UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NATIONAL PROGRAM FOR MANAGING FLOOD LOSSES

GUIDELINES FOR PREPARATION, TRANSMITTAL, AND DISTRIBUTION OF FLOOD-PRONE AREA MAPS AND PAMPHLETS

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by

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UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

For additional information write to:

Chief Hydrologist
U.S. Geological Survey
409 National Center
Reston, Virginia 22092

CONTENTS

CONTENTS - (continued)

ILLUSTRATIONS

NATIONAL PROGRAM FOR MANAGING FLOOD LOSSES

Guidelines for Preparation, Transmittal, and Distribution of Flood-Prone Area Maps and Pamphlets

By

George W. Edelen, Jr.

I. Introduction

This report presents information to assist Water Resources Division offices in preparing flood-prone area maps and pamphlets. Background and history of the program, legal authority, analytical techniques, printing, distribution, and other operational details are discussed.

The instructions and advice in this report should be considered primarily as guidelines. In general, the instructions for map bases, lettering sizes, and reproduction requirements must be followed quite closely whereas instructions pertaining to techniques of delineating flood boundaries may require liberal interpretation in unusual situations. Information concerning map preparation and reproduction is available from the Water Resources Division Publications Unit, and that related to technical problems of flood delineation can be obtained from the Surface Water Branch and the Regional Surface Water Specialists.

The 89th Congress (1966) in House Document 465 recommended preparation of flood-prone area maps to assist in minimizing flood losses by quickly identifying areas of potential flood hazards. The intent of Congress obviously was to obtain a nationwide "reconnaissance level" of information quickly. A basic premise of the recommendation is that a hydrologist quickly can identify potential flood areas from his assessment of readily available data and from skills obtained through experience. Although the greatest confidence cannot be placed in the exact position of the flood boundaries, the map serves as a general warning of potential flood hazards and as a basis for setting priorities of future detailed studies.

House Document 465 suggested that the U.S. Geological Survey prepare the flood-prone area maps, in recognition of the competent staff of hydrologists who are familiar with local flood conditions in areas throughout the United States. In 1968 maps showing "approximate areas occasionally flooded" were prepared. In the 1969 fiscal year the project was changed to delimit the approximate boundaries of the 100-year flood. This change was undertaken to assist the Federal Insurance Administration (FIA) which was charged with identification of the Nation's flood plains in the August 1968 flood insurance legislation. The FIA has defined the flood plain as the area subject to inundation by a 100-year flood.

Flood-prone area maps produced to date have been well received by individuals, private organizations, and local, State, and Federal governmental agencies. The maps have been particularly useful during floods in planning the evacuation of areas likely to be flooded.

At the end of 1976 fiscal year flood prone areas had been delineated on more than 12,000 quadrangles.

II. Objective and scope of project

1. Direction

House Document 465 of the 89th Congress (1966) recommended a three stage program to delimit major flood hazards: (a) listing of towns and streams with flood problems, (b) outlining the flood plain on maps or aerial photographs, and (c) accelerating the present program of flood-hazard information reports. The U.S. Geological Survey was assigned primary responsibility for item (b). The U.S. Army Corps of Engineers has completed item (a) and has accelerated its program relative to item (c).

The objective of the project is to quickly identify areas subject to flooding, without regard to detailed accuracy that will be provided at a later date under item (c). Areas inundated by the 100-year flood on all streams will be outlined on topographic maps or on photomosaics.

The scope of the project includes all areas of the United States where flooding from streams, lakes, and tides is a problem. Priority is given to areas in and near the 4,000 urban places with flood problems as listed by the Corps of Engineers under item (a) and to those communities that are interested in participating in the Federal Flood Insurance Program. In addition, flood prone areas will be identified in rural areas where bottom lands subject to flood damage are extensively farmed. Following this, maps will be produced for areas in the public domain where management or planning decisions are required and for undeveloped areas with recreational potential.

2. Distribution of maps

Local people must be alerted to areas of potential flooding to meet the primary objective of the Flood Prone Area Mapping Program. Maps showing flood-prone areas are distributed to Federal and State flood-control agencies, planning commissions, civil defense groups, lending-agency officials, public officials, and to the local citizenry. Reaching the concerned people is a substantial task that will involve positive action and planning at the WRD District level. Press releases, made from time to time to coincide with the completion of groups of maps, are an integral part of this program. Releases must be sent to major news media units and should be sent to as many county newspapers as is practical.

The maps are open-file releases. Copies of flood-prone area maps are available upon request to the appropriate district office.

Copies of published maps are to be routinely furnished as completed, to the following:

Chief, Engineering Division
Federal Insurance Administration
Department of Housing and Urban Development
HUD Building
Washington, D.C. 20410

3. Limitations-

The scope of this project does not include areas for which flood-plain information reports are already available or are being prepared by the Corps of Engineers or other agencies. WRD district offices are expected to maintain close contact with other agencies in order to be aware of all plans for preparing flood-plain reports.

Omit from the program, quadrangles in which very large areas are protected from flooding by major levee systems (areas along the lower Mississippi River, for example).

Generally, delineation of flood-prone areas narrower than 400 feet is not meaningful at scale 1:24,000, using recommended line width. See item V-1-B (page 7).

Where the quadrangle map extends beyond the borders of the United States into a foreign country (e.g. Canada or Mexico) do not delineate flood-prone areas in the foreign country. Add appropriate stick-on note such as "ONLY FLOOD PRONE AREAS IN THE UNITED STATES ARE SHOWN."

