Part II

FLOOD PLAIN PLANNING

Flood Mapping Program of the U. S. Geological Survey

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•THE ACT of March 3, 1879, creating the Geological Survey, did not specifically define its responsibilities in the water resources field. Annual appropriation acts, beginning with 1888, have authorized the use of appropriated funds for water resources investigations. Beginning with the fiscal year ending June 30, 1895, successive appropriation bills passed by Congress carried the following items: For gaging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells, and for the preparation of reports on the best methods of utilizing the water resources.

Successive appropriation acts have continued to define further the authorization for the water resource functions of the Survey. The current programs and any presently contemplated future recommendations are fully authorized in the language of the present appropriation act.

For more than 50 yr the mutual interests of the State and Federal governments in water resource problems have been implemented in the Geological Survey by cooperative investigations. These cooperative activities have been a major part of the work of the Survey. The current trend is for increased participation by States in cooperative water resources investigations. The present appropriation bill provides, "That no part of this appropriation shall be used to pay more than one-half the cost of any topographic mapping or water resources investigations carried on in cooperation with any State or municipality." The size and scope of the cooperative program clearly reflect the interest of State and local agencies in being "partners" in this nationwide water-resources appraisal task. All of the States plus American Samoa, Guam, Puerto Rico, the Virgin Islands, and the District of Columbia contribute to the Survey's water resources investigations through financial cooperation. More than 300 individual State and local agencies participate.

For many years the water resources problems of the country were such that the primary emphasis in the Geological Survey's program was the collection of basic water resources data. The increasing demand for solutions of increasingly complex water problems now necessitates greater attention to analytical, interpretative, and research phases of water resources investigations. One problem demanding attention is caused by man's occupancy of flood plains.

The natural function of a flood plain is to carry away excess water in time of flood. Failure to recognize this function has led to rapid and haphazard development on flood plains with a consequent increase in flood hazards. The average annual flood damage in the United States in dollars has increased from less than $100,000,000 at the begin-

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ning of the century to almost $300,000,000 today, even though about $5 billion has been spent for flood protection works. The increased damage is apparently not due to greater floods, but to increased encroachment on flood plains. It is reported that for every $6 spent by the Federal Government for flood control, $5 is spent by the public expanding onto the flood plain. The average annual flood protection expenditure, for 1937-60 period, was $288,000,000, whereas the average annual loss was $284,000,000; both figures adjusted to 1960 values. The problems of flood-plain development have been discussed in several excellent papers published by the University of Chicago, Department of Geography (1-5).

> It is economically infeasible and often physically impossible to provide adequate flood-control measures for every locality subject to flood damage. Hence, corrective and preventive measures must be taken in order to adjust man's activities on flood plains to the regimen of streams. Such measures, generally known as flood-plain zoning or planning, can help solve or ease many flood problems.
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> Fundamental to effective flood-plain planning is the recognition of the flood potential of streams and the hazards involved in flood-plain occupation. When necessary restrictions are imposed on communities in their flood-plain development, a marked reduction in flood damage is possible. Basic data on the regimen of the streams, particularly the magnitude of floods to be expected, the frequency of their occurrence, and the areas they will overflow, are essential to flood-plain planning. (6)

The Senate Select Committee on National Water Resources has recommended that the Federal Government in cooperation with the States should:

> Regulate flood plain use as a means of reducing flood damages whenever such regulation provides greater net benefits to the national economy than would be provided through other methods of preventing flood losses. Additional steps should be taken to delineate flood hazard areas so that the public will be aware of the risks involved in occupying flood plains. (7)

The documentation of flood events has long been an activity of the Geological Survey, acting through the Water Resources Division, Surface Water Branch. Descriptions of several hundred floods have been published in the water-supply paper series. Beginning in 1950, annual water-supply papers (WSP) have been published reporting on floods of each year. The first of this series was "Floods of 1950"; a similar title designates reports for subsequent years. Separate water-supply papers have been prepared for outstanding floods, as for the 1951 flood in Kansas, 1955 floods in northeastern States, and 1955-56 floods in farwestern States. It is interesting to note that the first Survey flood report, describing a flood on the Passaic River, Water-Supply Paper 88 (8) includes a topographic map of an area in the central basin of New Jersey that was inundated by floods of February-March 1902. Other water-supply papers showing flood inundated areas are:

