and floodwalls, (2) channel improvements, (3) channel diversions, and (4) reservoirs. Taken as a group, these works have been planned from a viewpoint which ignored certain important benefits and costs of the protective work itself, as well as the whole problem of whether or not flood-plain occupance deserved to be continued or modified. Many of them have strengthened and stimulated the national economy, while others have tended to embalm with public subsidies communities which have lost their part in regional and national life. Still others have reduced flood losses at a cost which appears far in excess of the cost of alternative adjustments.

Each type of protection work has been tried widely in the United States, and in the light of that experience it is possible to point out certain of the distinctive costs and benefits which attach to each of them. The problem of comparing costs and benefits in order to determine the limit of economic justification for flood protection applies with equal force to all protective works. and it is considered separately.

Levees and Floodwalls

These are the most readily designed of the four types of protection. Most Federal levee projects have been undertaken or authorized in the Northeastern manufacturing belt and in the alluvial valley of the Mississippi River. Barriers of earth have been the obvious defense first considered in most flooded areas. They were the principal measures in the early Federal plans for protection against floods in the lower Mississippi Valley and in the Sacramento Valley, and were employed by the few municipalities and the numerous levee districts which constructed flood-protective works prior to 1936.

In addition to the usual costs of acquiring land, clearing land, moving earth, and providing necessary drainage and cover, levees may require other costly changes in land occupance. The most common problem is that of disposing of drainage from the lands behind the levees, and pumping plants are an essential part of the project cost in such instances. In urban areas which lack interceptor sewers it may be necessary to make extensive readjustments in the gradient and layout of the sewer system. Similarly, levee construction may require the re-routing of highways and railways, or the establishment of new grades for them, or the maintenance for them of levee openings which may be closed quickly in an emergency. All these corollary costs were regarded until 1938 as items which should be provided by local interests, but recently the trend has been toward Federal assumption of the costs of pumping plants and of changes in storm-water drainage systems. In certain communities levees have been considered as unfortunate and undesirable advertisements of civic weakness. A desire to put the flood hazard out of mind, coupled with objection to the unsightliness and inconvenience caused by levees, has resulted in the rejection of certain offers of Federal assistance in levee construction.[1] A secondary consideration entering into opposition to levee plans in some instances undoubtedly has been that levee lines mark unmistakably those zones of a flood plain which remain unprotected, thus causing depreciation in the selling value of property in those zones.

For the same reason, levees may promote some reshuffling of land use. They tend to discourage intensive occupance of unprotected zones, and to increase the stability of land use within the protected area. They have been used to good advantage as highways at Cairo and as promenades, but they apparently do not cause major changes in land use in urban areas.

Wherever levee building has been carried out on the same flood plain by neighboring levee or drainage districts there is likely to be a further cost induced by injurious increases in flow lines. It is well established by hydrologic measurements that in the valleys of the Illinois River and the Yazoo River, to name two conspicuous examples, competitive building by neighboring levee districts has reduced the available channel capacity sufficiently to raise the crests of flood flows several feet above the height anticipated for them, thus rendering other levee works less beneficial and increasing still further the depth of flooding on unprotected lands.[2] In this manner the costs of one levee have cancelled out part of the expected benefits from another levee project downstream.

Channel Improvements

While the major Federal protection projects have centered upon levee construction, channel improvements have been applied more widely than any other protection measure. For the most part,

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[1]The most recent case is that of a residential section in Harrisburg, Pennsylvania, which preferred scenery and floods to a levee and no floods. 77th Cong., 2d Sess., Report of Chief of Engineers on "Susquehanna River," 1942.

[2]72d Cong., 1st Sess., Illinois River, Illinois, House Doc. No. 182.

they have been undertaken by municipal and county agencies and have involved small-scale changes. No complete record of them is available, but their extent and size is suggested by the fact that channel-improvement projects were authorized under the Works Projects Administration in at least 500 localities in the period 1938-1941.[1] These projects, having a total estimated cost of $57,857,000, and an average cost of $102,000 per project, were approved for construction as and when the relief load permitted. The location of all work-relief projects approved for flood protection between 1935 and 1941, and having a cost of more than $100,000 each, is shown in Figure 8. Their distribution helps to portray the large and widespread number of local flood problems in the United States.

The improvements involve (1) changing channel cross-sections by deepening and widening, (2) lining channel beds and walls, (3) altering channel thalwegs by elimination of curves and by cutoffs across meander bends, and (4) clearing vegetation and debris from channels and adjacent flood plains. Of these, the first two are aimed at reducing the flow line by maintaining an enlarged channel capacity. The second two are intended to have the same effect by increasing the velocity of flow.

Except in valleys where accelerated erosion induced by cropping practices has caused abnormal sedimentation, as in the upper Yazoo Basin in Mississippi,[2] or in valleys where careless lumbering practices have resulted in clogging streams with fallen logs and brush, as in the Flint River valley of Northern Alabama,[3] the channel improvements alter the natural relation of stream flow to bed erosion and debris deposition and may thereby set in motion important shifts in stream pattern. The dynamics of such shifts have been discussed in Chapter III. The physical processes are relatively slow in operation but in the brief experience with channel improvements there already have been some notable examples of downstream changes. In the Fox Basin, Missouri, the straightening

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[1] 76th Cong., 1st Sess., Comprehensive Flood Control Plans, Hearings before House Committee on Flood Control (Washington: Government Printing Office, 1941).

[2] Happ, Rittenhouse, and Dobson, op. cit., pp. 56-62.

[3] Unfavorable report of the Chief of Engineers on "Flint River, Alabama and Tennessee," January 31, 1941.

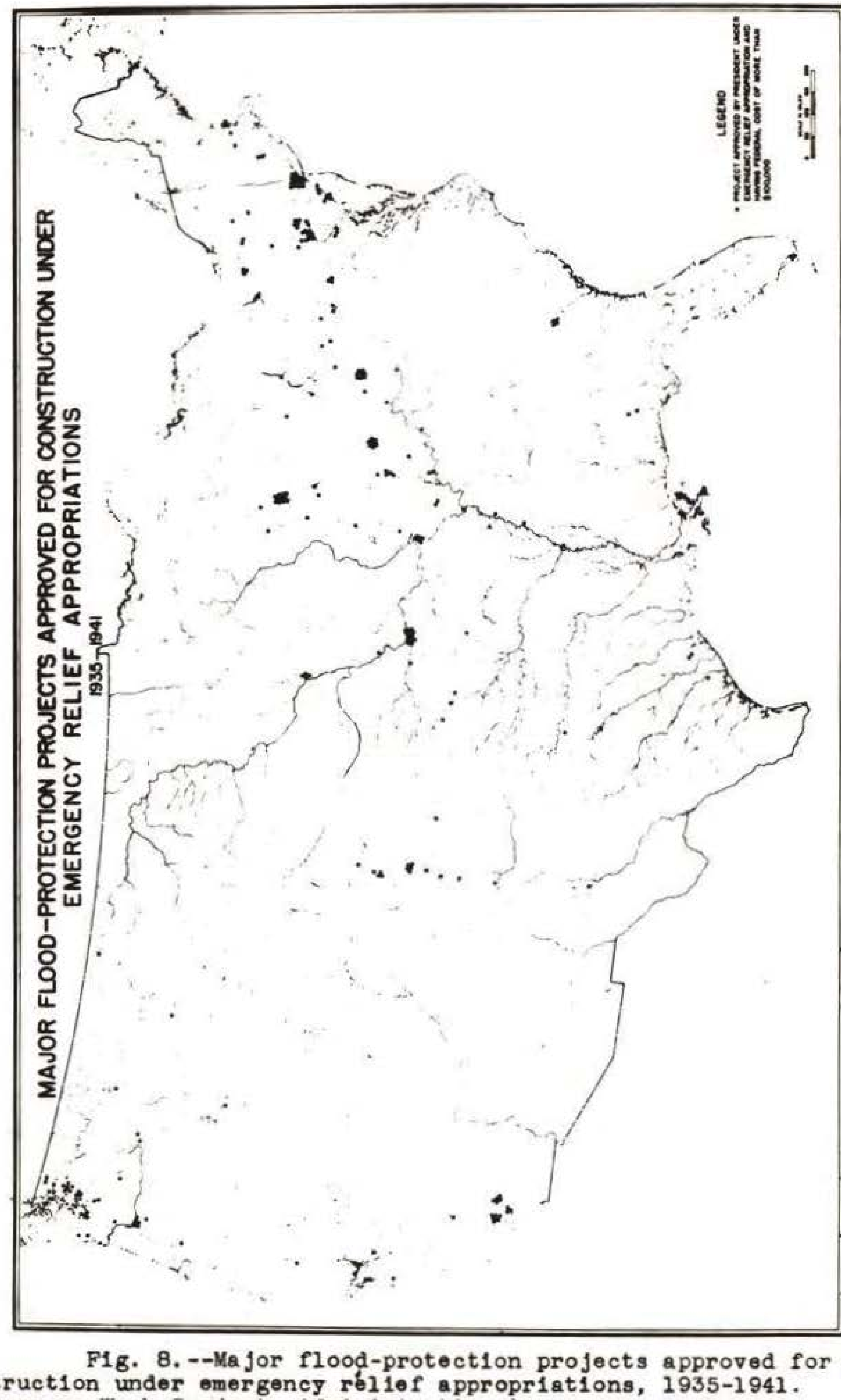

Fig. 8.--Major flood-protection projects approved for construction under emergency relief appropriations, 1935-1941. (Source: Work Projects Administration.)

of 59 miles of channel for flood protection during the period 1911-1922 has increased the erosive work of the stream so much that more than 500 acres downstream already have been damaged beyond hope of reclamation by heavy deposits of sand and silt. Channel capacity in the lower reaches has been reduced and flood heights have increased.[1] The investigations of Soil Conservation Service in the Tobitubby-Hurricane area of the Yazoo Basin reveal that stream-bank clearing, by promoting bank erosion, tends to cause channel enlargement and the lateral migration of channels across the flood plain.[2] They also show that the formation of alluvial fans and valley plugs at the mouths of tributaries which are subject to increased erosion through drainage channel operations upstream impedes the use of adjacent agricultural lands by blocking drainage outlets.

The effects of the largest single scheme of channel alteration--the cutoff plan of the Mississippi River Commission for the meandering reach of the river between the mouth of the White River and Natchez--are still matters of speculation. It was demonstrated in 1937 that the cutoffs may be expected to reduce flood crests substantially in that reach by increasing the flood slopes,[3] but there has not been sufficient time to observe the extent to which the stream-channel gradient will either increase the meander line or enlarge the channel capacity. The change in gradient may also influence rates of erosion and deposition in the tributaries, and it is not impossible that "knick point" phenomena involved in a lowered level of downward erosion may appear in the lower parts of those streams.

A different type of cost may result from straightening channels in urban areas where commercial land uses are affected. If portions of the commercial occupance in a city are separated from associated or tributary areas by a shift in a stream, as was done in connection with the proposed flood-protection works at Columbus, Ohio, pronounced changes may occur in the volume and

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[1]Unfavorable report of the Chief of Engineers on "Fox River, Missouri," December 20, 1941.

[2]Happ, Rittenhouse, and Dobson, op. cit., pp. 101 and 71.

[3]The cutoff program as of 1941 had reduced the length of the channel in this reach from 383 miles to 246 miles. 77th Cong., 1st Sess., Flood Control on the Lower Mississippi River, House Doc. No. 359 (1941), pp. 14, 20-22.

character of business transacted. This is relatively rare because a large proportion of channel-improvement work has been carried out in urban areas having narrow or medium-width flood plains where there has been extensive encroachment, and in such areas the cost of building and acquiring land for levees is likely to exceed the cost of channel deepening and widening.

Diversions

Techniques for setting aside a portion of a flood plain for the primary use of flood waters have been tried on a large scale only in the Lower Mississippi Valley and the Sacramento Valley. In both areas, floodways have been leveed off to carry floods that exceed the height of the set-back levees or controlled spillways at their head. From an engineering standpoint these measures are relatively simple, but they present exceedingly difficult problems from the standpoint of land use. There is an incentive to promote the agricultural use of the floodways because their hydraulic efficiency is many times greater if the land is cleared than if it is wooded. Moreover, there is heavy pressure by inhabitants of such areas to remain in their old homes.

In the Lower Mississippi Valley, the floodways constructed at Birds Point, Missouri, in the Atchafalaya Basin, Louisiana, and at Morganza and Wax Lake Outlet, Louisiana, have involved the erection of guide levees along the side limits of the floodways and of fuse-plug or controlled sections at their heads. The total area of approximately 1,700,000 acres has remained in private ownership while the Federal government has purchased or prepared to purchase flowage easements pursuant to the acts of June 26, 1928, and June 22, 1936. Much controversy has centered upon the question of whether or not the frequency of flooding in the floodway areas will be increased by their use for that purpose, and there has been strong agitation by influential groups of landowners to obtain authorization of alternative works, such as cutoffs, which would eliminate the need for the floodways and permit residents to enjoy the same degree of protection granted to their neighbors on the other side of the guide levees who are to be free from all floods. Such organized opposition resulted in 1941 in the substitution of additional levee and cutoff work for the Tensas Basin floodway which had been authorized in 1936 but never undertaken. The government has assumed no responsibility for land occupance in the floodways, and it has thus far withstood efforts to obtain Federal payments of damages to the floodway occupants when the emergency outlets are used, as they were at Birds Point in 1937. In an area of share-croppers the initial payments for easements to land owners are not passed on to the tenants, and, as a result, the chief victims of flood losses are no better prepared for them than if no payments had been made.

For these reasons, the present floodway policy of the Federal government seems unsatisfactory. It promotes neither the most efficient hydraulic capacity of the floodways nor improved adjustments of structures and land use to the flood hazard. It invites social resistance to continued use of the floodways, and it fails to cushion the impacts of flood upon their occupants. In the instance of the small Bonnet Carre spillway from the Mississippi River into Lake Ponchartrain above New Orleans, the acquisition of land in fee simple proved more satisfactory than mere purchase of easement, and a similar arrangement or a broadened easement plan probably would bring distinct advantages in the other floodway areas. In addition to correcting in large part the difficulties noted above, public purchase of the floodways might provide an opportunity to promote improved living conditions by favoring a better balanced farm economy and by initiating certain structural and land-use adjustments, such as the location of permanent dwellings outside of the floodways.[1] Its effectiveness would hinge upon the quality of subsequent management; with inept or impracticable management the adjustment to floods might be less satisfactory than if the present policy were to be continued.

There are a few instances of small-scale floodway construction by levee districts which has been abandoned or impaired because of sedimentation, but these dangers have not yet become threatening in the Lower Mississippi and Sacramento valleys.

Reservoirs

Two types of reservoir control are in use in the United

[1]The outstanding experience with public land management of this character is found in the Miami Conservancy District of Ohio, where lands in the detention reservoirs owned by the district are rented to farmers who build all permanent structures above the level of the maximum possible pool elevation and who pay rent only in years when the reservoir lands remain sufficiently dry to be cultivated.

States. Detention reservoirs have been constructed with the sole purpose of slowing up excess water-and-sediment flows in the Miami Basin of Ohio, the Winooski Valley of Vermont, the Upper Susquehanna and Delaware valleys in New York, the Los Angeles drainage area in California, the Fountain Valley above Pueblo, Colorado, the St. Francis Basin in Arkansas and Missouri, and a few other areas. Storage reservoirs which use all or part of their storage for other purposes have been undertaken by state agencies in the Hudson and Black basins of New York, the Muskingum Basin of Ohio, and the Colorado and Brazos basins in Texas. The Federal government has initiated the construction of storage reservoirs in the Merrimack, Connecticut, Savannah, Mobile, Mississippi, Colorado, Sacramento-San Joaquin, Willamette and Columbia basins. Of these, the most nearly complete system of control for a large drainage area has been developed in the Tennessee Basin by the Tennessee Valley Authority, and the most extensive system of reservoirs is that authorized by the Flood Control Act of 1938 for the Ohio, Upper Mississippi, Lower Missouri, White, Arkansas, and Red basins to aid in Lower Mississippi flood protection.