III. Work Plan

1. What is to be done

Lines marking the boundaries of flood plains of streams will be drawn on 7 1/2' or 15' topographic maps or photomosaics. The inundated areas will be marked "FLOOD PRONE AREA". The maps will be released to the open file and copies of individual maps will be distributed to local governmental agencies and to the public on request. The stock of flood-prone area maps will be kept in District offices of the Water Resources Division. Where part of a quadrangle sheet is covered by a detailed flood information report, the area will be identified and reference to the detailed report will be given.

A brief text will be shown on each map. The text will describe the need for flood-plain management and the nature, accuracy, and intended use of the information on the map.

Reliability of the depicted flood-plain boundaries will be a function of the flood information available, and of the scale and contour interval of the maps. About 75 percent of the 4,000 urban places with flood problems are covered by 7 1/2' topographic maps and an additional 18 percent by topographic maps in the 15' series.

2. How it is to be done

A. Data sources

Initially, House Document 465 should be reviewed carefully. It would be worthwhile to contact offices of other Federal, State, and local agencies to investigate ongoing and planned detailed flood studies, and to determine the availability of any data that might be useful in flood-prone area mapping work. It will be necessary for adjacent districts to reach an agreement on which district is to do the work on those maps that cover areas in both jurisdictions.

B. Specifications

The work of mapping flood plains will be carried out in District offices and will be governed by the following general specifications:

(1) Conform to the program discussed in House Document 465.

(2) Priority will be given to mapping populated areas where topographic mapping is available in the 7 1/2 or 15-minute series. About 93 percent of urban areas is mapped in one or the other of these series.

(3) Results of this project are to be shown on topographic maps having scales ranging between 1:24,000 and 1:62,500 or on available aerial photomosaics (photo indices).

C. Extent of mapping

Any quadrangle selected for mapping will be completely mapped, including both the rural and urban areas. Flood plains will be delineated at least for all streams having drainage basins larger than the following:

(1) Urban and suburban areas where the upstream drainage area exceeds 25 square miles, and preferably for much smaller streams.

(2) Rural areas in humid regions where the upstream drainage area exceeds 100 square miles.

(3) Rural areas in semiarid regions where the upstream drainage area exceeds 250 square miles.

IV. Techniques

The scope of the House Document 465, Recommendation 1b, requires that the flood plains be delineated rapidly and efficiently. Highly accurate flood-mapping methods that make use of refined techniques, accurate field surveys, backwater computations, and detailed frequency analyses are too costly and time consuming for this project. In contrast this series of flood-prone area maps will often be defined from less data, by techniques that produce boundaries in which there is a lower degree of confidence.

In general, the requirements of Recommendation 1b must be met with office work from information already available. No field work is needed.

These instructions outline four methods useful for delineating flood-prone areas from recorded information. Regional stage-frequency relations will be the method used for most quadrangles. Because of the variability of available information, it is likely that several of these methods will be required to complete the project in any District.

The four methods commonly used to estimate the 100-year flood boundaries are:

1. Regional stage-frequency relations

Most districts defined regional stage-frequency relations to the 50-year level for use in the 1969 program. Only a small amount of effort should be required to extend these relations to the 100-year level. Methods of defining regional stage-frequency relations were described by Thomas in Professional Paper 475-D and Gann in Professional Paper 600-D. See items VIII-3 and VIII-2 (page 18). Discharge-frequency relations can readily be defined from the Nationwide Flood Frequency reports--Magnitude and Frequency of Floods, Water Supply Papers (WSP) 1671 through 1689.

Average relations between flood depth, flood discharge, and frequency of occurrence have been defined for New Jersey (see New Jersey Water Resources Circular 14 previously sent to each district). Comparable relations can probably be defined for other areas. If so, they can provide information to define flood profiles and flood boundaries along streams shown on topographic maps but for which no local flood information exists.

For this project a modification of the New Jersey method will increase the utility of defined relations. It is suggested that the difference between stage of a 100-year flood and stage of median (50% duration) discharge be determined for all natural flow gaging stations having flood records of adequate length to define a flood-frequency curve. The regional stage-frequency curve can then be defined by plotting these 100-year flood heights against an estimating variable, preferably drainage area, or perhaps mean annual flood discharge. To develop relations of adequate accuracy, it may be necessary to define separate relations for local areas, geologic provinces, or other areal groupings.

To delineate flood-prone areas by this method, it is necessary to assume that the contours on a topographic map are exact and intersect streams at about the stage of median flow. A normal-flow profile can then be determined and drawn from measurements on the map. For selected sites along this profile the 100-year flood stage is determined from the regional stage-frequency curve and a flood profile drawn. Elevations along the 100-year flood profile can then be utilized to define the flood boundaries by interpolation on the topographic map.

Districts that have drainage area compilation reports will probably find this method the most efficient for delineating flood-prone areas along streams for which no flood information is available.

2. <u>Profiles of theoretical floods of specified frequency</u>

Profiles of floods of specified frequency are sometimes available from other governmental agencies. These profiles commonly show the 25-year, 50-year, and "Standard Project" floods (SPF). The SPF is often close to a 100-year recurrence interval but this should be checked. An increment of elevation, based on the shape of the stage-discharge relation, can be added to the 50-year profile to elevate the 100-year flood profile satisfactorily. A constant increment can be used over a long reach.

3. <u>Profiles of observed floods</u>

Profiles of past floods can sometimes be constructed from high-water marks. To use these profiles it is necessary to establish the recurrence interval of the flood and then adjust the profile to approximate the 100-year profile by using an increment of elevation based on the shape of the stage-discharge relation. For the accuracy requirements of this project it is usually satisfactory to assume that the recurrence interval of the observed flood is a constant for a considerable length of river reach.