1. WSP's 96, 147, and 162 (9-11) contain planimetric maps showing flooded areas at Kansas City (1903 and 1904); Trinidad, Colorado (1904); and Ithaca, New York (1905).
2. WSP 488 (12) shows on a 20-ft-interval contour map the area in San Antonio, Texas, flooded in September 1921.
3. WSP 838 (13) contains a sketch map showing overflow channels and areas in the vicinity of the mouth of the Ohio River, January-February 1937 flood.
4. WSP 843 (14) contains a sketch map showing areas flooded in the lower Sacramento River Basin, California, December 11-14, 1937.
5. WSP 1139 (15) shows areas inundated by July 1951 floods on Mississippi River in vicinity of St. Louis; along Kansas River from Junction City to the mouth; along Missouri River from Kansas City to the mouth; along Marais des Cygnes and Osage River above Lake of the Ozarks; along Neosho River and tributaries in Kansas; Kansas River at Kansas City; and in Kansas at towns of Lawrence, Manhattan, Ottawa, Salina, and Topeka.

6. WSP 1260-B (16) shows areas flooded by April 1952 floods; along Missouri River from Yankton, S. D., to Kansas City, Mo., between Bismarck and Mandan, N. D., at Pierre, S. D., at South Sioux City, Neb., and Sioux City, Iowa and at St. Joseph, Mo.; and flooding at Sioux Falls, S. D., by Big Sioux River.

7. WSP 1260-C (17) shows areas flooded by April 1952 floods on various streams; in Rock Island and Moline, Ill.; and Davenport and Bettendorf, Iowa; at Clinton, Dubuque and Muscatine, Iowa; at Carver, Chaska, Granite Falls, Mankato, Marshall, Montevideo, Moorhead, St. Paul, and Winona, Minn.; at Fargo, N. D.; and at La Crosse and Prairie du Chien, Wis.

8. WSP 1320-A (18) shows area flooded in June 1953 by Floyd River and major tributaries upstream from Sioux City, Iowa.

9. WSP 1420 (19) shows area inundated at Stroudsburg, Pa., on August 18, 1955.

Thus, it is noted that preparation of flood inundation maps is nothing new to the Survey. However, maps that just outline flooded areas are inadequate for modern needs. Engineering data are needed to evaluate the problem and to plan wise development of flood plains.

When man occupies a flood plain, he assumes a risk, and this risk must be evaluated if sound development is achieved. What is the chance of a flood reaching a particular location? The decision as to the kind of development and where to locate it will be governed by the chance of flooding. This chance can be evaluated by a knowledge of the frequency of floods of selected heights; thus, flood-frequency information is pertinent engineering data. Problems arising from the occupation of flood plains are economically important, and they make the development of sound flood-frequency methods imperative.

The subject of flood frequency has attracted many students of hydrology (20), but as yet there is no agreement that any one method is best. In view of this lack of agreement and of the fact that several methods appear to be of equal merit, the Survey has adopted and described (21) a method that has the practical advantage of simplicity. Significant features of the Survey method are as follows:

1. It is concerned with momentary peak discharges.
2. Recurrence intervals, T, are computed as $(n+1)/m$, where n is length of record and m is order number, the greatest being 1.
3. Curves are fitted graphically.
4. The mean annual flood is defined as the flood having a recurrence interval of 2.33 years.
5. A means is provided for computing flood frequencies of natural flow on any stream, gaged or ungaged.

Following standard Survey methods, regional flood-frequency reports have been prepared, mostly in cooperation with State highway departments, for 31 States and the Delaware River Basin (22); these processed reports are available from the Washington, D. C. office or from the Survey Surface Water office in the appropriate State.

Regional flood-frequency reports are being prepared or are in process of publication in a series of water-supply papers that will cover conterminous United States. Each volume will be for a part, each covering an area as now used for publication of gaging station records. These reports will contain regional flood-frequency curves plus a tabulation of flood peaks for gaging stations in the area. The first of these should be released soon and the others will follow at intervals over the next two or three years. The reports will be titled "Magnitude and Frequency of Floods in the United States" with a further designation, for example, "Part 4, St. Lawrence River Basin." A complete list is as follows:

1. WSP 1671. Part 1-A. North Atlantic Slope Basins, Maine to Connecticut.
2. WSP 1672. Part 1-B. North Atlantic Slope Basins, New York to York River.
3. WSP 1673. Part 2-A. South Atlantic Slope Basins, James River to Savannah River.