Without describing the engineering features of these great programs, which are covered adequately by the reports of the responsible constructing agencies, attention may be drawn to their distinctive costs and benefits. By taking the top off of the flood crests, detention reservoirs eliminate overbank flow and, where encroachment has not proceeded into the stream channel, permit bankfull discharge. They thereby prevent the sedimentation and cutting which accompanies overbank flow, at the same time allowing for the natural cleansing action of efficient flow within the banks. They do not affect stream regimen at other times. Storage reservoirs may be and frequently are operated to reduce flood crests more extensively so as to prevent the occurrence of flows approaching bankfull capacity, and they also are used to increase the volume of low flows. The more stable pools of storage reservoirs are likely to promote the formation of deltas and debris plugs in the lower reaches of tributary alleys, and to accelerate deposition of debris at the heads of the reservoirs. Reservoir construction on a large scale is so recent in the United States that there has been little opportunity to observe its effects upon the natural landscape. Experience with a few of the projects already suggests that the costs of reservoir construction in terms of deleterious landscape changes may amount to a sizeable proportion of the original construction cost.

Reference has been made to channel sedimentation and erosion caused by Elephant Butte Dam. Boulder Dam probably supplies an even more dramatic case of dislocations resulting from a reservoir having flood control as one of its objects. Two major dislocations have taken place since water storage was begun in the reservoir. The deposition of part of the Colorado River's silt load in Lake Mead has caused clearer flows below the dam, and has thereby increased the erosive capacity of the stream and large bodies of detritus are being subjected to renewed erosion and distribution.[1] A wave of scouring has begun to move downstream from the dam, and although it is diminishing in severity as it progresses and as a new equilibrium between bed conditions and stream velocity and turbulence is established, the ditch headings, pumping plants, and drainage works of irrigation districts along that reach of the river have suffered sufficient loss so that steps have been taken to recover damages from the United States.

Another reservoir cost heretofore largely ignored results from the dislocation of people living in or adjacent to reservoir areas. The expense of land acquisition has been taken commonly to include only the necessary reimbursements to land owners for land or for damages resulting from acquisition, as for example, where means of access to farm property are inundated, where city sewer systems are affected, or where farms are divided into uneconomic operating units. The total payments on those bases in settled portions of the country fall far short of covering the full social losses that attach to reservoir construction.

Geographical studies of the sparsely-settled section in the Southern Appalachians which was flooded by construction of the Tennessee Valley Authority dam at Hiwassee show the magnitude of losses that can result even where economic organization is relatively simple.[2] Reservoir construction required, in the

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[1]Godfrey Sykes, The Colorado Delta, American Geographical Society Special Publication No. 19 (Carnegie Institution of Washington and American Geographical Society of New York, 1937), p. 174.

[2]G. Donald Hudson and Malcolm J. Proudfoot, "The Proposed Fowler Bend Dam and Reservoir on the Hiwassee River--An Evaluation of Probable Effects," Tennessee Valley Authority, September 26, 1935.

opinion of the investigators, the purchase of approximately 24,100 acres, of which 7,100 acres were in the reservoir and 17,000 acres were on adjacent uplands. The purchase area had a population of 883, of whom 40 per cent were tenants. More than three-quarters of the lower valley lands in the reservoir area were owned by corporations. The farmers of the area were poverty stricken or at best had meagre financial resources. One out of eight was on relief. A land classification by the unit-area method showed that virtually all the land of excellent or good quality in the vicinity of the reservoir was in the valley bottoms. There were no promising opportunities for agricultural resettlement nearby, but it seemed possible that temporary employment might be found for the displaced farmers on the dam, and that some of them could be used permanently in maintenance of the dam and care of the forest lands and the recreational facilities to be developed in the purchase area. Under these conditions, the payment of land owners for the property acquired could hardly be expected to cover the expense which public agencies faced in caring for those displaced tenants who were without reserves to enable them to move to other locations. The same problem has been encountered on a much larger scale in other reservoirs of the Tennessee Valley Authority, and while the labor policy of the Authority has favored the employment and vocational training of displaced workers, there has not yet been a large Federal reservoir project in which specific provision was made in project plans and cost estimates for coping with the problems of such workers. In recent years, the Tennessee Valley Authority has made extensive investigations along these lines and has sought to evaluate the effects of reservoir construction not only upon agricultural income in adjacent areas, but also upon mineral, forest, wildlife, and manufacturing production and upon public health.

Greater progress has been made in evaluating the prospective benefits from multiple-purpose reservoir projects, and this is evident in recent reports of the Corps of Engineers, Bureau of Reclamation, Federal Power Commission, and Tennessee Valley Authority.[1] The problems associated with such evaluation are be-

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[1]This progress was best summarized as of January, 1940, in a series of duplicated papers prepared or collected by members of a Seminar on the Economics of Multiple-purpose Projects, sponsored by the Personnel Department of the Tennessee Valley Author-

yond the scope of the flood problem, and they are mentioned here only to indicate that the other purposes of navigation, electric-power generation, pollution abatement, wildlife conservation, and recreation may enter, some or all of them, into the design, justification, and operation of a storage reservoir project.

Limit of Justification

In the light of the general concept of justification for flood-plain readjustment suggested above, the appraisal of each of the four forms of flood protection involves, in essence, three steps: (1) determination of benefits, (2) determination of costs, and (3) comparison of benefits and costs. There can be little quarrel with such a statement of the appraisal process as applied to flood protection. Only in its application to specific flood plains is there room for disagreement, and there the variations among recent investigators are wide and deep.

Flood protection has been the subject of more quantitative valuation than all the other flood-plain readjustments.[1] From the accumulated experience of engineers in studying hundreds of prospective protection works, it is possible to select some of the essentials of a comprehensive and consistent appraisal, and also to examine the chief problems associated with such appraisal. If some of these problems appear to be issues of minutiae, it should be recalled that slight differences in procedure in the valuation of flood losses may result in large variation in the conclusions reached. Indeed, as will be demonstrated later, so great are the effects of slight manipulations in the appraisal techniques that some doubt is cast upon the utility of the entire process of determining justification. A review of current practice shows that, while a general formula of the form

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ity, and published by the members of the Seminar.

[1]Relatively exhaustive statements of valuation techniques employed by the Corps of Engineers are given in James B. Lampert, "A Study of Methods of Determining Flood Damages and of Evaluating Flood Control Benefits" (Master's thesis, Massachusetts Institute of Technology, 1939), and Edgar E. Foster, "Evaluation of Flood Losses and Benefits," Proceedings of the American Society of Civil Engineers, CVII (1941), 805-828. The problem of appraising benefits receives detailed analysis in Price's thesis noted above.

$$\text{Economic justification} = \frac{\text{Benefits}}{\text{Costs}} \qquad (3)$$

may state many of the considerations in evaluating flood protection, the resulting benefit-cost ratio in most instances of practical application hides in its apparently precise algebra a large body of assumption, inaccuracy, and arbitrary judgment.

Estimation of benefits.--Protection against floods yields benefits in three ways, as follows:

(1) Through eliminating or reducing the factor of flood loss.

(2) Through promoting a more productive adjustment to other floodplain factors, such as to alluvial soils.

(3) Through the beneficial effects which the protection-works themselves may have upon population and land use in the flood plain.

It is not enough to assume that the curbing of flood water will serve merely to prevent or reduce the occurrence in future of losses which otherwise would be experienced; new production values may be created by the reduction of the flood hazard and by the existence of the protection-works.

In so far as loss prevention or reduction is concerned, Lampert has shown that 5 major steps are involved in their adequate appraisal in any flood plain.[1] These steps are as follows:

(1) Estimation of the loss which is likely to result from floods of specified magnitudes for each type of occupance.

(2) Preparation of a curve or other device to show for a given reach of the stream the relation between amount of loss and stage for all crests less than the probable maximum crest.

(3) Estimation of the probable frequency of occurrence of each stage above flood stages.

(4) Calculation of the amount of losses which may be expected to occur during the period for which flood frequency is estimated.

(5) Estimation of the losses which would be prevented by the construction and operation of the anticipated protection works.

These five steps are involved in a comprehensive estimate of prevented losses wherever the hydrologic and economic data

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[1] Lampert, op. cit.

permit them. Obviously, if the basis for calculating flood probability is weak, or if the data concerning prospective losses are inaccurate, the relatively precise procedure suggested above may be inappropriate. One commonly-used alternative is to assume that flood losses in future will be approximately the same as those for an equal period of time in the recorded past. This simple method was used in many reports prior to 1935. It was applied in some areas with corrections for expected changes in flood-plain occupance or for differences in money value.

Estimates of loss to be experienced at a given stage of water can be made either by accepting the amounts recorded for past floods, or by field examination. Such estimates may involve (1) office use of recorded data on losses, (2) intensive investigation of sample areas, or (3) detailed house-to-house canvass throughout the entire flood plain. The choice of method used in the estimates requires consideration of the diversity of flood-plain occupance, of the reliability of past estimates, and of the degree to which the flood problem in the area justifies expenditures for survey purposes.

Without attempting to discuss these specific methods, it seems clear from the nature of flood losses and from the experience now available in estimating benefits that a sound estimate requires several conditions. First, there is need for a common base upon which all of the losses to be reduced can be evaluated. Property losses may be evaluated satisfactorily on the basis of sales price, or of capitalized income, whereas original cost and replacement cost may be used only with judicious allowance for depreciation and obsolescence. Whatever the basis selected, the total estimate is of questionable value unless those same criteria are applied consistently.

The test of consistency is more difficult to apply in the case of production losses and of losses through impairment of health and through emergency evacuation. No such readily-used valuation bases as capitalized income or sales price are available for the latter two classes of loss. Congressional guidance with respect to this problem is lacking, and, in its absence, the decision as to the base to be used in Federal valuation of flood protection is left to reporting officers. To the extent that the bases for any given project are mutually inconsistent, the estimates of total benefits do not reflect a balanced picture of the social impacts which are to be prevented or ameliorated by flood protection.

Second, due allowance should be made for non-recurring losses. To the extent that property is repaired or rebuilt in a way that renders it free from or less subject to the flood hazard, its loss at one time cannot represent a benefit to be experienced in future.

Third, reasonable correction should be made for prospective changes in flood-plain occupance. Neglecting for the moment major changes in productivity resulting from reclamation of overflow lands, there are numerous instances in which definite increases or decreases in intensity of occupance may be predicted. For example, the central business districts of cities such as Los Angeles and Detroit could in 1930 as well as in 1940, on the basis of local and national population trends, be expected to continue to grow. On the other hand, it seemed highly doubtful in 1940 that any significant expansion could be expected in the commercial areas of marginal producing towns in the Northern Appalachian coalfield. If predictions are to be sound, they must be based,of course, upon analysis of the economic future of the areas in question, and it is dangerous merely to extrapolate trend lines of population growth, as done in several cases. Some investigators have sought to apply percentage increases to the loss estimates obtained by the methods described above,[1] and others have taken the position that increases in intensity of occupance would offset the non-recurring losses and have, on that ground, retained the latter.

It is easy to allow the drama of flood disaster to distort the importance of benefits, and no indirect benefit is more subject to emotional bias than prevention of the loss of human life. Newspapers make headline-capital of hazards to life, and sometimes even a hard-headed engineer indulges in that tendency. In 1937, following the violent floods in the Ohio Valley, the Chief of Engineers, in recommending a $436,000,000 construction program to protect partially against the occurrence of the probable maximum flood, stated in his report:

> While figures have been compiled to establish the monetary benefits from the construction of the works that have been

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[1]76th Cong., 1st Sess., Brady Creek, Texas, House Doc. No. 441 (1939), p. 21.

> described, and to establish their economic justification, I am of the opinion that the real justification for this large expenditure is to be found in the saving of human life and suffering, and in the prevention of the disturbance of the affairs of the Nation brought about by a flood disaster.[1]

At least 140 lives had been lost, and more than 500,000 people had been driven from their homes. Construction of the recommended works would not prevent the occurrence of high water in those portions of the valley which would not be protected by levees and floodwalls, but even assuming that the project would eliminate great floods in the lower Ohio Valley, a truly humanitarian approach to the problem would inquire whether the same expenditures might not be used to better advantage in preventing the loss of 140 lives and the suffering of 500,000 people for a short time during the period of more than 100 years when a great flood probably will occur once. Pneumonia, which caused a large proportion of the loss of life in the 1937 flood, takes an annual toll in the United States of 150,000 lives. According to conservative estimates by public-health officials, that mortality could be reduced by more than 25 per cent by providing serum and laboratory diagnostic services for pneumonia cases that are amenable to serum treatment. The serum costs $25-75 per case, and there are only 8 states which have active programs for typing cases in order to determine the treatment required. A national program to give adequate diagnosis and to supply serum to the needy would cost $22,000,000 annually.[2] An expenditure for pneumonia treatment of $3,000,000, the amount probably required annually to maintain the Ohio River reservoir system when completed, would make possible the saving of approximately 4,800 lives annually. Considering this alternative for improving health, tremendous value must be assigned to "disturbance of the affairs of the Nation" in order to justify the recommended expenditure on the grounds of preventing human suffering and economic disturbance, especially in view of the modest effect which the 1937 flood seems to have had upon

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[1] 75th Cong., 1st Sess., House Committee on Flood Control, Hearings on Comprehensive Flood-control Plan for Ohio and Lower Mississippi Rivers, Committee Document No. 1 (Washington: Government Printing Office, 1937), p. 6.

[2] Interdepartmental Committee to Coordinate Health and Welfare Activities, Proceedings of the National Health Conference, July 18, 19, 20, 1938, Washington, D. C. (Washington: Government Printing Office, 1938), pp. 34-36.

the economic affairs of the nation as a whole.

Although the benefits from preventing flood loss may, under certain conditions of regional or national growth and change, be expected to increase or decrease during the life of protection-works, a second type of benefit may result from land-use changes directly induced by flood protection. This class of benefit includes (1) reclamation of wet or waste lands for agricultural or urban purposes, and (2) the stimulation of intensified occupance in areas already occupied.

Three of the more conspicuous examples of reclamation of wet lands in the United States--the Lower Mississippi alluvial valley, the Sacramento valley, and the Lake Okeechobee areas--were the result of land-drainage activities in combination with flood-protective works which since 1917 have been Federal responsibilities. Wet land reclamation is not contingent upon flood protection in every instance, but the two are associated in most reclamation enterprises in humid and subhumid climates. Without drainage, the protected lands cannot be cultivated effectively, and without protection even the best-drained lands are uninviting.

The amount of benefit attributable to flood protection under those conditions probably can be evaluated most accurately in terms of the increased income which is expected to accrue. The method of computing differentials in the value of protected and unprotected land of similar quality has been used widely,[1] but is subject to distortion resulting from the use of present selling prices of unprotected land. These often reflect anticipation of the time when protective works may be constructed. Moreover, such differentials are primarily a measure of benefit accruing to the landowner and do not take into account the net change in productivity from a national standpoint. Price points out this weakness of the differential method in his analysis of the Corps of Engineers' report on Ste. Genevieve County, Missouri, showing how the values obtained by land appraisal reflect only the probable increment in land rental, and neglect the total effect upon goods pro-

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[1]Examples are: 76th Cong., 1st Sess., Value of Flood Height Reduction from Tennessee Valley Authority Reservoirs to the Alluvial Valley of the Lower Mississippi River, House Doc. No. 455 (1939), pp. 15-56; and 75th Cong., 2d Sess., Chickasawhay River, Mississippi, House Doc. No. 410 (1937), p. 28.

duced.[1]

In the Yazoo backwater area, for example, the value of protection might be computed by comparing present land values with those for similar soil types now enjoying complete protection. Difficulty arises from the fact that speculators already have acquired large sections of the area with the hope of reaping profits if and when protection makes settlement possible. If protective work is properly guided, the national benefits from direct settlement activities in the backwater area can be large by comparison with the returns to land owners. As indicated in a recent Department of Agriculture study, there are great opportunities for peopling the fertile Delta soils on a self-sufficient basis, thus relieving the pressure of population upon the eroded and infertile soils of the Mississippi uplands. These opportunities are best measured in terms of the income-producing capacity of individual farm families.