Elevations and locations of high-water marks of past floods provide information for defining a flood profile. Where topographic maps are available, the profile can be transformed into flood boundaries by interpolation between contours. Distance along the stream channel, necessary for defining the profile, should be measured upstream from the mouth.

Several thousand miles of flood profiles can be developed from information published in Geological Survey flood reports. A great deal of additional floodmark information exists in engineering offices of Federal, State, and local governments.

4. Aerial photographs of flooding

To use aerial photographs of floods it is necessary to first construct a profile from information picked from the photographs, and determine the recurrence interval of the flood. The profile may then be adjusted to approximate the 100-year profile.

Flood plains usually can be defined by viewing pairs of photographs through a stereoscope. The edges can be marked directly on the photograph and then transferred to a map or photomosaic base with proportional dividers. Field checks may be necessary with this method. Complete photographic coverage of the United States is available and can be obtained from the U.S. Geological Survey, National Cartographic Information Center, National Center, Mail Stop 507, Reston, Virginia 22092.

V. Flood-prone area map

1. Map preparation

A. General

The maps produced should conform closely to the attached sample. Flood boundaries are to be drawn directly on a paper print of a 7 1/2' or 15' topographic base map with a No. 4 RAPIDOGRAPH pen or its equivalent in order to show a broad line. Every effort should be made to obtain for a base map the sheets that do not contain a green woodland tint. Although the reproduction process can filter out much of the green tint, the filtering process causes a loss of quality in the finished map. The map title, text, explanatory information, and the commonly used notations for indicating flood-prone areas are available as stick-on materials. Additional notes will be required on some maps and may be applied by lettering with a Leroy pen or by typing on white stick-on material or Scotch tape No. 810.

B. Minimum width of flood-prone area

Significant flood-prone areas wider than 400 feet will be delineated.

The width of the No. 4 RAPIDOGRAPH pen recommended for delineating flood boundaries is 0.043 inch. In practice, this pen produces an ink line about 0.05 inch wide on a paper print. At map scale 1:24,000 0.05 inch represents 100 feet. A flood prone area 400 feet wide, represented on the map by two 0.05-inch inked lines enclosing a 0.10-inch open space (total width, 0.20 inch) is about the minimum limit for showing meaningful flood-prone area information on 1:24,000 scale maps.

C. Continuity of flood boundaries

Care must be taken to maintain accurate continuity of flood-prone area boundaries at edges of adjacent quadrangles. The boundaries must match at quadrangle edges.

D. Stick-on type materials

Standard texts, titles, and a variety of appropriate notes have been prepared as "stick-on" materials. The stick-ons can be obtained directly from Chief, Current Conditions Group, U.S. Geological Survey, National Center, Mail Stop 419, Reston, Virginia 22092.

Skill in attaching the stick-on material can be readily acquired with a little practice. Note that the plastic covering on the front <u>must be removed</u>. It is best to start the separation from a corner on the back side by using a sharp knife such as "Exacto". When a small area has been separated, snip off a corner of the plastic with scissors, and then attach the stick-on (including the plastic covering) firmly to the map by use of a plastic or bone burnishing tool. If no burnishing tool is available, any smooth, hard object will serve the purpose provided that the plastic cover has not previously been removed. After the material has been firmly attached, it is easy to remove the plastic by starting at the chipped corner. Information available in stick-on form is shown on pages 29 and 30 and is listed below:

(1) A standard text in two forms to be attached in the lower left corner of the full-scale edition print of the topographic map. The text was arranged so that the printed block will cover the undesired printed matter on the map. The longer block should be suitable for 7 1/2-minute quadrangles, and the shorter block for 15-minute quadrangles. It will not matter if the bottom of the text extends below the margin of the map, but the width should be sufficiently short to allow the map scale to show. If the text does extend below the map margin, a piece of paper should be attached to the map to avoid mutilation of the stick-on material, during handling.