4. WSP 1674. Part 2-B. South Atlantic Slope and Eastern Gulf of Mexico Basins, Ogeechee River to Pearl River.
5. WSP 1675. Part 3-A. Ohio River Basin except Cumberland and Tennessee River Basins.
6. WSP 1676. Part 3-B. Cumberland and Tennessee River Basins.
7. WSP 1677. Part 4. St. Lawrence River Basin.
8. WSP 1678. Part 5. Hudson Bay and Upper Mississippi River Basins.
9. WSP 1679. Part 6-A. Missouri River Basin above Sioux City, Iowa.
10. WSP 1680. Part 6-B. Missouri River Basin below Sioux City, Iowa.
11. WSP 1681. Part 7. Lower Mississippi River Basin.
12. WSP 1682. Part 8. Western Gulf of Mexico Basins.
13. WSP 1683. Part 9. Colorado River Basin.
14. WSP 1684. Part 10. The Great Basin.
15. WSP 1685. Part 11-A. Pacific Slope Basins in California except Central Valley.
16. WSP 1686. Part 11-B. Central Valley of California.
17. WSP 1687. Part 12. Pacific Slope Basins in Washington and Upper Columbia River Basin.
18. WSP 1688. Part 13. Snake River Basin.
19. WSP 1689. Part 14. Pacific Slope Basins in Oregon and Lower Columbia River Basin.

A flood-frequency curve applies to a specific location; to be useful, it must be transferred along a stream to all locations in the study area. This transfer is achieved by developing flood profiles through the reach of the channel being investigated. These profiles may be defined by a survey made soon after a flood or by a flood routing process.

The task force on Flood Plain Regulations, Committee on Flood Control, Hydraulics Division, ASCE, states, in reference to data to be developed:

> The information to be collected and developed falls generally into two categories. First, topographic; and second, hydrologic....As a minimum, the report should incorporate a typical flood hydrograph, typical stream and valley cross sections, water surface profiles and overflow maps for selected floods, a tabulation and chart giving information on known floods, and typical flood photographs. (23)

Damage and destruction caused by the severe floods of August 1955 in the Northeastern States and of December 1955-January 1956 in the far Western States revived interest in flood problems. The Federal Flood Insurance Act of 1956, Public Law 1016, gave encouragement to the establishment of zoning restrictions. A manual for the guidance of those engaged in flood-plain planning, titled "Hydraulic and Hydrologic Aspects of Flood-Plain Planning," was prepared through a cooperative arrangement between the Geological Survey and the Commonwealth of Pennsylvania and was published as Survey Water-Supply Paper 1526 (6).

As an illustration of how flood information can be presented on a map, and to develop techniques, the Survey made pilot studies in several areas and published the results as map reports. These were published as Hydrologic Investigations Atlases, as have been all such Survey reports (24). These reports, usually on one sheet, show on a topographic map base the area inundated by a flood. In addition, there is shown a histogram of floods, a flood-frequency curve, flood profiles, photograph of area during flood, and a short text. The variety of conditions covered are as follows:

1. A large, single area covered by specific flood (HA-14).
2. Several separate areas on flat terrain covered by a specific flood (HA-39).
3. Flooded area shown on a photomosaic (HA-40).

4. Areas in a city covered by floods of selected frequency (HA-41).
5. Foothill and tidewater inundation (HA-54).
6. Inundation by ocean tides (HA-65).

COOPERATIVE PROJECTS

State and local interest in flood inundation problems is evidenced by the fact that 13 States, local agencies, and the Commonwealth of Puerto Rico have contributed funds for cooperative projects with the Survey.

Project Descriptions

General Description.—A report for an area consists of a map showing the area inundated by a specific flood, plus a histogram of flood peaks, a flood-frequency curve, and flood profiles. A short text explains the exhibits.

Some projects involved reporting on a specific event, whereas other projects have added a program for obtaining field data to provide information for making a more accurate report at a later time. Several projects have been for one or two maps, whereas others provide a series of maps covering large areas.

Colorado.—Boulder County cooperates in a continuing project to outline areas probably inundated by floods of selected frequency. The first study was of the City of Boulder, the second was an adjacent area in the county, and other studies are being made at population centers.

Illinois.—A five-year program is being conducted in cooperation with the Northeastern Illinois Metropolitan Area Planning Commission. The program provides for completion of forty-four 7½-min quadrangle sheets in six counties in the Chicago area. Work is being conducted from an office at Oak Park, Ill. As work is completed in each quadrangle, an open-file report is prepared for the cooperator, pending publication of data as an Hydrologic Investigations Atlas. These maps are used by local governmental agencies to help plan development of a rapidly growing suburban area. The reports have been found useful to county and city officials concerned with zoning, forests, parks, streets and roads, and other activities.

New Jersey.—A continuing program provides for progressive mapping in the Raritan River Basin. Open-file reports are made pending atlas publication.

Ohio.—Immediately after the great January 1959 floods, the State of Ohio, acting through the Department of Natural Resources, provided funds for mapping flooded areas in 12 cities. Publication of the last map of the project is imminent.