The second aspect of enhancement of productive capacity is that associated with an intensification of occupance in the area to be protected. In its most simple form, the type of farming may change in response to a reduction in flood hazard, as, for example, the prospective shift from pasture to feed crops in the Hords Creek Valley of Texas.[2] In its most complicated form, the central business district of a city may be encouraged to expand and rebuild in the flood plain, as in the Miami Valley, Ohio, after the flood of 1913.[3] Theoretically, such changes should be reflected in land values, but their effects are difficult to sort out among the secular trends in land value, and among the hysterical deflations and subsequent inflations of selling price which accompany any serious disaster. The writer is not aware of any well-defined efforts to make such measurements.

In this connection, mention should be made of depreciation in property value as an alleged flood loss. It has been shown that such depreciation may constitute a duplication of property and production losses in so far as it allows for prospective flood

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[1]Price, op. cit.

[2]76th Cong., 1st Sess., Pecan Bayou, Texas, House Doc. No. 370 (1939), p. 46.

[3]Alfred J. Wright, "Ohio Town Patterns," Geographical Review, XXVII (1937), 623.

losses. For the same reasons, it is believed that, to similar degree, the prevention of such depreciation is not properly a benefit and should not be considered in the analysis of flood protection.[1]

Protective works may yield benefits quite distinct from prevention of flood losses or from enhancement of productive capacity or from multiple purposes served by storage reservoirs.

These are the benefits that result from the construction of public works. Without attempting to enumerate those effects, attention may be called to one great advantage to be gained from reservoir construction. In some areas, such as the Tennessee Valley, reservoir work provides an opportunity to train the construction employees in vocational and citizenship skills which they need to improve their level of living. This benefit has been lost in the past by the Federal government in building almost all large flood-protection reservoirs.

Estimation of costs.--The contrast between an engineering approach to flood protection and a comprehensive approach to the same problem is nowhere more evident than in the estimation of costs. The first-named approach is that followed by the Corps of Engineers. All current reports by the Chief of Engineers calculate construction costs on the following basis:

(1) Federal annual charges are taken as the net Federal investment at 3.5 per cent, plus the amortization of that investment over a period usually not more than 50 years (depending upon the expected life of the works), plus the cost of Federal maintenance and operation incurred by the works, and less such operation and maintenance costs on existing Federal improvements as may be replaced. The item of net Federal investment comprises (a) the first cost of new construction, including such lands, ease-

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[1]Although differential in land values was used as the measure of benefit from flood protection in the Miami Conservancy District and in the formation of numerous drainage districts, it has been absent from most recent studies. Its utility depends upon the degree to which it appraises all factors affecting the productivity of the flood plain when protected and all of these may not be effective upon selling price. Otis M. Page in "Basic Economic Considerations Affecting Single and Multiple Purpose Projects," Proceedings of the American Society of Civil Engineers, LXVIII (1942), 411-420, suggests that the loss reduction and differential in land value methods should be used jointly, and that the one yielding the highest estimates of benefits should be accepted in each instance.

ments, rights-of-way, and damages as are not charged to local groups, (b) related expenditures by other Federal departments, as for fish hatchery relocation, (c) interest during construction at 3 per cent for half the construction period when it is more than two years, (d) value of Federal properties which will be destroyed or damaged by the project, and (e) deduction for accrued amortization charges of such existing Federal improvements as will be replaced by the project.

(2) Non-Federal annual charges are taken as the net non-Federal investment at 4.5 per cent, plus the amortization of that investment over a period usually not more than 50 years, plus the cost of non-Federal operation and maintenance, plus the loss of taxes transferred to public ownership, and less such savings in annual fixed charges and operation and maintenance costs as may be made through the replacement by Federal improvements of existing improvements owned by local groups. The item of non-Federal investment comprises (a) funds contributed to supplement Federal first cost of construction, (b) value of lands, easements, and rights-of-way to be furnished, (c) construction, such as utility relocation, at 4.5 per cent for half the construction period when it is more than two years, (e) value of non-Federal properties which will be destroyed or damaged by the project, and (f) deduction for accrued amortization charges on such existing non-Federal improvements as will be replaced by the project.[1]

So far as it goes, this method of estimation is believed to be sound, although the merits of charging interest, of amortizing first cost, and of charging a higher rate of interest for non-Federal than Federal investment are open to question on economic grounds which are not discussed here.

The method omits from consideration many social costs which result from the construction of a project as surely as do the benefits obtained through loss prevention. These additional costs, which have been described in foregoing sections, consist chiefly of (1) social dislocations incurred by reservoir construction, and (2) changes in stream channel and regimen caused by the engineering works. It is believed that evaluation of those items

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[1]War Department, Office of the Chief of Engineers, "Circular Letter," August 14, 1939, pp. 2-6. (Mimeographed.) The interest rates have since been changed to 3 per cent for Federal and 4 per cent for non-Federal charges.

is largely practicable, and that they can be placed on a fairly sound, even though less accurate basis, than the usual engineering estimates of first cost.

Indirect, intangible, and production benefits.--The foregoing discussion has carried forward the distinction made in the section on "Flood losses" between property and production losses. Property benefits have been distinguished from production benefits on the same basis. It is recognized, however, that certain production benefits, together with benefits resulting from the prevention of losses in health and from emergency evacuation and relief activities, are not susceptible to measurement by means now available.

Such terminology differs from that employed in numerous engineering studies of flood control. In many of those studies the terms "indirect" and "intangible" are used to mean any benefits, other than prevention of property loss, which in the investigator's judgment warrant receiving some weight in the equation for justification.[1] The terms "indirect" and "intangible" are not used here, partly because of the confusion in connotation to which such use would lead, and partly because their ambiguous meanings express a diversity of definitions which no longer seems necessary. By subdividing benefits into the classes noted above, it is possible to consider the effects of flood protection without making allowance for an unspecified and dimly-perceived class of effects.

Comparison of costs and benefits.--In the interest of consistency alone it may be argued that costs and benefits, unless calculated for the same discount period, are not strictly comparable, and that unless both are evaluated on the basis of the same assumptions with respect to the benefited area, the equation is an inaccurate measure of justification. The methods of comparison involve questions of economic theory which the writer is not qualified to discuss, but two aspects of the cost-benefit ratio seem pertinent from a geographical point of view.

First, it is recognized that protection from floods is likely to require works which have a much shorter life than the

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[1]The terms "general" and "special" may also prove useful under certain conditions. "Limit of Economic Justification for Flood Protection," Journal of Land and Public Utility Economics, XII (May, 1936), 135-138.

probable frequency of the project flood against which protection is to be given. In such instances the inhabitants of a flood plain may wish to increase arbitrarily the estimates of probable flood benefits by assuming that great floods will occur more frequently than is considered probable. This inconsistency does not seem objectionable so long as it is clearly a matter of public choice rather than of technical judgment.

Second, if the national point of view is taken in evaluating benefits, then to be consistent it should apply also to costs, and, likewise, to any assumption as to areal coverage involved in the respective costs and benefits. Any other course leads inevitably to placing a disproportionate weight upon one or more types of benefits or costs.

Although there is no single, precise method which is most likely to lead to a fair and judicious appraisal of the benefits and costs of flood-protective works, a number of essential elements in any such appraisal are disclosed by the foregoing analysis. Federal experience in flood protection is relatively short, and new lessons are being learned as the work progresses. At present, it may be said that for most types of flood protection in most flood plains, a sound appraisal has the following qualities:

(1) It attempts to appraise all relevant benefits and costs.

(2) It takes into account the possible benefits from promoting a more productive occupance of the flood plain and from construction of the protection works themselves, as well as the benefit from prevention of future flood losses.

(3) In evaluating possible benefits, it adopts throughout a consistent assumption as to the area to be benefited, and as to the basis for determining value.

(4) It makes due allowance for non-recurring losses, and, at the same time, makes reasonable correction for prospective changes in the use of the flood plain due to factors other than floods.

(5) It recognizes in evaluating costs that the effects of flood protection may extend beyond ordinary building costs into the dislocation of social organization, and into the disturbance of stream processes.

(6) It seeks to identify each class of possible benefit

or cost, and to assign to each a monetary value wherever practicable, but it avoids a degree of precision in measuring those values which is not warranted by the reliability of the data measured.

(7) It compares benefits and costs on a basis which takes account of the possible occurrence of the probable maximum flood, but which further assumes the same viewpoint--national, regional, or local--with respect to both benefits and costs.

Few currently-used methods for determining justification for flood protection embody all seven of these qualities. Most of them fail to allow for costs other than those directly involved in engineering construction. Most of them do not attempt a full appraisal of all possible benefits, nor do they venture a monetary appraisal of benefits for which relatively detailed statistical data are not available.

Probably the major departure from these essentials lies in the apparent precision with which the comparison of costs and benefits is expressed. Ratios to the second decimal place are used to compare findings based upon data which, at best, are not reliable beyond the first or second whole digits. One project is recommended for authorization because it has a benefit-cost ratio of 1:1.08.[1] Another is disapproved because it has a ratio of only 0.75.[2] If the estimated benefits for a given flood-protection project are calculated by computing recurring property losses with care and then applying a somewhat arbitrarily selected increase of as much as 40 per cent to allow for production losses, a difference of a few tenths of one per cent in the ratio of benefits to costs is hardly to be considered as significant in determining whether or not the work should be constructed. The ratio is particularly subject to inaccuracy when, in arriving at it, large groups of benefits and costs are ignored entirely. It is as though in determining the need for purchasing an automobile, the head of a family were to make his decision solely by (1) computing with great precision the purchase cost and probable cost of gasoline, (2) making a rough estimate of the probable cost of repairs

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[1]Report of Chief of Engineers on "Chittenango Creek and Tributaries," New York, November 3, 1941.

[2]Report of Chief of Engineers on "Whitewater River, Minnesota," September 25, 1941.

and tire replacement, and (3) comparing these costs with a carefully prepared estimate of savings in carfare and taxifare during the life of the car. The resulting ratio might be a useful guide in making a decision, but it would not reflect the benefits of being able to take vacation trips and to go for a doctor in an emergency, or the expense of increased family traveling or of having an invitation for the youngsters to wander far in search of amusement, any one of which might be the determining consideration.

This is not meant to suggest complete abandonment of the cost-benefit ratio. The ratio is helpful. It would be more helpful if more phases of benefits and costs went into its computation, and if it were recognized as having no more precision and accuracy than its least reliable components.

Emergency Measures

The obvious alternative to keeping floods out of a flood plain is to get damageable property and productive processes out of the way of floods. Staying out of a flood plain to begin with is the simpler procedure, and belated efforts now are being made to control further unnecessary encroachments, but such control does not relieve distress from time to time in areas already occupied. Where permanent readjustments do not prove justified, some of the distress can be alleviated by measures of a temporary character. The principal lines of emergency action are removal, flood fighting, and re-scheduling.

Removal

Temporary removal measures have been developed on a small scale in numerous flood plains, but only a few systematic attempts have been made to apply them to large or densely-populated areas.

The experience of two small storekeepers in an Ohio River town during the flood of 1936 illustrates some of the possibilities and difficulties of removal. Both stores are at the same elevation and the owners carry on approximately the same volume of business. One prepared for the predicted flood by using his delivery trucks to transfer, within six hours after receipt of the forecast, all the goods and movable fixtures to higher land. The loss amounted to the cost of $200 for moving, plus the cost of redecorating the interior. The other storekeeper piled his goods on cases and platforms in anticipation of a flood crest which would reach a height of five feet above floor level. The crest actually went several feet above that level and caused a complete loss in damageable goods, amounting to $3,000. Prompt action following a forecast may result in large savings, but if the action assumes accurate forecasts and if the forecasts prove to be too low, the loss may be greater than if no forecast had been made.

A steel plant in the Wheeling area illustrates well-developed adjustments involving removal. Protection of the plant by levees is planned but has not yet been initiated. Meanwhile, the managing company, like several other large corporations on that reach of the Ohio River, has planned and maintained its own system for evacuation. Each division of the plant is carefully marked and labeled so as to show its elevation above low water and the point at which flood waters would cut it off from dry land or would inundate critical items such as power machinery and pumps. When flood waters are expected to reach or exceed one of these critical heights in a given division, evacuation begins according to plan. Machinery is hoisted above the reach of the water, office records and supplies are removed, and pumps are arranged so as to be of maximum value in cleaning up the plant after the flood has receded. In these and many other ways the company gets its damageable property out of the way of floods in so far as time permits. The expense of preparing maps and plans for the entire plant was relatively low, most of the work being carried on as part of the normal management operations. Officials have estimated that savings from operating the plant during a large flood amounted to more than 50 per cent of the losses that otherwise would have occurred. Some losses could not be prevented, of course, inasmuch as damage resulted from closing down blast furnaces and from interruption of rolling operations. There can be no doubt, however, that the adjustment already has paid for itself. The feasibility of undertaking such an adjustment rests in large measure upon the mobility of the property affected. The relative amount of removable property governs the extent to which temporary evacuation is possible, and the value of such property sets an economic limit upon the expenditure for removal. Whether or not it is the most effective form of adjustment can be determined only after appraising other possibilities.

Scores of examples of removal techniques applied by individuals might be cited. These range from the Pittsburgh shopkeepers, who have their first-floor showcases mounted on rollers so as to facilitate removal by elevators to upper stories, to the Kansas City railways with their plans to elevate their bridges over the Kansas River, when a flood approaches, by using a system of emergency jacks.

Several district chapters of the American Red Cross were responsible for drafting a similar evacuation plan on a larger scale for the Lake Okeechobee area in Florida. The farmers and townspeople of the Everglades lands surrounding the Lake suffered tremendous losses in 1928 when a passing hurricane generated a flood wave which swept over the lake shore and inundated areas extending several miles from the shore. Heavy loss of life occurred. Flood-protection levees and outlet works were authorized in 1930, but as a substitute during the construction period and as an added precaution later, the Red Cross chapters worked out a plan to prevent a repetition of the 1928 experience if a hurricane should again threaten disaster. Under that plan complete arrangements are made to move approximately 20,000 people and their readily transported possessions out of the area by train. Time schedules for the assembly of trains, the notification of refugees, the assembly of refugees at shipping points, and the routing of trains were drawn in detail.[1] Definite responsibilities were assigned to persons or agencies for providing warnings, transportation, food, shelter, medical care, and other necessities. Provision was made to revise the assignments and schedules currently. Arrangements also were made for an orderly reoccupation of the flooded area. Fortunately, the plan has never been used, but it is always ready, and, if executed properly, is certain to reduce losses substantially.

Prior to 1937 Red Cross chapters had developed only a few such disaster plans, but the flood of that year directed attention to the need for them on all unprotected flood plains having relatively dense populations. By 1941 the national organization had stimulated the preparation of plans for virtually all of the Ohio River urban areas, and for a number of other towns and cities. Each disaster-relief plan provides for: (1) the organization of a

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[1]South Florida Red Cross Safety Committee, Florida Refugee Evacuation Plan, Lake Okeechobee Area, July, 1936.

continuing local group to prepare, revise, and execute the plan, (2) identification of the area exposed to the flood hazard, (3) dissemination of warnings, (4) rescue of persons from flooded areas, (5) medical care, (6) transportation of the refugees to suitable living quarters, (7) purchase of necessary supplies, and (8) registration and information services for refugees and others affected.[1] These plans have been used with good effect in some areas. Given an active, efficient local chapter, aided by experts assigned from the national organization, the Red Cross units become the directing agencies for mobilizing and coordinating the resources of the communities in dealing with flood sufferers. This work assumed gigantic proportions during the disasters of 1937 and 1938, and taxed the local organizations to the utmost in dealing with hundreds of thousands of refugees.[2]

The local plans are being supplemented by state-wide disaster relief plans which have been prepared in cooperation with the states of Alabama, Arkansas, Illinois, Kentucky, Louisiana, Ohio, Pennsylvania, Rhode Island, Virginia, and West Virginia. Larger problems, such as the transportation of refugees, the use of National Guard units for emergency policing, and the disposition of state public health personnel are covered in the state plans. In these plans the responsibility of Federal, state, and local agencies for the required work is clearly divided and assigned.[3] These plans and allocations for responsibility minimize administrative confusion in time of flood and make it possible to provide long in advance for warning services, emergency communications, and refugee concentration camps.