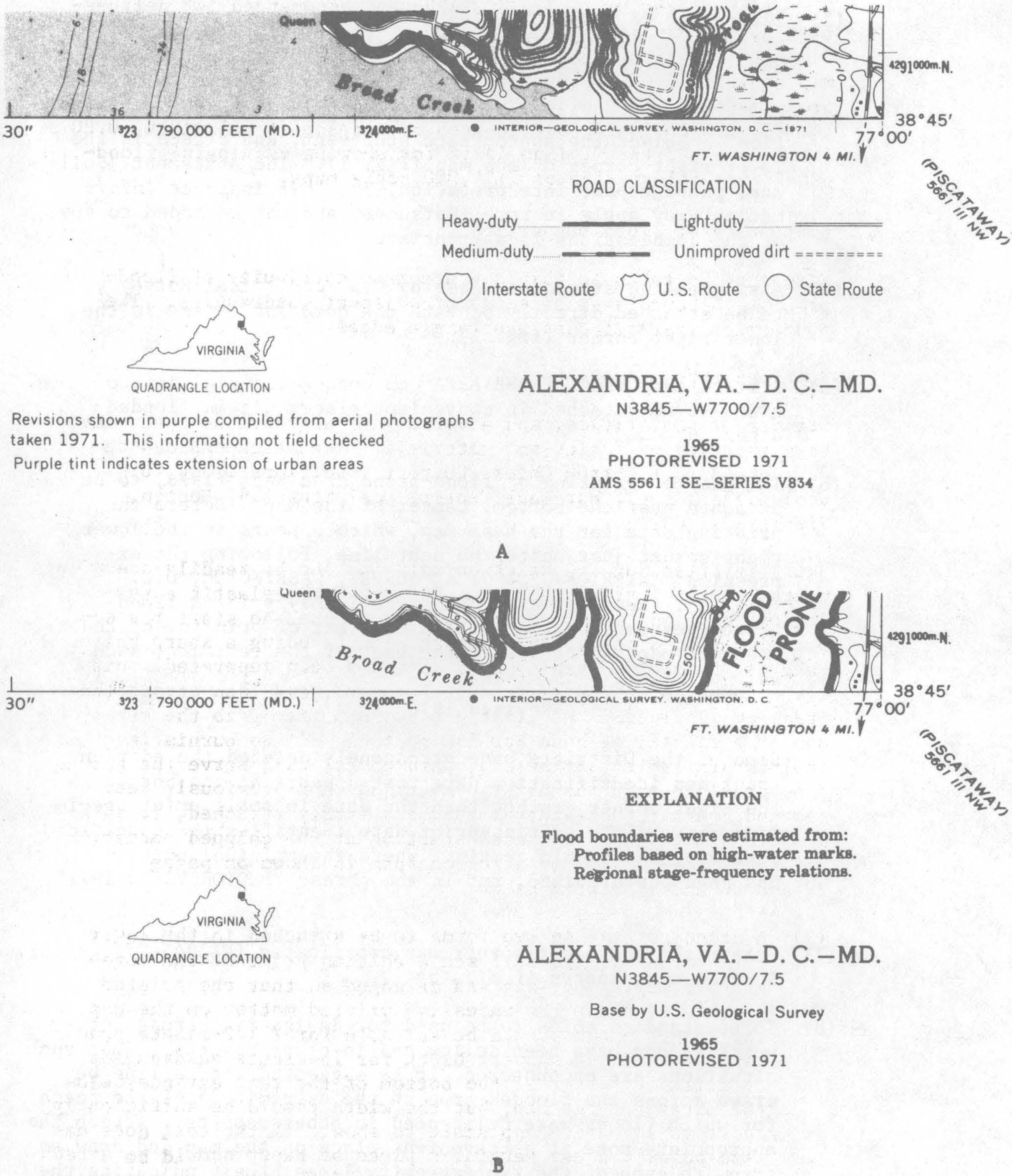

Figure 1.-Right bottom margin of typical 7 1/2-minute, 1:24,000 scale, USGS topographic quadrangle map.

A. As published.

B. Showing stick-on information and deletions required on flood-prone area maps.

(2) Title "MAP OF FLOOD PRONE AREAS", to be placed at the top of the map. Select from the two sizes, the title that is appropriate for the size of the topographic map.

(3) Six combinations of statements to be used under "Explanation". Select the appropriate statement, and attach in the lower right corner of the map (fig. 1). The statement "Soil map, photographic interpretation, or other indirect information" may apply in rare instances, and can be added to any of the combinations if appropriate.

(4) A single-line statement "Base by U.S. Geological Survey", to be attached directly beneath the quadrangle name in the lower right corner (fig. 1).

(5) A statement "FLOOD PRONE AREA" on opaque material in two sizes to be attached in convenient places within flooded areas.

(6) The year of printing of flood-prone area maps (1976) to be attached near the bottom, center of the map. Delete the printing date for the base map, which appears in the lower right corner just below the neat line, following the expression "INTERIOR-GEOLOGICAL SURVEY, WASHINGTON, D.C." (fig. 1). Revised versions of previously printed flood-prone area maps should contain the year of printing of the previous map together with the year of the revision, such as:

1969
Revised 1976

Some of the Districts have erroneously deleted the edition print map identification date that appears at the bottom in the right corner, rather than the date in small print specified above. The edition-print date identifies the specific base map, and should remain. Where the original edition has been photorevised, retain the phrase "PHOTOREVISED 1971". (fig 1.)

(7) Retain the southeast corner map coordinates (N 3845-W7700/7.5). Furnish coordinates if missing.

(8) Three standard notes to be used for designating areas for which floods have been delineated in other reports. When such situations are encountered, it is suggested that a line be drawn across the flooded area at the extremities of the reach for which floods were delineated in other reports. Attach the appropriate note at a convenient place on the map and draw an arrow to each of the two extremity lines, thus indicating the extent of delineation in the other report.

(9) On many base maps, there is a statement at the bottom, center, which reads, in general, "This map complies with national map accuracy standards - for sale by U.S. Geological Survey, etc.". Such a statement applies only to the base-edition print and not to the finished map that we will produce; therefore, it should be deleted.

E. Placement of stick-on type.

Care should be used in placing stick-on type on the map to avoid covering significant map information.

The "FLOOD PRONE AREA" stick-ons may be appropriately placed within the flood area where there is no interference with basic map information. Otherwise the stick-ons should be placed outside the flood area with arrows leading to the affected area.

F. Map-color interference

The solid red overprint used to identify urban areas and green overprint indicating vegetation on topographic maps show up in various tones of gray on the printed flood-prone area maps. Special photographic treatment is used in printing to screen the red and green.

All stick-on material now furnished is opaque. Transparent stick-ons frequently produce unsatisfactory results in photography because of interference of base linework and colors.

2. Special notes

Levees

The maps show boundaries of the 100-year flood under natural conditions without regard to protection afforded in some cases by levees. The statement "FLOOD PRONE AREAS IF LEVEES ARE BREACHED" has been discontinued.

The following instructions apply in areas protected by levees:

(1) Do not include in the program quadrangles on which large areas are protected from flooding by major levee systems, for example, the areas along the lower Mississippi River.