Puerto Rico.—Following the August 1961 floods, the Commonwealth provided cooperative funds to prepare flood studies of six areas. Considerable work was done by Commonwealth officials surveying flood boundaries at many locations. The main interest appears to be in problems related to flood zoning and flood protection works.

Tennessee.—The City of Chattanooga provides cooperative funds for a continuing study on Chattanooga Creek. Gages have been installed and cross-sections determined for obtaining field data in a very complex area. Part of the study consists of flood routing by electronic computer.

Texas.—The City of Dallas provides cooperative funds for a continuing study on White Rock Creek and its tributaries. Field data are being obtained at selected sites to aid in the study.

Virginia.—An extensive, almost county-wide, program is being conducted in cooperation with Faixfax County, in an area rapidly changing from rural to suburban and urban. Many stage and precipitation gages have been installed. A 1- or 2-ft-interval contour map was made of about 80 miles of stream channels; stream cross-sections are taken from these maps. Extensive flood routing by electronic computer is involved. The newly tried features of this program make it a "pilot project."

Project Reports

California.—Floods in Almeda Creek Basin at Fremont: report published as Hydrologic Investigations Atlas-54, shows areas between foothills and San Francisco Bay that were flooded in December 1955 and April 1958.

Floods near Fortuna: HA-78 shows area along lower Eel River that was flooded in December 1955.

Floods on San Dieguito River and its tributaries, Santa Ysabel Creek and Santa Maria Creek, in San Diego County. (Report to be published by State Cooperator.)

Colorado.—Floods at Bounder: HA-41 shows areas in Boulder that would be inundated by floods of 25- 50- and 100-yr recurrence intervals.

Floods on Boulder Creek below Boulder (U. S. Geological Survey open-file report).

Floods on St. Vrain and Lefthand Creeks at Longmont (open-file report).

Florida.—Map showing area along Hillsborough River at Tampa flooded in March 1960 (HA-66).

Illinois.—To date six Hydrologic Investigations Atlases have been published for the Chicago area: (1) Arlington Heights Quadrangle (HA-67), (2) Aurora North Quadrangle (HA-70), (3) Near Chicago Heights (HA-39) financed by Federal funds, (4) Elmhurst Quadrangle (HA-68), (5) Highland Park Quadrangle (HA-69), and (6) Wheeling Quadrangle (HA-71).

In the process of publication are maps for nine other quadrangles: (1) Harvey (HA-90), (2) Hinsdale (HA-86), (3) Joliet (HA-89), (4) Libertyville (HA-88), (5) Palatine (HA-87), (6) Park Ridge (HA-85), (7) Geneva (HA-142), (8) Lombard (HA-143), and (9) Wadsworth (HA-144).

As work is completed in each quadrangle, an open-file report is prepared for the cooperator pending publication of the atlas.

Iowa.—Floods on Des Moines River, Raccoon River, Walnut Creek, and Fourmile Creek at Des Moines, in 1947, 1954, and 1960 (HA-53).

Kansas.—Floods in the Arkansas River Basin at Wichita in 1942, 1944, 1951, 1955, 1957, and 1960 (HA-63).

Floods of the Kansas River, Topeka, in 1935 and 1951 (HA-14).

Louisiana.—Floods of 1962 near Baton Rouge (HA-126).

Michigan.—Floods on Clinton River, North Branch and Middle Branch of Clinton River and Harrington Drain, Mount Clemens (HA-59).

Mississippi.—Floods on Pearl River at Jackson in 1961 (HA-127). An open-file report was prepared June 1963.

New Jersey.—Atlantic Ocean tidal floods of 1960 and 1962 on Absecon Island and Atlantic City (HA-65).

Extent and frequency of inundation of flood plain in the vicinity of Bound Brook in Somerset and Middlesex Counties (open-file report).

Extent and frequency of inundation of Millstone River Flood Plain in Somerset County (open-file report).

Extent and frequency of inundation of flood plain near Raritan (open-file report).

Extent and frequency of inundation of flood plain in the vicinity of Somerville and Manville (open-file report).

Ohio.—Floods on Tuscarawas River and Wolf Creek at Barberton (HA-49).

Floods on Middle Branch and East Branch Nimishillen Creek at Canton (HA-50).

Floods at Chillicothe (HA-45).

Floods at Circleville (HA-48).

Floods on Scioto River, Olentangy River, and Alum Creek at Columbus in January 1959 (HA-52).

Floods on Sandusky River at Fremont in 1959 (HA-47).