The Red Cross plans relate to basic needs for life-saving, health, food, clothing, and shelter for persons in distress. They do not cover the reduction of property loss or the maintenance of essential public services. In a number of cities, among which

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[1] American Red Cross, Sample Disaster Preparedness Plan, Black County Chapter, April, 1941.

[2] American Red Cross, Ohio-Lower Mississippi Flood Disaster of 1937 (Washington: American Red Cross, 1937).
American Red Cross, New York-New England Hurricane and Floods, 1938 (Washington: American Red Cross, 1939).

[3] An example is The Arkansas Plan for Flood Relief in Eastern Arkansas, Arkansas State Planning Board cooperating with the American Red Cross and other agencies, 1938.

Cincinnati and Los Angeles are outstanding, plans have been prepared and used to coordinate Red Cross work and the work of individual plant operators by maintaining electricity, water, gas, transportation, fire protection, police, and other essential public services under municipal authorities having broad emergency powers.[1]

Flood Fighting

Floods may be fought back temporarily by (1) works to protect towns or other large areas and (2) works to protect individual building units or pieces of property within buildings. As a temporary expedient until permanent works are constructed, or as a measure which is less expensive than the construction of permanent works, flood fighting has been used successfully in a few sections of the United States.

In Washington, D. C., prior to the building of the levee to protect government offices in the West Triangle, the Corps of Engineers had detailed plans for emergency sand-bagging along the line of the proposed levee, and during the Potomac flood of 1937 the nearby companies of the Civilian Conservation Corps were called upon to carry out the work. The Corps now has very broad authority to assist in such work throughout the United States, and its district offices have made or are making plans for emergency action in appropriate localities.

During the flood of May, 1941, the Weather Bureau forecast of stages of the upper Rio Grande resulted in the construction by the Civilian Conservation Corps and the State Engineer of an emergency levee to protect the village of Espanola, New Mexico, from water which otherwise would have caused property losses estimated at $136,000. (The losses would have been high by comparison with the total value of property, because 64 of the 68 buildings in the village are of adobe construction and would have melted away as the waters rose.) It is not possible to estimate the cost of making the forecast in this instance, but the levee work cost approximated $13,000.[2] Regardless of the feasibility of providing

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[1] Proposed emergency code of the City of Cincinnati.
Burton L. Hunter, "Disaster Preparedness Plan Used During Los Angeles Flood," Public Management, XX (1938), 119-120.

[2] Unpublished report of Weather Bureau on "Flood Loss

permanent protection for Espanola, or of moving the village to a less vulnerable location, it is apparent that the costs of making a forecast and of hastily erecting temporary protection works were amply warranted by the benefits obtained that year.

On a smaller scale, the same technique of erecting temporary barriers to keep water out of critical areas has been tried rather widely and successfully. The flood of July, 1938, in the Pawtuxet Basin in Rhode Island caused direct losses twice those of the flood of March, 1936, although it was not notably higher, the increase in loss being principally the result of the failure of emergency sandbagging and pumping operations at a single manufacturing plant.[1] If that emergency work had been effective, the estimated benefits from flood protection for the basin would have been reduced by at least one-half. Inasmuch as the manufacturing plants which are crowded into the narrow flood plain of the Pawtuxet account for 70 per cent of the total flood losses, it seems possible that well-planned flood fighting at the few other plants affected might largely reduce future losses, in which event complete protection by engineering works might be much less desirable.

On a still smaller scale, there are numerous techniques which have been developed principally by manufacturers to fight against losses within flooded buildings. Just as towns or buildings may be protected effectively by emergency measures, so also may the parts or contents of a building be hastily guarded if time permits. Among the more important of these measures are the following:

(1) Sandbagging transformers, generators, and other machinery, particularly electrical equipment, to keep water out.

(2) Covering plate-glass windows with aluminum or wooden shields to prevent breakage by floating debris.

(3) Filling empty tanks with water to prevent them from floating from their foundations on the flood crest.

(4) Coating metal parts with heavy grease to prevent rusting.

(5) Packing machinery with grease or other packings to

Reduction in Selected Areas in the Upper Rio Grande," 1941.

[1]76th Cong., 3d Sess., Pawtuxet River, Rhode Island, House Doc. No. 747 (1940), p. 22.

prevent or reduce the deposition of silt in delicate parts.

(6) Sandbagging and riprapping of eroding embankments during flood flows, particularly along railway roadways and bridges. All these measures, and many more, to cope with special loss problems, may be used to good advantage to cut down the impacts of flood. As indicated in Table 13, they vary in their applicability for the major classes of loss. Recalling the characteristics of flood losses as discussed in Chapter III, it is clear that flood fighting is especially well suited to the prevention of certain classes of loss. Whereas plate glass windows and machinery account for an outstanding proportion of commercial and manufactural losses, respectively, and are therefore susceptible to substantial reduction by emergency measures, the agricultural losses are not likely to be affected by them in an important degree.

Re-scheduling

The third class of emergency measures--re-scheduling--comprises shifts in public service and other production schedules which result in maintaining service in time of flood. As noted in the preceding chapter, the public utilities of the country have an enviable record for performance in the face of severe flood disaster. This reflects hard work and ingenuity. Increasingly, also, it reflects careful preparation to shift the schedule of services when necessary.

These shifts range from changes in national communication networks to local arrangements for providing emergency repair crews. During the 1938 flood in Southern California, all telephone lines between Los Angeles and San Bernardino were cut, and it became necessary to route calls through Phoenix, Denver, Salt Lake City, San Francisco, and then back to Los Angeles. At the same time the domestic gas supplies were retained in service because the utility company had the forethought some months before to distribute emergency supplies of pipe, cable and demountable A-frames to the arroyo crossings where flood threatened. The floods did wash out the old lines at many such places, but repair men were on hand to replace the pipe promptly and to maintain service.[1]

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[1] Gas Age, LXXXI (April 14, 1938), 36 and 40.

TABLE 13

RELATIVE SUSCEPTIBILITY OF FLOOD LOSSES TO REDUCTION BY EMERGENCY MEASURES BASED ON FLOOD FORECASTING

Class of Loss	Degree to Which Loss May Be Reduced by Emergency Measures Based on Timely and Accurate Flood Forecasts			Emergency Measures
	Large	Medium	Small or None	
Agricultural				
1. Crops				
a. Unharvested mature crops............	-	x	-	Re-scheduling--Early or more rapid harvest
b. Decrease in yield...................	-	-	x	-
c. Reseeding perennial crops...........	-	-	x	-
d. Crops not planted...................	-	-	x	-
e. Replanting of crops.................	-	-	x	Re-scheduling--Delay in planting
2. Stored crops.........................	x	-	-	Removal
3. Orchard..............................	-	-	x	-
4. Farm timber..........................	-	-	x	-
5. Livestock & livestock products.........	x	-	x	-
6. Residence--see "Urban Residential"				
7. Furnishings..........................	x	-	-	Removal
8. Personal belongings..................	x	-	-	Removal
9. Other farm buildings.................	-	-	x	-
10. Farm machinery & equipment............	x	-	-	Removal, flood fighting
11. Automobiles, trucks, wagons, boats.....	x	-	-	Removal
12. Fences, roads & outdoor improvements...	-	-	x	-
13. Drainage & irrigation works...........	-	-	x	-
14. Land..................................	-	-	x	-
15. Non-farm income.......................	-	-	x	-
16. Evacuation & re-occupation............	-	-	x	Re-scheduling

TABLE 13 - Continued

Class of Loss	Degree to Which Loss May Be Reduced by Emergency Measures Based on Timely and Accurate Flood Forecasts			Emergency Measures
	Large	Medium	Small or None	
Urban Residential				
1. Residence				
a. Foundation	-	-	x	-
b. Superstructure	-	-	x	-
c. Improvements (fixed)	-	x	-	Flood fighting
d. Decorations	-	-	x	-
2. Furnishings	x	-	x	Removal
3. Personal belongings	x	-	-	Removal
4. Garage & other buildings	-	-	x	-
5. Automobiles, wagons, trucks	x	-	-	Removal
6. Grounds & outdoor improvements	-	-	x	-
7. Loss of property income	-	-	x	-
8. Evacuation & re-occupation	-	-	x	-
Retail & Wholesale Commercial				
1. Building--see "Urban Residential"				
2. Furnishings	x	-	-	Removal, flood fighting
3. Equipment	x	-	-	Removal, flood fighting
4. Stock of merchandise	x	-	-	Removal
5. Minor buildings	-	-	x	-
6. Automobiles, wagons, trucks, etc.	x	-	-	Removal
7. Grounds & improvements	-	-	x	-
8. Business interruption				
a. Production of goods and services	-	x	-	Re-scheduling
b. Productive equipment & supplies	-	x	-	Flood fighting, removal, re-scheduling
c. Excess cost of delayed sales	-	-	x	-
9. Evacuation & re-occupation	-	-	x	-

TABLE 13 - Continued

Class of Loss	Degree to Which Loss May Be Reduced by Emergency Measures Based on Timely and Accurate Flood Forecasts			Emergency Measures
	Large	Medium	Small or None	
Manufacturing				
1. Buildings--see "Urban Residential"				
2. Office furnishings & records..........	x	-	-	Removal
3. Plant machinery......................	-	x	-	Removal, flood fighting
4. Stock of raw materials or finished goods..............................	x	-	-	Removal, flood fighting
5. Minor buildings......................	-	-	x	-
6. Automobiles, wagons, trucks, etc......	x	-	-	Removal
7. Grounds & improvements...............	-	-	x	-
8. Business interruption				
a. Production of goods................	-	x	-	-
b. Productive equipment & supplies....	-	x	-	-
c. Excess cost of delayed production..	-	-	x	-
9. Evacuation & re-occupation...........	-	-	x	-
Public Buildings & Grounds				
1. Buildings--see "Urban Residential"				
2. Furnishings..........................	x	-	-	Removal
3. Equipment............................	-	x	-	Removal, flood fighting
4. Stocks of supplies...................	x	-	-	Removal
5. Public records, books or other valuables............................	x	-	-	Removal
6. Minor buildings......................	-	-	x	-
7. Grounds..............................	-	-	x	-
8. Automobiles, wagons, trucks, etc......	x	-	-	Removal
9. Evacuation or re-occupation..........	-	-	x	-

Some of the other measures which have proved effective are: re-routing of rail and highway traffic; supplying bottled gas for hospitals and other key institutions; accumulating maximum possible supplies of water and gas in storage tanks before the pumping plants are flooded; providing for supplies of emergency filling materials to be used on eroding railway road beds; delaying the planting or cultivation of crops until after a predicted flood; and raising the cross-bars on telephone line poles. Each flood reveals a few more tricks which can be used later to soften the impact of high water, and it is increasingly apparent that a very large proportion of the interruptions in public services which have characterized past floods will be prevented in future by temporary measures based upon adequate forecasts.

Rehabilitation

Losses can be prevented after a flood recedes as well as before it rises.

In ignorance of ways of recovering and rehabilitating damaged goods, people often discard property which can be repaired at far less cost than it can be replaced. A familiar scene in the slimy dooryards of a flooded town are the pianos that have been dhrown out unceremoniously almost as soon as the waters receded. They are dreary pieces of muddy, warped veneer and wire. Yet, if taken in hand soon enough, they may be put in good shape at modest cost. Likewise, books often are discarded when they might be retained in readable shape if properly pressed, dried, and cleaned. Another common error in salvage has been to begin repainting before the damaged surfaces were thoroughly dry.

With the exception of a useful pamphlet issued by the U. S. Department of Agriculture for farmers, and informal advice from Red Cross workers and others experienced in flood-relief work, little help has been given to property owners in reclaiming damaged goods.[1] Large manufacturing and commercial units have learned means of salvaging the most out of flooded property, but their experience is not widely known. Probably 5 per cent of current losses could be recouped if full information were to be made

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[1]U. S. Department of Agriculture, First Aid for Flooded Homes and Farms (Washington: Government Printing Office, 1937), pp. 1-16.

available as a part of relief activities. Not much good would come from education ahead of a flood; the sufferers rarely are interested beforehand.

Value of Emergency Measures

With the exception of a few sample studies made by the Weather Bureau during 1941, no detailed investigations have been made of the extent to which total flood losses might be reduced by emergency measures of the three classes described above. The Weather Bureau's estimate that approximately $15,000,000 has been saved annually on the average by flood warnings during the period 1924-1940 is based upon such illusive data that it cannot be accepted as a measure of present reductions.

Excluding flood fighting for large areas, because it is subject to the same analysis as that made for permanent protection works, it seems probable on the basis of the evidence at hand that certain classes of residential, commercial, and manufactural losses may be reduced as much as 70 to 80 per cent under favorable conditions. Essential public services can be maintained with a high degree of efficiency. It has been demonstrated that large populations in both urban and rural areas can be evacuated promptly and in an orderly manner without significant loss of life or impairment of health. It also has been shown on numerous flood plains that property losses involving stored goods, store fixtures and windows, household furniture, machinery, railway rolling stock, and other movable equipment can be reduced largely by a combination of removal and flood fighting. Such reductions are possible only in urban areas. They now are practiced most widely by large commercial and manufactural concerns. They also have been adopted most effectively by persons and institutions located in the lower flood zones.

It is the writer's observation in the Potomac and Ohio basins that wherever a damaging flood is followed by another within a year or two, the losses to movable goods are materially less for the second flood. So long as the experience of the first disaster is fresh in mind, the shopkeepers are alert to the flood forecast and they are quick to move their goods upstairs, batten down windows, and otherwise prepare for the emergency. Reports from the rock-products plants along the Ohio River following the 1937 flood indicate that whereas the upstream plant operators in river reaches which had been under water in 1936 and in which the 1937 crest did not exceed the previous high were quick to move their motor equipment above the flood stage, many operators downstream were caught unprepared.[1] Where floods do not exceed the stages of relatively recent infrequent floods, the use of removal techniques seems to approach a maximum among manufacturers. One of the key problems of successful emergency plans is to find ways of preventing this alertness and knowledge from being entirely lost as years pass without floods. Experience has shown that unless floods are frequent the householders and small businessmen, and even some large stores and manufacturing plants, tend to forget the flood lessons.

It therefore appears that emergency measures afford the most promising opportunities for loss reduction in the upper zones of flood plains having urban occupance with high proportions of residential and small and medium-size commercial and manufactural occupance.

To be successful, all such measures require three conditions: (1) public information as to the extent of the flood hazard, (2) adequate plans and equipment for removal, flood-fighting, or re-scheduling operations, and (3) adequate forecasting of floods.

Without public understanding of the flood hazard, essential participation cannot be obtained from those who most benefit. As demonstrated by the unexpected magnitude of the 1937 flood in the Ohio Valley, it is still difficult to predict the probable maximum flood for a given stream, and even when such a flood is predicted there is no agency which makes a business of promptly informing all persons within the affected zones. Moreover, the absence of floods over a period of time may lull the residents of flood plains into a false sense of security which may retard emergency action.

Inasmuch as the planning of emergency measures has been largely a matter of private initiative, it is plain that the possibilities of using emergency measures are not recognized fully.

The whole arrangement of emergency measures can be effective only if built around accurate flood forecasts made for a sufficient period in advance, and adequately disseminated. An inaccurate forecast may cause more harm than good. If it is too

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[1]Nordberg, <u>op. cit.</u>, pp. 44-47.

low, much property will be caught by the advancing waters; if it is too high, people will lose confidence in the forecasting system and fail to heed it when next it is needed.