(2) For all quadrangles included in the program on which there are levees, continue to plot the boundaries of the 100-year flood under natural conditions, and use one of the following notations, where appropriate.

a. Flood-prone area prior to levee construction.

b. Flood-prone area prior to levee construction. Information on levees in this area available from _______________.

c. Flood-prone area prior to levee construction. Levees designed by _________________ to protect against ____________ year flood.

The use of notations b or c is preferable. Information on levees should be sought from the agency responsible for the design. The headquarters office of the Corps of Engineers has assured us of the cooperation of their district offices in providing this information on levees which they have designed.

3. <u>Printing notes</u>

A. Map dimensions

Maps are printed on paper 22 x 27 inches. The presses used can handle 4 quadrangles at one time, provided the length and width of the maps, including at least 1/4-inch white margins all around, do not exceed these dimensions. Larger quadrangles must be trimmed to maximum allowable size.

B. Margin

Make sure that there is at least 1/4 inch white margin between the last line of stick-on text and edge of map at bottom.

If the stick-on text is too long, that is, the overall measurement of the map exceeds 27 inches because of a long text, then transfer the last few lines of text to form a second column. If practicable aline the last line of text of second column with the last line of text of first column. Leave half an inch of space between the two columns.

C. Correction paint

Avoid using white paint around patches. This extra effort is unnecessary. Some of the white paint will have peeled off by the time the map goes to press and the peeling interferes with the printing process.

4. General

A. Reviews and transmittal

All maps should be sent preferably in flat boxes, by registered mail (do not use certified mail) to the following office:

Chief, Current Conditions Group, WRD
U.S. Geological Survey
National Center, Mail Stop 419
Reston, Virginia 22092

Review of the maps is a district responsibility. The maps must be in final form technically, cartographically, and editorially. No additional work will be done on the maps after transmittal from the district.

B. Director's approval

The finished flood-prone area maps will be open-file releases for which blanket approval has been obtained from the Director; therefore it is not necessary that they be routed through the usual channels required for other reports.

The Geohydrologic Map Editor, Publications Unit, Reports Section, WRD, gives final review and authorizes printing of the maps by the Publications Division, and arranges for distribution of the maps to WRD District offices.

C. Printing

Publications Division will print and send to the District office 200 black and white, full scale copies of each flood-prone area map for free distribution. The photographic negative used in the printing process will also be sent to the District office. Other options for map reproduction may also be arranged.

VI. Pamphlets

In addition to the full scale quadrangle maps, attractive information pamphlets that describe the program and the maps will be prepared for selected cities and towns that have significant present or potential flood problems. The pamphlets will be printed, in color, in large quantities (1,000) for general distribution to the public. It is proposed to place them in public buildings such as post offices, banks, and libraries. The folders will cost more to print than the larger maps, and available funds are not adequate to permit a pamphlet for each large map. Pamphlets are prepared only for quadrangles where flood prone area maps have been completed.

One side of the pamphlet will contain a standard text that will be prepared through National Headquarters. The other side will contain a 7-inch by 9 1/2-inch cut-out part of the large map, and a short text applicable to the area of the cut-out. The district is requested to select from the maps prepared, urban places with flood problems. The number of places selected should not exceed a third of the number of maps. An appropriate area 7 inches by 9 1/2 inches should be cut out and pasted on a plain 8-inch by 10 1/2-inch sheet of paper, by the districts. The flooded area of the cut-out need not be colored; this will be done professionally in National Headquarters. An easy way to prepare the cut-out is to trace the selected area on a second topographic map. The district is also requested to prepare a short text applicable to the cut-out area, type it in a space 3 1/2 inches by 8 inches on a plain sheet of paper, and attach the text on the right of the cut-out map. The overall dimensions of the pamphlet should be 8 inches by 14 inches.

VII. Questions and answers

Because of questions arising from previous experience, the following questions and suggested courses of action are listed:

1. Q. What should be shown in areas protected by levees?

   A. Show a solid line along the levee (located from information on maps, not by field investigations) as the boundary of the 100-year flood. Show a broken line for the boundary of natural-condition flooding. Use an appropriate note in the protected area as shown in item V-2 (page 11).

2. Q. What should be shown downstream from a major flood-control reservoir?

   A. If profiles or other flood information for controlled conditions are available, define the flood boundaries for the regulated conditions. If there is no information on regulated flood conditions, define the flood boundaries for natural conditions and use an explanatory note such as "Flood-prone area prior to reservoir construction".

   The text of a pamphlet prepared for an area downstream from a major flood-control reservoir should contain an explanation of the influence of the reservoir. For example, add the following kind of explanation

   > "The map prepared for the Ottumwa area shows the extent of the natural flood plain and does not take into account the areas protected by the construction of Red Rock Reservoir, Des Moines River

channel improvement, or other flood-protection systems. For up-to-date information on flood-protected areas, contact the Director of Planning, Ottumwa, Iowa 52501."

3. Q. New highway or railroad embankments change the inundation pattern; should these landform or cultural changes be shown?

   A. Generally no attempt should be made to change any base map features. Delimit the flood boundaries to the best of your ability.

4. Q. How do we estimate flood heights on small streams when we have no small stream data?

   A. Develop a regional stage-frequency relation and extend it as necessary. See item IV-1 (page 5).

5. Q. How far should backwater from a main stream be shown to extend up a tributary valley on which flood boundaries are not to be defined?

   A. Hook the mainstream boundaries a short distance into each side of the tributary valley, and leave the boundary open across the tributary valley.