Floods on the Kokosing River, Dry Creek, and Center Run at Mount Vernon in 1959 (HA-40). Flooded area shown on photomosaic, pending completion of topographic map.

Floods on Licking River, North Fork and South Fork of Licking River, and Raccoon Creek at Newark in 1959 (HA-44). Flooded area shown on photomosaic, pending completion of topographic map.

Floods at Springfield in 1913 and 1959 (HA-43).

Floods on Mahoning River at Warren in 1959 (HA-51).

Floods on Crab Creek at Yongstown in 1959 (HA-56).

Floods at Zanesville (HA-46).

Pennsylvania.—Floods on the Susquehanna River at Harrisburg in 1936 (HA-57).

Puerto Rico.—Floods at Bayamón and Cataño (HA-77).

Floods at Toa Alta, Toa Baja, and Dorado (HA-128).

Reports are in preparation for Río Cibuco, Río Grande de Arecibo, Río Grande de Manití, and Humacao.

Tennessee.—Floods on Chattanooga Creek at Chattanooga (open-file report) (25).

Texas.—Floods on White Rock Creek above White Rock Lake at Dallas (open-file report).

Two flood-map reports prepared for areas in New Jersey were put to immediate use. (1) Data in the Millstone River report were used by the State to position flood-marker signs. These show the level of the 1938 flood, one of the highest known on this stream. The program of sign erection is one part of a comprehensive plan authorized by the 1962 New Jersey Legislature to "avoid pressure for increased governmental expenditures for the construction of flood control structures to protect property unwisely located in flood-hazard areas." (2) Atlantic City flood-map information was used in a study of design criteria for an expressway into Atlantic City. Minimum grade elevations across four miles of tidal marsh were determined primarily on data and frequency relations of the flood-map report (26).

In another State, the design of a highway crossing was influenced by a flood-inundation study. On a contour map, the Survey report showed the areas of a town that would be inundated by a flood of selected frequency: (a) with no bridge and approach fills in place, and (b) for several different bridge designs. The differences between the two showed areas in the town that would be inundated due to construction of bridge and approaches.

Projects of the type described here are conducted by district offices of the Surface Water Branch, Water Resources Division of the Geological Survey. Consultative service is provided by the Washington, D. C. office staff. District offices are located in almost every State, usually at the State Capitol. Office staffs remain relatively permanent, thus, they become familiar with local problems and acquire knowledge needed for consideration of peculiar local situations.

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HA-41, Floods at Boulder, Colorado.
HA-43, Floods at Springfield, Ohio.
HA-44, Floods at Newark, Ohio.
*HA-45, Floods at Chillicothe, Ohio.
*HA-46, Floods at Zanesville, Ohio.
HA-47, Floods at Fremont, Ohio.
*HA-48, Floods at Circleville, Ohio.
HA-49, Floods of Barberton, Ohio.
HA-50, Floods at Canton, Ohio.
HA-51, Floods at Warren, Ohio.
HA-52, Floods at Columbus, Ohio.
HA-53, Floods at Des Moines, Iowa.
HA-54, Floods at Fremont, California.
HA-56, Floods on Crab Creek at Youngstown, Ohio.
HA-57, Floods at Harrisburg, Pennsylvania.
HA-59, Floods at Mount Clemens, Michigan.
HA-63, Floods at Wichita, Kansas.
HA-65, Tidal Floods, Atlantic City and Vicinity, New Jersey.
HA-66, Floods at Tampa, Florida.
HA-67, Floods in Arlington Heights Quadrangle, Illinois.
HA-68, Floods in Elmhurst Quadrangle, Illinois.
HA-69, Floods in Highland Park Quadrangle, Illinois.
HA-70, Floods in Aurora North Quadrangle, Illinois.
HA-71, Floods in Wheeling Quadrangle, Illinois.
HA-77, Floods at Bayamón and Cataño, Puerto Rico.
HA-78, Floods near Fortuna, California.
*HA-85, Floods in Park Ridge Quadrangle, Illinois.
*HA-86, Floods in Hinsdale Quadrangle, Illinois.
*HA-87, Floods in Palatine Quadrangle, Illinois.
*HA-88, Floods in Libertyville Quadrangle, Illinois.
*HA-89, Floods in Joliet Quadrangle, Illinois.
*HA-90, Floods in Harvey Quadrangle, Illinois.
*HA-104, Floods on Raritan and Millstone Rivers, New Jersey.
*HA-126, Floods near Baton Rouge, Louisiana.
*HA-127, Floods on Pearl River at Jackson, Mississippi.
*HA-128, Floods at Toa Alta, Toa Baja and Dorado, Puerto Rico.
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