Only a few flood plains in the United States now enjoy accurate flood forecasts. The forecasts for the lower Mississippi River and the lowermost reaches of its major tributaries--the Arkansas, Red, Missouri, Ohio, Tennessee, and Upper Mississippi--are relatively reliable, as are those for the Columbia River, the larger Pennsylvania streams and the lower reaches of the Potomac, Savannah, Alabama-Coosa and other South Atlantic drainages. On the other large streams of the country the forecasts are useful, but not accurate for highly infrequent crests. In only a few of the headwater areas are there relatively precise forecasting systems, and even in an area such as the Monongahela Basin, the Weather Bureau's forecasts do not cover more than a few points on the stream and are not sufficiently frequent or widely distributed to be of use to many of the persons affected.[1] With the exception of a few places where the Bureau has helped establish a special warning service, and with the exception also of Los Angeles County, there are no small drainage areas for which forecasting systems have been well developed.

Structural Adjustments

More widespread than any other adjustment to floods is the practice of altering or designing structures so as to reduce losses that otherwise would occur. Without changing the use of land and without emergency efforts at removal, flood-fighting or re-scheduling, it is possible to reduce flood losses in some towns and cities as much as 50 per cent by simple engineering alterations. Likewise it is practicable to enhance the productivity of certain valley farms by adopting structures that turn flood waters from liabilities into assets.

The chief forms of structural adjustments which have been used successfully are in building design; layout and elevation of

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[1]A reconnaissance of this area by the Weather Bureau observers after the flood of June 4-5, 1941 showed that many householders had no real warning of that sharp rise, and that a number of the larger manufacturers and river boat operators looked to their own observers and to lock tenders for forecasts.

public utility systems; culvert and bridge openings; highway and railway roadbeds; water diversions; and fence and hedge layout.

Buildings

Many swamp-dwellers in the alluvial valley of the Mississippi River use their building foundations to prevent flood losses. Perching their homes and schools on posts so as to stand above the relatively frequent floods, they pay in inconvenience and in the cost of the higher foundations for freedom in most years from high water. This practice is rarely found outside of swamp and marsh areas,[1] but in some flood plains, summer cottagers have been quick to adopt similar measures for reducing losses. Along Neshaminy Creek, near Philadelphia, 30 per cent of the summer cottages are reported to have been raised since 1937 above the height of the probable maximum flood.[2] The major difficulties with this rather inexpensive measure seem to be that the raised cottages are more subject than others to being undermined by swift currents and that danger to life is increased by the inclination of people to remain in the houses after a flood has begun. Recreational land users are peculiarly responsive to the need for structural adjustments because they must arrange for the contingency that floods will occur while they are away, and because the water course gives them a special incentive to rebuild in the same sites after flood losses have been experienced.

Buildings, bridges, and other structures have been designed to withstand high water in some areas where strong currents and heavy debris loads are as damaging as flood water itself. For example, the international highway bridge over the Rio Grande at Laredo, Texas, was outfitted with a removable set of bridge railings after experience during the flood of 1932 indicated that the old concrete railing presented half or more of the total resistance of the entire cantilever structure to the stream current.[3] A variation in design is found in the Coquaille Valley on the

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[1]77th Cong., 1st Sess., Unfavorable report of the Chief of Engineers on "Neshaminy Creek, Pennsylvania," 1941.

[2]73d Cong., 2d Sess., Eel River, California, House Doc. No. 194 (1934), p. 41.

[3]J. W. Baretta, "Bridge Railings Removable in Case of Floods," Engineering News-Record, January 28, 1936, pp. 121-123.

Oregon coast, where the fertile alluvial bottom lands are used intensively for dairy pasture and where many dairy barns are constructed with two levels of milk rooms so that the herds can be moved upstairs when tidal floods inundate the ground floor.[1]

Anchoring is an important phase of design for insubstantial buildings and for tanks which are likely to be floated off their foundations by flood crests. A familiar scene in almost every narrow flood plain during a flood is the piling up of tanks, small frame buildings, and other debris against bridges. These debris dams cause an increase in the flow line upstream and result in the flooding of areas that otherwise would remain dry. This was the case along Wills Creek in Cumberland, Maryland, in 1936. Moreover, if the tanks contain inflammable liquids the hazard of fire is increased tremendously. Recognizing this danger following the Ohio Valley flood of 1937, the National Board of Fire Underwriters prepared a set of regulations with respect to the construction and operation of containers for inflammable liquids, and urged their adoption by municipalities having flood problems.[2] These measures, which include provision for anchoring, have been recommended for use wherever a municipality does not prohibit the storage of oil on its flood plains.

Public Utilities

On a larger scale, the same type of adjustment has been made by public utilities seeking to prevent interruption of their services at flood time. If water pumps, gas plant, electricity plant and substations, and telephone exchanges can be kept in operation, the major inconveniences from interruption of public service can be minimized. Following the flood of 1937, Ohio Valley utilities that previously had been inclined to design their works to withstand water 2 feet above the 1884 crest, began to take the newly estimated probable maximum flood as a criterion and to rearrange their facilities accordingly. Intakes, pump houses, substations, switchboards, vaults, and other key items in

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[1] 73d Cong., 1st Sess., Coquaille River, Oregon, House Doc. No. 78 (1931), pp. 27-28.

[2] National Board of Fire Underwriters, Recommended Safeguards for Flammable Liquids Storage Tanks in Regions Subject to Floods, n.d.

the systems were elevated or moved or protected. Transmission systems were modified so that electric power could be brought in from other areas when the riverside plants were under water. In numerous less dramatic ways the systems were prepared to withstand an even larger blow.[1] From such experiences as these the water works and utility plant operators have had costly lessons for many years, but they have been slow to apply the knowledge and it is rarely that we find one of them advising appropriate work before rather than after floods.[2]

Bridges and Culverts

Bridges and culverts are variously designed to pass flood flows. Some are intended to carry probable maximum floods, and others are expected to suffer flooding from time to time. The early railroad builder's attitude toward culvert and bridge design is expressed by this statement:

> The advisability of designing a culvert to withstand any storm-flow that may <u>ever</u> occur is considered doubtful. Several years ago a record-breaking storm in New England carried away a very large number of bridges, etc., hitherto supposed to be safe. It was not afterward considered that the design of those bridges was faulty, because the extra cost of constructing bridges capable of withstanding such a flood, added to interest over a long period of years, would be enormously greater than the cost of repairing the damages of such a storm once or twice a century. Of course the element of danger has some weight, but not enough to justify a great additional expenditure, for common prudence would prompt unusual precautions during or immediately after such an extraordinary storm.[3]

Proper design to render a bridge structure secure involves, in addition to providing an adequate cross-section to pass flood waters, a design of foundations, piers, and abutments that will withstand the stream erosion which reaches its peak with the flood crest but which may be vigorously in progress at other periods. It has been estimated upon the basis of incomplete data that as a result of floods 9,000 highway bridges of 20-foot span or more

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[1]National Board of Fire Underwriters, <u>The Flood Problem in Fire Prevention and Protection</u> (Advisory Engineering Council reprint, n.p., May, 1939), pp. 32-43.

[2]F. W. Hall, "Temporary Protection of Water Works in Flooded Areas," <u>Journal of the American Water Works Association</u>, XXIV (1932), 1853-1854.

[3]Walter Loring Webb, <u>Railroad Construction: Theory and Practice</u> (New York: John Wiley & Sons, Inc., 1932), p. 254.

were lost between 1900 and 1937, and that at least 911 bridges were lost between December, 1935 and April, 1936, in the United States.[1] While some highway engineers take the position of the railway engineer quoted above, others consider that an extra expenditure of 5 to 8 per cent of the total construction cost would be sufficient to eliminate such losses in future.[2]

This much seems clear. There are sufficient hydrologic data to be able to predict flood flows for most drainage areas in the United States. There are adequate engineering techniques for designing openings to pass those flows. The question is whether or not it would be more desirable to build more expensive structures which would be free from flood hazard. The economic considerations may shape the answer, but, in addition, the public policy increasingly reflects the view that when a governmental agency builds it must do so in a fashion free from flood loss, even though at large cost. This attitude seems to accompany centralized administrative responsibility, and it parallels the mounting caution of the railways in such matters as they become larger and more rigidly organized.

The railway companies have now developed elaborate means of protecting their roadbeds from washouts. These include riprapping, anchoring of track, relocation of stream channels and ditches, planting of protective vegetation, rodent control, special treatment of foundations in scouring streams, drop outlet spillways, and levees to concentrate flow at adequate bridge openings.[3] On the whole, the record in this respect is good. Perhaps no other class of loss displays such a high proportion of non-recurring items. For example, in the Nishnobotna Basin in Western Iowa and Missouri, most of the transportation losses of previous years will not be repeated during future floods because the damaged highways and railways have been abandoned, strengthened, or raised in the course of making repairs.[4] Similar improvements

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[1] Russell J. Borhek, "Flood, Bridges, Foundations and Failures," Roads and Streets, LXXXII (1939), 66 and 68.

[2] Ibid.

[3] American Railway Engineers Association, Manual, revised to March 12, 1936, pp. 1-11.

[4] "Following some of the larger floods in the past, repairs and changes were made to the transportation system which will pre-

are becoming standard practice in highway design.

Water Control

Special structures may be erected with advantage in some areas to retard the erosive effects of flood waters, and, on agricultural lands, the deposition of water and silt. In the bottoms along Neskowin Creek on the Oregon coast, farmers reduce their losses from tidal overflow by placing piling in front of their buildings to guard against the drift carried by high waters.[1] It is the writer's observation that in many flood plains landowners have overlooked opportunities to check erosion from floods by tree and bush planting and by protective arrangement of fences and hedges. Damages to land and buildings can be reduced thereby and some benefits may be gained from silt deposition. As noted in Chapter III, slight differences in ground cover and simple man-made obstructions to flow are highly effective in causing deposition and preventing scouring.

The outstanding examples of turning floods to good use in agricultural areas are the water-spreading devices of the semi-arid and arid regions. Using single barrier and debris structures, as in the Southwest, or series of wing dams, as in Montana, flood waters may be deployed from a stream channel over wide areas so as to deposit heavy debris behind barriers, to promote absorption in underground water-bearing formations, and to increase the

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vent a recurrence of considerable damages in the event of a recurrence of floods of the same magnitude. After the flood of 1931 on the West Nishnabotna River, which caused $15,500 damage to the Chicago and Northwestern Railroad, this portion of the line was abandoned; therefore, this damage is not subject to recurrence. On the east branch of the West Nishnabotna River, the bridge which caused a loss of $125,000 to the Rock Island Railroad during the 1939 flood has been replaced with a more substantial structure, which will prevent any similar loss in the future. During the floods of 1917 and 1929, highways, roads and bridges on the West Nishnabotna River sustained losses amounting to $49,800, and the flood of 1929 caused $16,000 damage to these improvements on the East Nishnabotna River, yet during the large flood of 1939 no such severe losses occurred. . . . ." Report of Corps of Engineers on "Nishnabotna River, Iowa and Missouri," December 26, 1941.

[1] 77th Cong., 1st Sess., Unfavorable report of the Corps of Engineers on "Neskowin Creek, Oregon," 1941.

moisture content of soil. In the arid regions, debris control and ground-water recharge are the principal benefits, and elsewhere the increments of silt and water to the soil are most beneficial. A few permanent pastures in Piedmont Plateau Valleys of Maryland and Pennsylvania have small deflecting dams and barriers which divert flood waters, thus reducing bank erosion and improving soil fertility. The agricultural values of these devices overshadow any benefits from reduction of flood losses.[1] Indeed, measures for the obstruction of water flow may increase the crest of a given flow, inasmuch as surface resistance decreases velocity and promotes the storage of water in that reach of the valley.

Taking all of these structural adjustments together, it is evident that large and reliable reductions in flood losses may be obtained without protection works. They have the disadvantage, however, of encouraging continued occupance of flood plains in time of flood, and thereby increasing slightly the hazard to human life. Successful structural adjustments for occupance that is related to advantageous flood-plain factors may attract other occupance that is less well suited to the locality involved. Thus, improved public services due to structural adjustments may encourage undesirable residential occupance. Most structural adjustments may be carried out by individual property owners in the course of normal repairs and replacements. There is a continuing opportunity, accordingly, to make appropriate structural adjustments; while it reaches a peak immediately after floods, it exists at all times.

Land Use

Emergency measures and structural changes may reduce flood losses, but a more reliable readjustment is permanently to remove damageable property and services beyond the reach of floods. In many instances this readjustment involves changes in land use. Such changes have developed progressively in some flood plains over many years. In others similar readjustments cry out for attention, and although there is doubt as to the degree to which public aid can be used effectively to promote the changes, there

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[1] Jay A. Bonsteel, Soils of the Eastern United States and Their Use--XXXIX, Meadow, Bureau of Soils Circular No. 68 (1912), p. 13.

is little doubt that public powers can and should be exercised in greater degree to prevent an extension of unwise flood-plain occupance.

When the Potomac River floods of 1936 and 1937 lapped at the margins of Washington, D. C., they covered there at least 900 acres of non-agricultural land. Yet they did little damage. Most of the area that would be under water during the probable maximum flood is in parks, and the remainder is used for boathouses, shipping yards, sand and gravel works, and similar structures. With the exception of several score low-class residences, a few manufacturing plants which grew up along the old Chesapeake and Ohio Canal, and three great blocks of Federal office buildings along Constitution Avenue, the built-up parts of Washington are on ground free from the probable maximum flood. The 1937 flood injured the public park areas only by shutting off some cross-river traffic for a time, and by damaging the gardens, walks, and grass. Intentionally or not, Washington has neatly adjusted its public land use to the flood hazard. With the completion of an artfully-concealed levee to protect the office buildings, the greater part of the built-up occupance either suffers little from floods or remains on the riverbank because of advantageous factors of location near the water course.

The meadow lands bordering numerous streams throughout the country bear testimony to a similar type of adjustment. Commonly, they are used for permanent pasture rather than crops; rarely are they used for building sites unless the valley is narrow and the neighboring uplands rough. Factors of drainage have combined with the flood hazard to make it advantageous for farmers to keep their cash crops and buildings out of frequently-flooded meadows unless artificial drainage works are provided.[1] Similarly, in the Cumberland Enclave area of Kentucky, the rural communities while centering upon valley floors are arranged so that buildings generally are above the flood plain which is planted regularly to corn.[2] This adjustment is so common that it is taken for granted and no question is raised as to why other farmers find themselves flood victims.

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[1] Ibid., p. 19.

[2] Carl Ortwin Sauer, Geography of the Pennyroyal, Kentucky Geological Survey, Series VI, XXV (Frankfort: Kentucky Geological Survey, 1927), 177-179.

Changes in Crops

The successful arrangement of crops by some farmers suggests the practicability of curbing flood losses more widely by that means. For example, dairy farmers along the narrow valley of the Umpqua River, Oregon, commonly plant the flood plain with alfalfa or perennial grasses which suffer only slightly from floods.[1] Inasmuch as cultivated crops vary tremendously in their tolerance to flooding and to deposition of silt, it is important to select species of plants that will resist both. Moreover, studies in the Ohio Valley and in Vermont show that slight differences in cover crops may have a marked effect upon the work of flood water. During the Ohio River flood of 1937, under conditions which were similar in other respects, a pasture covered with sod gained one-fourth to three-eighths of an inch of silt loam while a clean-tilled cornfield lost the same amount; a field of rye gained half an inch of loam while a nearby cornfield lost three-quarters of an inch.[2] Thin stands of certain grasses were highly beneficial, whereas other crops, such as soybeans, had a pronounced loosening effect upon the soil and were conducive to removal. The effects of land use were particularly important in narrow flood plains. These relationships between cover and loss are recognized fairly well by farmers in some flood plains subject to frequent overflow, but they have not been studied widely or intensively, and farmers in most zones of less frequent flooding seem unfamiliar with them.

Urban Relocation

Records of urban occupance show that once firmly established in the path of floods, cities and towns and parts thereof are slow to retreat to higher ground. Where withdrawal from a flood plain has taken place in whole or in part, one of several processes of change have governed. In early urban settlements on flood plains it is somewhat common for the town to move to or above the higher flood zones after a flood has shown the hazard

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[1] 76th Cong., 3d Sess., Umpqua River, House Doc. No. 684 (1940), p. 15.