6. Q. How do we handle ice jams that may frequently cause flooding to an unknown degree?

   A. Use personal judgment to get the best job possible. Add explanatory note, where appropriate.

7. Q. What do we do where flat land slopes and (or) large contour interval make boundary determination weak?

   A. Use personal judgment to get the best approximation possible.

8. Q. Should we transfer boundaries from previous studies such as a Geological Survey Hydrologic Atlas or a Corps of Engineers flood report onto the flood-prone area maps?

   A. If a complete quadrangle has been flood-mapped, that quadrangle will be omitted from our Nationwide project. If only a part of the quadrangle had been flood-mapped, use the boundary lines shown as a guide to transfer the flood delineation to our map. The flood boundaries for the previous report need not necessarily coincide with our boundaries.

For example, the Corps of Engineers frequently show two or three floods, and the largest (usually called "standard project flood") may be much greater than the flood that we propose to show. Refer to the report from which flood boundaries have been transferred.

9. Q. Another agency is currently working on a flood study of a reach but the report is not yet available; should we draw boundaries through the reach?

   A. No. Place a note along the reach such as: "U.S. Army Corps of Engineers flood studies for this reach are in progress."

10. Q. The flood-prone area covers the entire quadrangle map. Should we include the quadrangle in the program?

   A. Yes. Add an appropriate explanation, such as "Flood-prone area extends over entire quadrangle."

11. Q. "Floodways" have been defined by other agencies; should we define flood boundaries where "floodways" are defined?

   A. If the floodways are a reasonable approximation of the areal extent of flooding, do not define flood boundaries on the flood-prone area maps. If the floodways are defined only to show areas of high stream velocity, without regard to areal extent, draw flood boundaries.

12. Q. May other notations be used rather than "Flood-prone area?"

   A. Yes. Where appropriate use such notations as "Approximate area flooded April 1956" or "Approximate area flooded April 1965 when levees were breached."

13. Q. Should we field check areas of weak flood boundary definition?

   A. No. The purpose of these maps is only to show approximate boundaries, and the allowable cost per map rule out any field work.

14. Q. Should finished maps be transmitted in small lots for review and processing?

   A. Yes. Maps are printed in batches of 40 (four maps to a press plate) and pamphlets are printed in batches of 20. Maps received in lots of two or three or more, from all District offices are accumulated in batches of 40 and forwarded for printing.

15. Q. May we prepare a flood prone area pamphlet without preparing first a full quadrangle flood prone area map?

A. No.

16. Q. May we use a photographic base in lieu of a topographic base for a flood-prone area pamphlet?

A. No. A photographic base would be too costly for the program.

17. Q. Should flood boundaries along lake shorelines and coastlines be shown?

A. Yes. Delineate flood-prone area boundaries along lake shorelines and coastlines.

18. Q. Should flood-prone areas be delineated in wooded marshes and swamp areas?

A. The presence of ground water at or near the ground surface creates soil conditions which generally discourage development. Infiltration into the sandy soils is high and runoff from precipitation in marsh areas is slow with a net result of sustained high base flows in most streams, but not much flooding in marsh areas.

The treatment proposed for wooded marshes and swamp areas, is to delineate 100-year flood boundaries in those areas subject to flooding from <u>overflow of streams</u>, and to omit flood boundaries in those areas not subject to riverine flooding.

19. Q. How should depression areas be treated?

A. Ponding takes place in the lower parts of small closed basins in depression areas. Ponded water evaporates and seeps into the ground but generally stands long enough to eliminate vegetation. These areas are generally small enough to be disregarded.

20. Q. Is the Geological Survey's reputation of accurate work at stake?

A. The Geological Survey was directed by Congress to provide only a quick and general appraisal of flood-prone areas. Our proficiency in mapping, hydrology, and hydraulics undoubtedly will allow us to do this job more efficiently than any other organization.

VIII. Additional information

The following exhibits are attached or are available on request:

1. List of U.S. Geological Survey hydrologic atlases published to August 1976. See page 19.

2. Gann, E. E., 1968, Flood height-frequency relations for the plains area: U.S. Geol. Survey Prof. Paper 600-D, p. 52, 53. (Item IV - 1, page 5.) See page 25.

3. Thomas, D. M., 1964, Height-frequency relations for New Jersey floods: U.S. Geol. Survey Prof. Paper 475-D, p. 202, 203. (Item IV - 1, page 5.) See page 27.

4. Stick-on type notations. See pages 29 and 30.

5. Sample flood-prone area map (not included). Available on request to Chief, Current Conditions Group. See page 13 for address.

6. Information pamphlet (not included). Available on request to Chief, Current Conditions Group. See page 13 for address.

FLOOD-PLAIN MAPS PUBLISHED IN THE HYDROLOGIC ATLAS SERIES

The list below identifies the many flood-maps published by the U.S. Geological Survey as "hydrologic investigations atlases." Each atlas consists of a topographic map (or maps) or of a photomosaic base map on which is shown the area covered by one or more outstanding floods or by hypothetical floods of specified frequencies. The scale of each map is 1:24,000, except where noted otherwise. Each flood map is accompanied by explanatory data that describe the stages and profiles of the flood.

These maps have been prepared in cooperation with State, county, and other governmental agencies. The flood maps are important planning documents for those zoning, planning, construction, and insurance groups concerned with the orderly development and economic use of flood-plain areas. Orders for atlases listed below, of areas east of the Mississippi River, should be sent (with check or money order payable to the U.S. Geological Survey) to the Distribution Section, U.S. Geological Survey, 1200 South Eads St., Arlington, Va. 22202. Orders for maps of areas west of the Mississippi River should be sent to Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO. 80225.

(NOTE: Prices are subject to change)

Alabama

HA-408 Hurricane Camille tidal floods of August 1969 along the Gulf coast, Grand Bay quad., Ala. 1969. $2.00.