[2] Brown and Brown, op. cit., pp. 98-99.

in the lower zones. At Los Angeles, for example, the first Spanish pueblo was located by specific direction of the Spanish Governor at a site on the banks of the Los Angeles River as near as possible to the river without incurring danger of floods, but a few years later it was moved when floods were found to reach to the site first selected.[1]

After flood-plain settlement is well established, a process of gradual withdrawal has taken place in a few areas with which the writer is familiar.[2] At Harpers Ferry, the first settlement was on the flood plain and adjacent hillside of the Shenandoah at its junction with the Potomac. There the Chesapeake and Ohio Canal and the Baltimore and Ohio Railroad crossed the mouth of the Shenandoah Valley, there an early ferry and later a highway crossing were established, and there a Federal arsenal was built prior to the Civil War to use the available water power. Although the early settlement centered in the flood plain, there was afterward a slow and irregular uphill movement. New residences were built above flood level, and a new commercial center took root on the relatively flat upland half a mile from the old center. By 1936 the flood plain was occupied by the railroad station, a small power plant on the Canal, a pulp mill, approximately twenty store buildings, a garage, two dozen residences, and the remains of the old arsenal. In the next year the river flooded the plain to a depth of as much as ten feet. One-half of the stores failed to reopen, the mill was abandoned, and two-thirds of the residences were destroyed or abandoned.

In only three places in the United States have complete, outright changes in urban units been made in later years. The little town of Columbus, Kentucky, moved out of the Mississippi River flood plain in 1928, and Leavenworth, Indiana, and Shawneetown, Illinois, went uphill out of reach of the Ohio River in 1938 and 1940, respectively.[3]

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[1]Ruth E. Baugh, "Site of Early Los Angeles," Economic Geography, XVIII (1942), 91.

[2]A case of partial withdrawal is described by Glenn T. Trewartha in "The Prairie du Chien Terrace: Geography of a Confluence Site," Annals of the Association of American Geographers, XXII (1932), 120, 137-153.

[3]There are records of a few earlier relocations. For example, Ste. Genevieve, Missouri moved following the flood of

All three relocations have been uphill fights against more than floods and terrain. Social inertia, the attractions of flood-plain locations, and the task of organizing group action have tended to retard such shifts. Shawneetown's migration was a difficult and tedious experience for all concerned, and it is not yet complete. Leavenworth moved with less difficulty. Nevertheless there were numerous complications, large and small, in the Leavenworth experience which illustrate on a small scale the problems of readjusting urban land use.[1] Near Leavenworth the Ohio River flows through a valley bordered by alternating covered terraces. Early steamboat landings developed at these wide places in the valley plain, and the little village of Leavenworth began at one of them in 1820. The town was under water at least twelve twelve times between 1831 and 1937. Then the 1937 flood, the greatest of record, covered the main street to a depth of more than 15 feet, inundating all but eight homes, a factory building, and a schoolhouse, driving the 420 inhabitants to these places and to the nearby bluffs, causing physical damages estimated at $272,000, carrying away or wrecking 46 residences and five business buildings, and leaving behind a thick coat of mud. Sustained chiefly by retail trade and a button factory using river shells, tired and discouraged by the tragic experience, why, inquired the townpeople, should they rebuild there? They set out to find a safe alternative. With the help of the American Red Cross, and of the Indiana State Planning Board and other public agencies, a new town plan was designed for a site one and one-fourth miles inland and 400 feet higher at the top of the bluff. Red Cross funds in the amount of $100,000 were used to build and outfit new homes, such aid being on the basis of need rather than of losses sustained. A Disaster Loan Corporation loan was obtained to cover the required local contribution of $25,000 for the Work Projects Administration to build streets, a water system, a sewer system, sidewalks, and a town hall, at the new site, and a park at the

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1785. Francis J. Yealy, Sainte Genevieve, The Story of Missouri's Oldest Settlement (Ste. Genevieve: Bicentennial Historical Committee, 1935), pp. 25, 61-62.

The town of West Hennepin, Illinois was abandoned a few years after its founding in 1836. Barrows, op. cit., p. 84.

[1]Robert E. Bondy, The Story of Leavenworth, Indiana, Reprint from The Red Cross Courier, January and February, 1938, 12 pp.

old site. Upon petition of the town board, the state highway was relocated through the new site. The Federal contribution for this project amounted to $100,000. The total expenditure of more than $225,000 of public funds in addition to the expenses borne by private individuals compares with an assessed valuation for tax purposes of $163,000 and with an expenditure of $490,000 which the Corps of Engineers estimated as necessary to protect the old town by means of a levee, but it meant the end of the flood problem at Leavenworth. Although a few of the inhabitants are remaining in the old town and it was unnecessary to move the button mill, the possible losses in future will be small. The remainder of the land at the old site is held by the town as a park, as already noted. Leavenworth retains most of the advantages which is possessed before the move, and has escaped the disadvantage of flooding. It is connected with a main highway and secondary highways leading to agricultural trade areas, the button factory furnishes some employment, and it is a suitable home for retired farmers and road workers. In addition, it is new in appearance, and enjoys a beautiful view across the Ohio River. Probably it will not grow. It is less likely to decline than would be the case but for removal, and it is removed from the liability side of the national ledger in time of flood.

The Leavenworth move was impeded by social resistance. There were recalcitrants to be persuaded and placated. Some old families were reluctant to leave. Others were sure that the new town could not be as comfortable as the old one, or that the expense would be prohibitive. Each family presented an individual financial problem to be considered in relation to the finances of the town as a unit. The need for direct relief and for loans and the capacity to pay tax assessments were different with each family. The acquisition of the new site and the transfer of titles for the old site were involved procedures. But the change was made.

It was aided materially by the violence of the 1937 flood, and by the guidance provided by state and national officials. With bitter experience of the flood fresh in their memories, most of the townspeople were receptive to the idea of a change.

Urban readjustment by means of changed land use has distinctive costs that result from abandoning productive capital and from relocation. Useful buildings and municipal facilities are demolished or allowed to fall into disrepair while new ones are constructed at a distance. Such costs are inevitable unless alternative uses can be found for the old structures. The relocation costs are manifest in the planning and organization of changes and in the social dislocations which may follow from moving families and business enterprises. A change is not necessarily beneficial; it may serve to freeze a type of occupance in a new location for which it is not suited, or to buoy up an occupance that is deteriorating in any event because of market conditions, technological advances, or related economic circumstances.

Relocation may also stimulate new life, and induce urgently-needed community reorganization. The Leavenworth move resulted incidentally in the merger of three church groups. Properly designed and executed on a favorable site, relocation stimulates civic improvements and revitalization.

Public Measures to Promote Improved Land Use

There is an increasing tendency for public agencies to promote effective land use on flood plains by public measures. At least four such measures now are available. They are (1) subsidized relocation, (2) subsidized abandonment, (3) land acquisition, and (4) zoning.

Subsidized relocation.--The Leavenworth move was symptomatic of public discussion of the question of relocating communities that had suffered during the Ohio Valley flood of 1937. So many flooded towns were in a declining economic condition and the costs of protecting many of them from floods by means of levees was so great that interest was created in possible alternatives. One measure of the costliness of the protection program studied by the Corps of Engineers is that of the 158 communities affected in that flood, 80 had an assessed property value less than the amount required to build protection works.

To cope with this situation in part, the Flood Control Act of June 28, 1938, in authorizing levee construction, provided:

> That in any case where the construction cost of levees or flood walls included in any authorized project can be substantially reduced by the evacuation of a portion or all of the area proposed to be protected and by the elimination of that portion or all of the area from the protection to be afforded by the project, the Chief of Engineers may modify the plan of said project so as to eliminate said portion or all of the area: Provided, That a sum not substantially exceeding

> the amount thus saved in construction cost may be expended by the Chief of Engineers, or in his discretion may be transferred to any other appropriate Federal agency for expenditure, toward the evacuation of the locality eliminated from protection and the rehabilitation of the persons so evacuated: And provided further, That the Chief of Engineers may, if he so desires, enter into agreement with States, local agencies, or the individuals concerned for the accomplishment by them, of such evacuation and rehabilitation and for their reimbursement from said sum for expenditures actually incurred by them for this purpose.

In no instance has this authority been used to date. Parts of New Albany, Indiana, and Ripley, Ohio, were relocated in 1937 through the efforts of the American Red Cross, but otherwise little progress has been made. The reasons for the lack of application of this subsidy for relocation are not clear, and probably could be determined only by a study of the relative advantages and disadvantages of each community's location and of the attitudes of municipal and Federal officials involved. One contributing consideration is that unless such relocations are undertaken promptly after a flood, civic interest in them is soon lost. In this instance the authorizing act did not pass until a year and five months after the flood, although the engineering reports on which protection was based had considered that alternative.[1]

Subsidized abandonment.--In certain flood plains it may be in the public interest to subsidize the abandonment of an enterprise which is highly vulnerable to flood losses and which performs public services of a restricted character. This seems to be the case in the Rapid Creek Valley in the Black Hills of South Dakota. The flood of 1907 on Rapid Creek ripped out 104 bridges and damaged 18 miles of roadbed of the Rapid City, Black Hills and Western Railroad, with a total loss of $233,000. The railroad company went into bankruptcy, but continued operations. The surface features of the Black Hills make Rapid Creek canyon the only relatively economical location for a railway. A flood as high as that of 1907 would do equally great damage now, and it is possible that a much larger flood may occur. This factor, combined with the poor economic condition of the railroad, has led the officials of the road to feel that it would be preferable to abandon the road,

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[1]In a few other reports it has been suggested that relocation might be desirable for occupance which could not be protected by levees. For example, 72d Cong., 1st Sess., Choctawhatchee River, Florida, House Doc. No. 242 (1932), p. 18.

for a settlement of $350,000 liquidation damages, than to continue operations with part of the road relocated in connection with the construction of the proposed Pactola reservoir for irrigation and water supply purposes on Rapid Creek.[1] The proposal is now under study by Federal agencies, and if adopted it will mark a new form of public effort to reduce flood losses.

Land acquisition.--Public land acquisition has been suggested by many as a means of promoting desirable shifts in land use, and it is well established as a Federal instrument for dealing with rural land-use maladjustments of related character, such as appear in over-grazing, soil erosion, and forest abuse. Alvord and Burdick, in dealing with the Columbus, Ohio, situation in 1913, were among the first engineers to realize this possibility. They recommended that acquisition also be used to prevent further encroachment, saying:

> The City of Columbus, about 1885, commenced to grow west onto the bottom lands of the Scioto River. These cheap and accessible lands were exploited by real estate dealers, subdivided and sold. What should be done, therefore, to prevent a recurrence of this kind of public mistake? It is believed that it is the part of wisdom for Columbus, as well as any other city similarly situated, to purchase outright such low-lying bottom lands, and remove them from the danger of being settled, by preserving them for commons, parks, open spaces, or any other purposes the future may point to as being most desirable. No other alternative seems to present itself which will with certainty and effectiveness prevent the population from spreading itself in localities obviously endangered by flood water. Such a provision has, therefore, formed a part of every project herein, and is deemed an indispensable and fundamental requirement to the flood protection of the future.[2]

The Corps of Engineers recently investigated the practicability of using leveed lands along the Illinois River for flood-control and navigation storage, and, in concluding that no such storage uses were warranted, recommended that one of the districts, having an area of 1,880 acres, be purchased, the levees degraded, and the land used as a floodway and for wildlife propagation.[3] This was justified chiefly on the basis of improving flow lines

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[1]Unfavorable report by Chief of Engineers on "Rapid Valley, South Dakota," November 6, 1941, pp. 19 and 38.

[2]Alvord and Burdick, Flood Protection for Columbus, Ohio, p. 275.

[3]Partially favorable report of Chief of Engineers on "Illinois River--Use of Levee Districts as Reservoirs," August 23, 1941.

downstream. Thus, land originally conveyed to the state by the Federal government under the Swamp Land Acts, on which subsequently drainage construction assessments of $147,210 were levied, is now to be returned to its original condition at a cost of $91,700 to the Federal government if the recommendation is adopted. Notwithstanding agitation for the return of other Illinois River bottomlands to non-agricultural uses,[1] no study has been made of the relative productivity of those lands under the suggested alternative uses. Indeed, the Cincinnati City Plan Commission study has been almost alone in its attack upon the flood problem in terms of land-use readjustments.[2]

Zoning.--Another partial remedy for unwise land use is regulation through zoning ordinances, building ordinances, and subdivision control.[3] Regulation of flood-plain use serves either or both of two objectives. First, it may limit land occupance which causes a constriction of natural stream channels. This "channel-capacity" regulation is aimed at dumping waste and building bridge approaches and abutments, highways and other structures which decrease a channel cross-section, reduce water-carrying capacity, and increase the height of flood flows. Zoning measures or building regulations may be employed to prevent such structures to the extent that they cause an increase in the height or duration of floods.

Second, regulation may limit the use of a flood plain to purposes which do not suffer unduly from the action of a flood or which do not cause serious damage to persons or interests located outside of the flood plain. This "land-use" regulation is to prevent or discourage occupance rendered uneconomic or contrary to community welfare by the flood hazard. Zoning ordinances may be employed to prevent new residential use, to encourage the evacu-

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[1]"I believe the people of the State, instead of seeing additional millions of public money expended to set back and enlarge the levees that now enclose 200,000 acres of land that were once the property of the people of the State and constituted a vacation land where they could hunt and fish and picnic, want to see these lands restored to the river, to the fish and wildlife, and made public lands." Everett M. Dirksen in the House of Representatives, March 31, 1937.

[2]Kraemer, op. cit.

[3]See Henry C. Klein, Flood Plain Zoning and Evacuation, Reprint from Quarterly of National Fire Protection Association, April, 1939.

ation of a residential area over a relatively long period of time, and to limit new manufactural and commercial uses to those requiring certain advantages of the flood plain.

The two objectives are combined in some regulations, and are independent in others.

Most effective flood-plain zoning in the United States has been accomplished by New Jersey, Pennsylvania, and New York. Cities have utilized it in a few instances. The powers of Federal government to promote zoning have not been exercised as fully as possible and desirable.

New Jersey provided for channel-capacity regulation under authority of its so-called Home Rule Act of 1917, as amended in 1929. That act provides that every municipality in the state may make and enforce ordinances for the purpose of "The defining of the locations and the establishing of widths, grades and elevations of any stream, creek, river or other waterway, and the preventing of encroachments upon the same."[1] Counties of the second class have substantially the same powers, and the State Water Policy Commission is empowered to prescribe conditions under which the erection of any new structure or the renewal of an existing structure may be permitted within the natural and ordinary high water mark of any stream.[2] The Commission also is authorized to require the removal or repair of existing structures in the interest of the public safety. Encroachment lines adopted by the municipalities and counties are subject to approval by the Commission.

The State Water Policy Commission performs two interlocking functions. First, it issues permits for construction or alterations of bridges, culverts, walls, fills, and other structures throughout the state.[3] Second, it makes intensive surveys of individual streams looking to the setting of encroachment lines and the preparation of specific plans for channel improvement. Ideally, the surveys should be completed before action is taken on

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[1] Rev. Stats., Title 40, c.56-1 (k) as amended by Laws 1938, c. 229.

[2] Ibid., Title 58, c. 1.

[3] State Water Policy Commission, Information for Applicants for Permits for Construction or Alteration of Encroachments on Streams, Bridges, Culverts, Walls, Fills, and Other Structures (Trenton: The Commission, 1938).

applications for permits to build or alter structures. Practically, the Commission acts on many applications on the basis of office or reconnaissance studies of channel and run-off conditions.

At this writing no lines have been adopted by municipal ordinance, although many recommended improvements have been constructed by county or municipal governments or by property owners. The lines are generally recognized by the responsible local officials; delay in formal acceptance has occurred in the municipal councils.

In addition to providing a basis for the issuance of permits by the State Water Policy Commission, the surveys are used by state and local officials as a guide to (1) removing channel obstructions such as sewer crossings, (2) constructing retaining walls and other channel-improvement works, (3) asserting title to the natural stream bed, and (4) advising property owners on desirable limits of improvements. The authority of the Commission has not been questioned in the courts. Neither has the state paid any damages for removals or alterations required by it. The entire process seems to have been a cooperative one in which acceptance of the principle of staying out of the stream channel has been gained by education and skillful negotiation.

The Commission has required the design of bridges and culverts with capacity adequate to pass safely the probable maximum flow. It has not set encroachment lines at the limit of the probable maximum flood. In general, floods of 15-25 year frequency have been used in calculating desirable channel capacity, thus leaving available for unrestricted occupancy many flood-plain areas which are inundated at less frequent intervals.

Authority to regulate stream-channel encroachment also is vested in state and municipal agencies in Pennsylvania. The State Water and Power Resources Board is authorized to issue permits for the construction of any water obstruction in any stream or body of water or for any other action changing the course, current, or cross-section of such water bodies.[1] If the Board determines that any obstruction is unsafe or in any way is "derogatory to the regimen of the stream," it may require the repair or removal of the obstruction.

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[1] Pamphlet Laws, 555, §§ 1-3 (Act of May 6, 1937); Pamphlet Laws, 555, §§ 1-10 (Act of June 25, 1913). Act of June 12, 1931.

The Pennsylvania Board has established encroachment lines in several cities and localities, but it has confined its activities chiefly to the inspection of dams, bulkheads, and other structures projecting into normal stream channels. In rare instances only has it attempted to regulate land occupancy in those portions of a flood plain located above the level of mean stream discharge.

Although the powers of municipalities in Pennsylvania are much broader than those of the Board, the latter has review power over action by the municipalities and it is in a position to guide zoning of flood plains on a state-wide basis.

The progress made under the above-mentioned legislation in Pennsylvania differs in minor degree from that in New Jersey.

In 1935 the State of Washington authorized its Supervisor of Hydraulics to establish "Flood control zones" on all streams in the state and to issue permits necessary to control the erection, operation, or maintenance therein of any structures which might "adversely influence the regimen of a stream or body of water or might adversely affect the security of life, health and property against damage by flood water."[1] The submission of application for permits is mandatory. The State Supervisor is given ample powers to enforce his regulations. By May, 1940, 14 flood-control zones had been established, more than 100 permits had been issued, and no appeals had been made to the courts.[2]

As part of its revision of state planning laws in 1938, the State of New York provided that planning boards should take into account peril from flood in determining whether or not the land in plats for new subdivisions can be used safely.[3]

The writer is not aware of important efforts to regulate flood-plain use in other states. In some states, notably Maryland,[4] state agencies are authorized to investigate waterway obstructions and, if desirable, to order their repair or removal.

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[1] Session Laws, 1935, c. 159.

[2] P. Hetherton, Flood Damage Prevention, Washington State Planning Council, May, 1938, p. 3; Letters from Chas. J. Bartholet, State Supervisor of Hydraulics, August 23, 1937 and July 14, 1940.

[3] Wayne D. Heydecker, "Recent Amendments to New York State Planning Laws," Planners' Journal, IV, 91-93, chaps. 44, 205, and 264.

[4] Cumulative Supplement to 1924 Maryland Code, Art. 96B §9.

In other states, notably Wisconsin,[1] counties have authority to regulate the construction of certain structures which would affect stream flow, but it has not been used generally to set encroachment lines or to establish zones. The Wisconsin counties possess broad powers to determine areas in which "trades and industries, and the location of buildings for specified uses may be prohibited."

Fragmentary data at hand indicate that a few local governments have used the police power to regulate flood-plain encroachment. Outstanding examples are the zoning ordinance for Jefferson County, Wisconsin;[2] the zoning of the California section of Cincinnati, Ohio;[3] the zoning ordinance for parts of Los Angeles County, California;[4] and the building ordinance for Keene, Connecticut.[5]

To date, state regulations have been directed chiefly at maintenance of channel capacity and county and municipal regulations at land use in a broad sense. The state work has been a fundamental step; without it, channels may be subject to progressive constriction. At the same time, uneconomic encroachment in the higher portions of a flood plain may be expected to spread so long as zoning and building ordinances do not limit buildings in the path of floods.

Extension of either type of regulation is difficult, and even the relatively simple process of channel-capacity zoning has encountered serious obstacles.

The chief conditions which retard the regulation of flood-plain use appear to be as follows: (1) data relating to flood magnitudes and frequencies are scanty; (2) studies of land utilization in flood plains are even more sparse; (3) present or prospective land users in a flood plain exert strong pressure against any measures calculated to limit their choice of land use; and

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[1] Wisconsin Laws, 1935, c. 303, § 1.

[2] J. M. Albers, "New Uses for County Zoning: The Jefferson County, Wisconsin Ordinance," Journal of Land & Public Utility Economics, XIV (November, 1938), 460-462.

[3] State ex rel. Bateman v. Zachritz, et al., 22 N.E. (2d) 84 (1939).

[4] Additions to Ordinance No. 1494 (new series) authorized by the Board of Supervisors, June 11, 1940.

[5] American Land Co. v. City of Keene (Conn.), 41 Fed. (2d) 484 (1930).

(4) there is little legal precedent for utilizing the police power of a state in order to prevent or restrict uneconomic land use which does not affect channel capacity.

None of these obstacles is insurmountable. Regulation of flood-plain use is known to be practicable in many instances and it is capable of wide expansion.

With the exception of the establishment of "harbor lines" and "channel lines" for purposes of maintaining navigability, the Federal government has not sought to regulate the occupance of flood plains. In several instances during 1940-41 the Chief of Engineers, in recommending local flood-protection works, made as one of the conditions of Federal participation the enforcement by local interests of adequate measures to prevent further encroachment upon stream channels. None of these recommendations has thus far been adopted by the Congress in authorizing the construction of projects.

Public Relief

If a flood were to strike in a densely-settled river valley of the United States in 1942 the losses suffered by the flood-plain dwellers would be borne in two ways. Most of the losses would be borne by private and public property owners and wage earners, as described in the following section. The remainder would be carried by public grants and direct rehabilitation work.

Federal Aids

As noted in Chapter I, the proportion of the burden carried by public relief in the form of credit, grant, and rehabilitation operations has increased progressively during the past 75 years, and the Federal share has increased even more rapidly. Under present policies, the following Federal relief would be available to sufferers:

Loans

1. Disaster Relief Corporation loans at 3 per cent for repairs and rebuilding of private and public property. Collateral is at the discretion of the Corporation. "Character" loans may be made, and interest charges may be waived for 4 months.

2. Farm Security Administration loans for repairs, rebuilding, purchase of livestock and seeds, and other farm rehabilitation expense. Rate of interest and period of loans are determined upon the basis of current policy and need.

Grants

3. Red Cross grants for any rehabilitation work found to be necessary.

4. Farm Security Administration grants for any farm rehabilitation found to be necessary.

5. Work Projects Administration projects providing employment for any persons thrown out of work as a result of the flood.

Direct Rehabilitation

6. Work Projects Administration projects for cleaning up and repairing public property, and for cleaning up private property found to constitute a public health hazard.

7. Civilian Conservation Corps assistance in cleaning up and repairing public property.

There are few wants, indeed, that cannot be covered by one or another of these relief services.

During the period of its operations since 1921 the national organization of the Red Cross has dispensed more than $56,000,000 to flood sufferers. This amounts to 60 per cent of the organization's total expenditures for relief of all types of disaster during the same period. Many disasters are aided solely by funds drawn first from local chapters. If the distress is severe, funds are drawn next from the national organization's treasury, and finally, in the event of great disasters, special fund-raising campaigns are conducted on a national scale. During the past twenty years the Red Cross has spent approximately $19 per capita on an average of 290,000 persons assisted annually (See Table 14).

Records of expenditures by other relief agencies are fragmentary, but it is known that following the floods of 1937, 4,976 loans amounting to $5,013,148 were authorized by the Disaster Loan Corporation, and that 9,071 loans amounting to $1,817,000 were made by the Farm Credit Administration to flood sufferers.[1] At the same time, Work Projects Administration expended more than $3,933,000 for rehabilitation of flooded areas in addition to $10,780,000 expended for relief work and flood fighting during the emergency. The Farm Security Administration made loans totalling $193,000, and spent $206,000 outright in grants and emergency purchases. Out of the total estimated losses for that year of

[1]These data and the other data concerning relief following the 1937 flood are taken from reports submitted to the 75th Cong., 1st Sess., in response to S. Res. 119. The reports are published in Sen. Docs. 63, 72, 78, and 84, and in a letter appearing on page 4077, Congressional Record, Vol. LXXXI, April 30, 1937.

TABLE 14

RELIEF ACTIVITIES BY AMERICAN RED CROSS IN FLOOD DISASTERS, 1920-1940[a]

Fiscal Year	Expenditures		Flood Disasters				
	Flood Disasters	All Domestic Disasters	Number	Buildings Destroyed or Damaged	Persons		
					Killed	Injured	Assisted by Red Cross
1922	724,943	903,723	22	75	105	b	36,035
1923	67,440	264,499	7	314	4	b	413
1924	77,659	419,320	10	3,105	66	1	1,361
1925	6,814	1,602,174	9	332	1	10	2,696
1926	13,146	3,600,026	6	541	12	10	1,448
1927	3,161,086	7,904,149	21	3,743	341	5	622,060
1928	15,129,348	16,544,258	9	3,805	46	30	71,045
1929	1,280,110	4,618,736	34	22,218	79	466	70,487
1930	584,193	958,110	15	2,998	7	19	40,801
1931	52,540	11,621,272	5	1,004	5	2	1,936
1932	127,616	3,598,699	5	13,362	22	3	53,957
1933	31,579	1,106,504	22	10,726	88	41	67,933
1934	342,556	1,567,048	13	5,539	75	170	26,718
1935	147,998	464,413	17	2,861	44	108	75,747
1936	4,190,649	5,099,206	24	81,790	109	6,851	457,254
1937	22,500,623	23,309,288	19	71,668	113	507	1,117,109
1938	6,238,779	6,634,810	37	9,172	216	57	80,941
1939	1,069,474	2,276,109	31	24,087	509	741	110,368
1940	209,318	748,838	11	9,776	120	55	41,881
1941	119,276	946,626	35	9,919	67	57	80,652
Totals	56,075,147	94,187,808	352	277,035	2,029	9,133	2,960,842

[a]Source: Annual reports of the American Red Cross.

[b]Not reported.

$440,000,000, at least 7 per cent was covered by the Red Cross and Works Projects Administration operations. This is the minimum part of the burden that was spread among tax-payers and contributors generally, there being other large, but unmeasured, expense which was incurred by municipal, county, and state governments in their own cleaning and repair work. Much of this relief was granted solely upon the basis of need.

Effects of the Public Relief Policy

Aimed at relieving distress and at cushioning the impacts of flood losses as much as possible for the individuals affected, the prevailing policy of public relief tends to spread the flood blows widely through the nation, and, in caring for individual needs, it influences the character of flood-plain occupance. It offers the same help to the foolhardy who needlessly occupy the flood plain as to those who are located there because of advantageous factors in earning a livelihood. The policy therefore encourages present occupants of flood plains to remain where they are by helping to minimize the economic shock of flood losses. In similar manner it induces further encroachment upon flood plains. It tends to discourage readjustments to the flood hazard at private expense, such as those in structures and land use described above, inasmuch as they involve an immediate expenditure of private funds whereas public relief may cover all or a part of future losses.

On the whole, public relief policy helps to freeze present occupance, to encourage further encroachment, and to obscure the differences in factors of advantage and disadvantage between the flood plain and nearby areas. If no relief were to be given, flood sufferers would be inclined after every flood to consider whether or not the advantages of the flood plain outweighed the disadvantages of the flood hazard. Business and residential occupance which did not find strong advantages in their locations would find it hard to compete with similar occupance outside of the flood plain, and there would be an impetus to finding a more favorable location elsewhere. To the extent that public relief softens flood losses by individuals, those differences in location are effaced.

Perhaps it is no mere coincidence that flood losses and flood relief costs have mounted together during the past 75 years.

Neither has deterred the other. On the contrary, public relief has reduced human suffering from floods in such a way as to promote or, at least, to fail to check the growth of causes for even greater suffering in future.

Insurance

In so far as public relief does not cushion the impact of flood losses, property owners and wage earners cover such losses by (1) charging them to operating expense, (2) covering them out of reserves set up for that purpose, (3) insurance, or (4) becoming insolvent and passing the losses on to the creditors. Business failures due to floods have been rare in the United States. Insurance has been tried sporadically and is available for a very small portion of the annual losses. Reserves against flood losses are relatively uncommon. The greater part of the losses seems to be carried out of regular operating expenses. Business men and wage earners simply attempt to take the flood hazard in their stride without making any marked adjustment to it, but flood insurance may offer an opportunity to reduce its detrimental effects at modest cost.

Corporation Operating Expenses and Reserves

An examination of the income accounts and balance sheets of the principal corporations operating manufacturing, public utility, and railroad enterprises in flood plains shows that only a few of them provide for reserves which are maintained specifically to cover flood losses. The Wheeling Steel Corporation and several others have at times established flood reserves to be paid out of corporate surplus, but the others either charge flood losses to regular operating items of maintenance and depreciation, or draw upon general reserves that cover other contingencies as well as floods.

Inadequacy of Present Insurance

A small amount of insurance against flood damage is written in the United States, and most of it is in connection with policies designed for other hazards. According to the financial statements of the stock companies and mutuals writing fire, marine, automobile, earthquake, sprinkler, tornado, and similar forms of insurance, there are more than thirty organizations that write some type of policy covering flood damages.[1] In 1938, which was taken as a year when the threat of flood was fresh in the minds of countless business men, those policies yielded an income of approximately $400,000 to the companies, and required disbursements of approximately $120,000. There could not have been an extensive coverage, therefore, of the flood hazard by straight policies for that purpose.

In so far as losses are insured it is chiefly in connection with automobile, personal property, inland marine, and other specialized policies covering all risks to specified property. For example, the Los Angeles flood of 1938 caused losses estimated by the Corps of Engineers to exceed $25,000,000. Of this amount, according to an estimate made by the Fire Companies Adjustment Bureau, $90,000-100,000 was paid as indemnification under all-risk personal property floater policies, $40,000-60,000 was paid on other all-rish coverage, and $135,000-162,000 was paid under comprehensive automobile coverage.[2]

The first stock companies organized in the United States to deal with flood risks in the 1890's were wiped out by the heavy indemnification that was made, and, indeed, the home office of a company founded at Cairo, Illinois, was itself destroyed by the floods of 1899.[3] By 1927, more than 30 companies had begun to write such insurance, but the severe floods of that year required heavy indemnities, and the coverage again was abandoned. While it still is possible to obtain insurance for virtually any property or production process desired, the amounts handled are so small that the premiums are prohibitive for most property owners.

Private insurance of flood losses seems to have failed for the same reasons, in part, as private efforts to provide all-risk crop insurance. Flood insurance was put into effect in limited areas, thus incurring the danger of excessive losses in one year, and it was based upon inadequate data as to the degrees of risk.[4]

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[1] Best's Insurance Reports (Fire and Marine Edition) (1939-1940 ed.; New York: Alfred M. Best Co., Inc., 1939).

[2] The Western Underwriter, VII (June, 1938), 11.

[3] Alfred Manes, Insurance: Facts and Problems (New York: Harper & Bros., 1938), p. 160.

[4] 75th Cong., 1st Sess., Message from the President of the

Crop insurance for wheat and cotton now is a practical reality under Federal administration, and the plans allow for indemnification of flood losses and for the setting of premiums after considering the flood hazard as well as other elements of risk. Unemployment caused by flood also is subject to indemnification under the provisions of the Social Security Act, but there is no record of the extent to which floods, as distinguished from other causes, have been responsible for losses. The wheat and cotton crops, and unemployment, are the only flood losses in the United States that can be covered fully by insurance at low premiums.

Is National Flood Insurance Practicable?