Alaska

HA-294 Flood of August 1967 at Fairbanks, Alaska. 1967. $1.75.

California

HA- 54 Floods at Freemont, Calif. 1962. $2.00.
HA- 78 Floods near Fortuna, Calif. 1963. $2.00.
HA-348 Floods on Napa River at Napa, Calif. 1970. $1.75.
HA-422 Floods of January 1969 near Carpenteria, Calif. 1971. $1.25. (Photomosaic, scale about 1:12,000.)
HA-423 Flood of January 1969 near Ventura, Calif. 1971. $1.75.
HA-424 Flood of January 1969 near Azusa and Glendora, Calif. 1971. $1.25. (Photomosaic, scale about 1:6,000.)
HA-425 Flood of January 1969 near Cucamonga, Calif. 1971. $1.75. (Scale 1:6,000.)

Colorado

HA- 41 Flood at Boulder, Colo. 1961. $1.75. (Scale 1:6,000.)

Florida

HA- 66 Floods at Tampa, Fla. 1962. 2 sheets. $4.00 per set. (Scale 1:12,000.)

Georgia

HA-418 Floods in vicinity of Ellijay, Ga. 1971. $1.75.

Hawaii

HA-239 Floods in Kahaluu area, Oahu, Hawaii. 1966. $2.00. (Scale 1:12,000.)

HA-314 Floods in Waimanalo area, Oahu, Hawaii. 1968. $2.00. (Scale 1:12,000.)

HA-473 Floods in Punaluu-Hauula area, Oahu, Hawaii. 1973. $1.25. (Scale 1:12,000.)

HA-531 Floods in Waiahole-Waikane area, Oahu, Hawaii. 1974. $1.75. (Scale 1:12,000.)

Idaho

NOTE: The title of each atlas below is "Teton Dam flood of June 1976, (name of quadrangle) Idaho." 1976. $1.75.

HA-565 Newdale
HA-566 St. Anthony
HA-567 Parker
HA-568 Moody
HA-569 Rexburg
HA-570 Menan Buttes
HA-571 Deer Parks
HA-572 Rigby
HA-573 Lewisville
HA-574 Idaho Falls North
HA-575 Idaho Falls South
HA-576 Woodville
HA-577 Firth
HA-578 Rose
HA-579 Blackfoot
HA-580 Moreland
HA-581 Pingree

Illinois (all northeastern Illinois)

HA- 39 Floods near Chicago Heights, Ill. 1960. $1.75.

HA-449 Floods on Loop Creek and Richland Creek near Belleville, Ill. 1972. $1.75.

NOTE: The title of each atlas below is "Floods in (name of quadrangle), Ill." Price is $2.00 unless noted otherwise.

HA- 39 Chicago Heights - see above.
HA- 67 Arlington Heights. 1963. $1.75
HA- 68 Elmhurst. 1963.
HA- 69 Highland Park. 1963. $1.75.
HA- 70 Aurora North. 1963
HA- 71 Wheeling. 1963. $1.75
HA- 85 Park Ridge. 1964.
HA- 86 Hinsdale. 1964.
HA- 87 Palatine. 1964.
HA- 88 Libertyville. 1964.
HA- 89 Joliet. 1964.
HA- 90 Harvey. 1964
HA-142 Geneva. 1965
HA-143 Lombard. 1964. $1.75.
HA-144 Wadsworth. 1964.
HA-145 Palos Park. 1966.
HA-146 Romeoville. 1965.
HA-147 Elgin. 1965.
HA-148 Wheaton. 1965.
HA-149 Sag Bridge. 1966.
HA-150 Barrington. 1965.
HA-151 Fox Lake. 1965.
HA-152 Tinley Park. 1965.
HA-153 Blue Island. 1966.
HA-154 Naperville. 1965.
HA-202 West Chicago. 1965.
HA-203 Streamwood. 1965.
HA-204 Mokena. 1966.
HA-205 Lake Calumet. 1966.
HA-206 River Forest. 1966.
HA-207 Wauconda. 1966.
HA-208 Lake Zurich. 1966.
HA-209 Steeger. 1966.
HA-210 Normantown. 1966.
HA-211 Manhattan. 1966
HA-226 Antioch. 1966.
HA-227 Sugar Grove. 1966.
HA-228 Plainfield. 1966.
HA-229 Elburn. 1966.
HA-230 Grayslake. 1967.
HA-231 Frankfort. 1967.
HA-232 Pingree Grove. 1967.
HA-233 Zion. 1967.

Illinois - continued

HA-234 Waukegan. 1967.
HA-251 Peotone. 1967.
HA-252 Berwyn. 1967.
HA-253 Crystal Lake. 1967.
HA-254 Elwood. 1967.
HA-255 McHenry. 1968.
HA-256 Woodstock. 1968.
HA-257 Beecher West. 1968.
HA-301 Dyer. 1968.
HA-302 Beecher East. 1969. $1.75
HA-303 Richmond. 1969.
HA-304 Wilton Center. 1969. $1.75.
HA-305 Symerton. 1970.
HA-306 Wilmington. 1971. $1.75.
HA-361 Huntley. 1971. $1.75.
HA-362 Channahon. 1971. $1.75.
HA-363 Hebron. 1971. $1.75.
HA-449 Belleville - see above.
HA-458 Maple Park. 1972. $1.75.
HA-459 Hampshire NE. 1972. $1.75.
HA-472 Big Rock. 1973. $1.75.
HA-495 Marengo North. 1973. $1.75.
HA-496 Harvard. 1973. $1.75.
HA-497 Garden Prairie. 1973. $1.75.
HA-498 Capron. 1973. $1.75.