Success to date with all-rish crop insurance raises the question of whether it would be practicable to establish and operate a national system of insurance against flood losses. A definitive answer would require the type of investigation of risks and premium schedules in sample areas which preceded the authorization of the crop insurance plan. A tentative answer on the basis of related experience and of prospective risks is that a system of flood insurance appears to be feasible and workable under certain conditions, and that it would offer important advantages in promoting sound adjustments to floods.

Experience in France, Russia, and Switzerland with insurance against damages from floods and other natural catastrophes has shown that national enterprises can cover flood risks at low cost with a satisfactory financial record.[1] Moreover, there have been successful efforts in this country by groups of insurance companies to join in covering similar specialized risks, such as oil risks.[2]

Rough estimates of the premiums which would be involved

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of the United States Transmitting the Report and Recommendations of the President's Committee on Crop Insurance, House Doc. No. 150 (1937), pp. 2-3.

[1]H. Lanz-Stauffer, "Calamities Naturelles et Assurance," Premier Conference Internationale pour la Prot..tion contre les calamities naturelles (Paris: La Commission Française d'Études des Calamite, 1938), pp. 467-476.

Curt Rommel, "Bases de l'Assurance Contre les Damages Causes par les Elemente Naturels," Materiaux Pour L'Étude des Calamities, II (1937), 123-147.

[2]Manes, op. cit., pp. 164-165.

in insuring risks in the Pittsburgh area also favor the possibility of flood insurance inasmuch as they indicate that premiums would not be prohibitive.[1] The data now available concerning flood frequencies, flood magnitudes, and flood losses are sufficiently detailed and comprehensive to permit the preparation of fairly reliable estimates of risk for the centers of greatest flood loss.

To be successful, a national system of flood insurance would require national coverage, so that all major areas of flood loss would be represented and so that the various zones of hazard in each flood plain would be involved. It also would require some governmental guarantee to bear the indemnities that would have to be paid if a great flood were to occur in a densely-settled flood plain during the early operation of the system. Otherwise, no private company would be willing to write a large amount of insurance with the prospect that a flood of the magnitude of the 1936 flood in New England, for example, might occur the next year. This initial guarantee might be made through Federal reinsurance of private insurance, or it might be provided simply by complete Federal operation as in the case of Federal crop and unemployment insurance.

Whatever the form of organization, such an enterprise would be certain to encounter difficulties in computing risks, in obtaining the participation of property owners who preferred to rely upon public relief, and in maintaining premium payments in dry years or cycles when floods seemed remote. Probably some cooperation from Federal credit agencies in the housing and agricultural fields in requiring flood insurance would be necessary to stimulate and maintain such payments.

If flood insurance were established on a national scale with solid financial backing, it probably could serve to indemnify flood losses wherever other adjustments were either impracticable or delayed, and could do so promptly and without the stigma of public relief. Insurance would have the further advantage of providing for a regular inspection system, similar to that maintained by fire underwriters, which undoubtedly would be used to promote adoption of emergency measures and structural adjustments to re-

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[1] Prentiss B. Reed, Flood Insurance, Office memorandum, New York, September 29, 1937.

duce potential flood losses. Moreover, by setting premium rates upon the basis of the hazard involved, an insurance system would emphasize differences in hazard and would make property owners more sensitive to them. In this fashion, insurance would tend to stimulate the movement of unsound occupance out of flood plains and to favor the stable continuation of successful occupance which did not warrant protection.

CHAPTER V

CONCLUSIONS

In the light of the preceding evidence relating to possible adjustments to floods and to factors affecting those adjustments, the geographical approach to the flood problem which was outlined briefly in Chapter I may now be reconsidered with a view to making it more specific, and to indicating its relationship to prevailing public policy and geographical research.

Essentials of a Sound Approach to the Flood Problem

If the resources of the flood plains of the United States are to be used in the public good so as to yield maximum returns to the nation with minimum possible social costs, it seems clear that action affecting their continued occupance will be based upon four essentials.

(1) It will take account of all possible adjustments which might be made to the flood hazard. At least eight forms of adjustment have been tried successfully. Singly or in combination, they offer lines of readjustment where present occupance has been unsuccessful, or where the flood hazard is unduly costly under existing conditions.

Land elevation provides a permanent means of escape from floods at relatively high construction costs. It is impracticable for densely-settled areas, but may be suited to new urban developments, to strategic sections of highways and railways, and to isolated residential, commercial, and manufactural occupance in sparsely-settled flood plains.

Flood abatement by means of erosion control, forest-fire control, forest planting, and related methods of land improvement and management in areas upstream from a flood plain affords the possibility of reducing the magnitude of floods in a few sections. The complexity of the hydrologic factors involved and the scarcity of detailed field observations make it impracticable to generalize as to the opportunities for reducing the frequency of floods, checking the movement of debris, curbing bank erosion, and reducing highway erosion by these means in all parts of the country, but in a few areas such opportunities have been shown to exist. Experience to date suggests that land-management measures are the most feasible remedy for flood losses in a few places, and that such measures are a corollary of engineering works wherever heavy flows of debris threaten the life of the works. Their major benefits accrue to the owners and operators of the land on which the improvements are made, however, and such programs in the interest of reducing flood losses should be considered also as a part of integrated programming for all relevant phases of rural land use.

Flood protection by levees and floodwalls, channel improvements, diversions, and reservoirs is the most reliable and, in many instances, the easiest means of reducing flood losses. In balancing the costs of protective works against the benefits expected from them, it should be recognized that expenditures greater than engineering costs may be involved in the disturbance of urban land use through levee and floodwall construction, of the populations and industries of reservoir areas, and of the occupants of floodway areas, and in deleterious effects which the works may have upon erosion and sedimentation processes in the flood plain and stream channel involved. Levees and floodwalls carry a special disadvantage; if overtopped by a flow greater than the design flood, the maximum loss occurs. The other three types of works result in only partial loss when their designed capacity is exceeded. In the light of meager evidence it seems possible that reservoirs and channel improvements unless supplemented by land-use measures may induce or promote further encroachment upon a flood plain, and so may increase rather than decrease mean annual losses. Sound evaluation of flood-protective works requires appraisal of these possible costs, but also appraisal on a consistent basis of all benefits, in addition to those resulting from prevention of flood loss, which are involved in enhancing the productivity of the area to be protected, in improving public facilities through the protective works themselves, in training laborers on the projects, and in stimulating better land use. Just as amelioration of flood conditions through land-use practices can be evaluated effectively only in conjunction with broader programs for land improvement and management, so flood-protective works, if fully effective, must be planned with an eye to the needs and possibilities of water control and use in the same drainage area for other purposes, such as navigation, irrigation, power, and pollution abatement.

Emergency measures may reduce greatly the impact of floods if there are accurate, timely forecasts of their occurrence and height, if efficient plans for emergency action have been prepared, and if the persons affected know the plans sufficiently to act promptly. Properly-organized emergency removal measures have proved effective in evacuating large populations with a minimum of discomfort and distress, and with no serious effects upon public health. They also have been used and can be used to prevent losses of movable property, such as furniture, store furnishings, stored goods, and machinery, items which in urban areas account for a large proportion of the total property losses. Flood-fighting measures, ranging from emergency levees and bulkheads to coating parts of immovable machinery with protective oil, can serve well to decrease damages. Re-scheduling operations by manufacturers, transportation companies, and public utility agencies can assist materially in maintaining essential services and in minimizing production losses. It is believed that in most urban areas the mean annual flood losses could be reduced at least 15 per cent, and, under favorable circumstances, as much as 50 per cent by these emergency measures. They have been adopted by only some of the public utilities and large manufacturers, and they are generally not practiced or even understood by small property owners and by occupants of upper flood zones.

Structural adjustments may be used to good advantage to prevent, or reduce losses of valuable property, interruption of essential public services, and scouring of farm land. Without attempting to provide protection for an entire area subject to floods, changes in building design, building layout, communication lines, street grades, and the like can be made while previous flood losses are being repaired, and can be executed as a part of regular replacement and maintenance operations. Such measures, in conjunction with emergency flood-fighting and re-scheduling measures, can minimize, or even eliminate, public-utility interruptions in urban areas, and they can reduce materially losses to buildings and lands in rural areas.

Land use readjustment can largely prevent those losses in agricultural areas which accrue to property and crops that do not depend upon special advantages of flood-plain location, and also can curb unsound urban occupance of undeveloped land. The chief deterrent, particularly in urban areas, lies in obtaining group action by land owners in readjusting the uses. Such readjustment therefore depends for its effectiveness upon public subsidy of urban relocation, public subsidy of property abandonment, public acquisition of land, and public land-use regulation. Zoning has been an effective means of preventing further impairment of channel capacity through human encroachment, and it promises aid in promoting improved land use in flood plains.

Public relief will remain a necessity in cushioning the social impacts of floods so long as other adjustments are not adopted. It has come to be well organized under Federal auspices.

Insurance against flood losses has failed under private management in the United States, but it is a measure which probably would be practicable if national coverage and guarantees against catastrophic losses were to be provided during the early years of operation. Once in operation, it would allow systematic indemnification of losses, and an inspection service which would promote the adoption in unprotected areas of emergency measures and of structural and land-use readjustments.

(2) In comparing possible adjustments for a given area, the benefits and costs of each adjustment will be evaluated on a consistent basis which recognizes all costs of appropriate remedial action, and which considers benefits in terms of the welfare of the entire community affected. Such comparison involves various costs and benefits to which precise monetary values cannot be assigned, but which must be given judicious weight in the comparison in order to prevent the unwarranted dominance of other items in deciding upon desirable lines of action. It is believed that there has been a general tendency to place undue emphasis upon hazards to life and health, and to assume without much foundation that production losses from flood were large in proportion to property losses. Because these components of costs and benefits are complex and difficult to measure, caution should be exercised in any attempt to express the feasibility of a given adjustment as a simple ratio of measured costs to measured benefits. Such a ratio may be more misleading than helpful unless all available data have been properly evaluated.

(3) Any action will seek to take full account of all fac-

<u>tors affecting the success of the occupance which is possible under the various adjustments or readjustments</u>. In so doing, it will recognize:

(a) That location upon a flood plain may be essential to certain types of land occupance, such as generating stations, because of special factors of slope and contour, soil, surface water, ground water, and corridor facilities.

(b) That for many types of land occupance, some flood plains afford marked advantages of location which do not, however, necessarily outweigh the disadvantages of flood hazard.

(c) That much occupance has developed on flood plains in association with other occupance depending upon flood-plain features, but without itself being related directly to such features.

(d) That the present occupance of many flood plains reflects an earlier adjustment to advantageous factors which, because of technological changes, are no longer significant.

(e) That many alluvial flood plains afford opportunities for maintaining a permanent agriculture on soil free from erosion and subject to replenishment by natural means.

(4) <u>Any action will promote adjustments or readjustments that favor the type or types of land occupance most likely to contribute to effective use of flood-plain resources</u>. Some considerations that might affect a choice in terms of this principle of action are the following:

(a) All possible adjustments except those in land use and insurance tend to favor the preservation of existing land occupance.

(b) Public relief favors further encroachment upon a flood plain by bearing part of the costs of such encroachment.

(c) Effective emergency measures also may favor encroachment in less degree by reducing the hazard of flood loss.

(d) Encroachment upon flood plains is likely to continue so long as the riparian doctrine is not modified by public regulation.

(e) Insurance and structural adjustments, by requiring a property owner to make some payment for the advantages of flood-plain location which he enjoys, stimulate the abandonment or movement of occupance that is not profitable.

(f) Flood abatement, flood protection, and public relief, by placing upon public agencies the major burden for reduction of losses, encourage the occupants of flood plains to seek those adjustments at public expense even though other adjustments at private expense might be less costly and more effective from the standpoint of the nation.

Present Public Policy

Prevailing public policy in the United States falls short of the foregoing four essentials in several respects. Under present legislative directives the Federal government's concern with reducing flood losses is limited to flood protection, flood abatement by land management, certain types of emergency measures, public relief, and relocation of a community if it can be accomplished at a cost less than that of protection. Surveys of the flood problem by Federal agencies are directed at flood protection and flood abatement primarily, and a large and outstanding engineering organization has been developed for that purpose. The forecasting system maintained by the Weather Bureau is unsatisfactory in its coverage of small drainage areas and its dissemination of forecasts for large drainage areas. Hence opportunities for stimulating emergency measures, structural adjustments, land-use changes, and insurance are largely lost. So long as present surveying and forecasting methods are not expanded, the potentialities of such adjustments will remain undeveloped.

In estimating the limit of feasibility for flood-protective works, no consistent basis is in use for evaluating benefits and costs. Unless some agreement is reached among the agencies responsible for flood investigations or unless a suitable Congressional policy is adopted, important classes of costs and benefits will be overlooked or will be compared in a misleading manner.

None of the present survey procedures for flood protection takes adequate account of the factors which, in flood-plain occupance, have been advantageous or disadvantageous for the present uses. As a consequence, it cannot be said with confidence that present Federal activities have the net effect of promoting sound land use. Public relief, flood abatement, and flood protection favor the retention of present occupance, whether desirable or undesirable. With little or no attention to the desirability of such occupance, present policy helps to stabilize uneconomic occupance. Works for protection and abatement minimize the flood hazard at public expense for the most part, and in the process provide increments in land value to land owners, some of whom occupy the flood plain on a highly speculative basis. Heavy losses by small property owners are largely subsidized by the government. Further encroachment is thereby tacitly encouraged, and Congress has not yet seen fit to require regulation of encroachments as a condition of Federal participation in flood protection. In effect, the national treasury bears a large part of the costs of those who prefer to live on flood plains, and does so without inquiring as to whether or not such plains afford any pronounced advantages for such occupance.

In areas where neither protection nor prevention is found to be economically feasible, the Federal government assumes no responsibility for fostering types of adjustment other than public relief. It goes to great lengths to provide protection from floods if the cost-benefit ratio is favorable, but contents itself with merely helping to relieve and rehabilitate flood sufferers in areas where the ratio is unfavorable. Inasmuch as the cost-benefit ratio is no index of the economic vigor of a community, protection is given to some towns that are definitely decadent, while it is withheld from some areas where development, though recent, is highly promising. Indeed, the more vigorous types of occupance which are highly dependent upon flood-plain locations, such as power plants, water works and railways, have been leaders in developing emergency measures and structural adjustments, quite independently of publicly-financed protection measures. Their successful activities have attracted, in many instances, subsidiary residential and commercial occupance which has lacked the foresight and skill to make such adjustments, and which has been more dependent, therefore, upon public aid.

On the whole, present policy fosters an increasing dependence by individuals and local governments upon the Federal government for leadership and financial support in dealing with the flood problem. While encouraging solicitation of further Federal aid and the establishment of types of occupance requiring such aid, the policy does not help or stimulate beneficiaries to explore the possibilities of making other adjustments with a view to promoting the most effective use of flood-plain resources.

Needed Geographical Contributions

In arriving at these conclusions concerning the characteristics of a sound approach to the flood problem, a general theory as to the factors affecting human adjustment to floods has been stated tentatively. This, it is believed, deserves more detailed examination and experimental application in the light of field studies. Meanwhile, it seems to provide a useful frame of reference for two lines of geographical research which are needed as contributions to the solution of the flood problem in the United States.

First, the development of new and improved adjustments to floods would be promoted by intensive studies of adjustments in representative areas here and in other countries, studies designed to identify the conspicuously successful and unsuccessful adjustments for each important type of flood plain and of flood-plain occupance. Second, it would be helpful to have studies of the present and prospective importance of the various factors affecting adjustments to floods in areas where protective works are under consideration and particularly in areas where protection has not been deemed to be justified.

If the flood plains of the United States are to be developed progressively so as to utilize as fully as practicable the advantages afforded by them, and to minimize their disadvantages, it will be necessary to adopt a broad geographical approach of the type outlined in the preceding pages. That approach will demand an integration of engineering, geographic, economic, and related techniques. The solutions will not involve a single line of public or private action but will call for a combination of all eight types of adjustments, judiciously selected with a view to the most effective use of flood plains.

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