Iowa

HA- 53 Floods at Des Moines, Iowa. 1963. $2.00.

Kansas

HA- 14 Floods at Topeka, Kans. 1959. $1.75.
HA- 63 Floods at Wichita, Kansas. 1963. 5 sheets. $10.00 per set.

Kentucky

HA-328 Floods on Levisa Fork in vicinity of Paintsville, Ky. 1969. $1.75. (Scale 1:12,000.)
HA-329 Floods on Licking River in vicinity of Salyersville, Ky. 1969. $1.75. (Scale 1:12,000.)
HA-342 Floods on Triplett Creek in vicinity of Morehead, Ky. 1969 $2.00. (Scale 1:12,000.)

Louisiana

HA-126 Flood of 1962 near Baton Rouge, La. (and data sheet on flood of 1964). 1965. $2.00.
HA-374 Flood of April 1968 at Many, La. 1970. $1.75. (Photomosaic, scale about 1:12,000.)

Massachusetts

HA-371 Flood of March 1968 on the Sudbury, Assabet, and Concord Rivers in Massachusetts. 1970. 2 sheets. $3.50 per set. (Photomosaic, scale about 1:12,000.)
HA-419 Flood of March 1968 on the Charles River, Mass. 1971. 2 sheets. $2.50 per set. (Photomosaic, scale about 1:12,000.)
HA-482 Flood of March 1968 on the Ipswich River, Mass. 1973. $2.50. (Scale 1" = 1,000'.)
HA-500 Flood of March 1968 on the Neponset River, Mass. 1973. $1.25. (Scale 1" = 1,000'.)

Michigan

HA- 59 Floods at Mount Clemens, Mich. 1962. $2.00. (Scale 1:18,000)

Mississippi

HA-127 Flood on Pearl River at Jackson, Miss., in 1961. 1964. $1.75. (Photomosaic, scale about 1:21,000.)

NOTE: Titles of HA-395 to 407 are "Hurricane Camille tidal floods of August 1969, (name of quadrangle), Miss." 1969. $2.00 each.

HA-395 Logtown.
HA-396 English Lookout, La-Miss.
HA-397 Kiln.
HA-398 Waveland-Grand Island Pass.
HA-399 Vidalia.
HA-400 Bay St. Louis.
HA-401 Gulfport Northwest.
HA-402 Pass Christian.
HA-403 Gulfport North-South
HA-404 Biloxi.
HA-405 Ocean Springs-Deer Island.
HA-406 Pascagoula. (Scale 1:62,500.)
HA-407 Kreole-Grand Bay Southwest, Miss.-Ala.

Nebraska

HA-188 Flood of August 1966 in the lower Loup River basin, Nebr. 1967. 2 sheets. $2.00 per set.
HA-258 Floods in Seward quad., southeastern Nebraska. 1967. $2.00.
HA-352 Flood of June 1967 at Grand Island, Nebr. 1970. $1.75.

New Jersey

HA- 65 Tidal floods, Atlantic City and vicinity, N.J. 1962. $1.75. (Scale 1:12,000.)
HA-104 Floods on Raritan and Millstone Rivers in Somerset County, N.J. 1964. $2.00.
HA-245 Floods on Millstone River and Stony Brook in vicinity of Princeton, N.J. 1967. $2.00.
HA-246 Floods at Easton, Pa.-Phillipsburg, N.J. 1967. $2.00.
HA-263 Floods on Delaware River in the vicinity of Belvidere, N.J. 1967. $2.00.
HA-359 Floods in upper Millstone River basin in vicinity of Hightstown, N.J. 1969. $2.00.
HA-378 Floods in Beden Brook basin in Somerset and Mercer Counties, N.J. 1970. $2.00.

New Mexico

HA-318 Flood of August 1966 at Carlsbad, N. Mex. 1968. $1.25. (Scale 1:14,000.)

New York

HA-297 Floods on Chenango River and Canasawacta Creek at Norwich, N.Y. 1968. $2.00. (Scale 1:12,000.)
HA-350 Floods on Susquehanna River at Oneonta, N.Y. 1969. $2.00. (Scale 1:20,000.)
HA-518 Flood of June 1972 at Elmira, N.Y. 1973. $1.75. (Scale 1:18,000.)
HA-519 Flood of June 1972 at Corning, N.Y. 1973. $1.75. (Scale 1:18,000.)

North Carolina

HA-323 Floods on Boone and Winkler Creeks at Boone, N.C. 1968. $1.75. (Scale 1:4,800.)
HA-331 Floods on Little Buffalo Creek at West Jefferson, N.C. 1969. $1.25. (Photomosaic, scale about 1:5,500.)

Ohio

HA- 40 Floods at Mount Vernon, Ohio. 1964 (revised). $2.00. (Scale 1:12,000.)
HA- 43 Floods at Springfield, Ohio, in 1913 and 1959. 1961. $2.00.
HA- 44 Floods at Newark, Ohio, 1964 (revised). $2.00.
HA- 45 Floods at Chillicothe, Ohio. 1964. $2.00.
HA- 46 Floods at Zanesville, Ohio. 1964. $2.00. (Scale 1:12,000.)
HA- 47 Floods at Freemont, Ohio. 1962. $2.00.
HA- 48 Floods at Circleville, Ohio. 1964. $2.00. (Scale 1:12,000.)
HA- 49 Floods at Barberton, Ohio. 1962. $2.00.
HA- 50 Floods at Canton, Ohio. 1962. $2.00.
HA- 51 Floods at Warren, Ohio. 1963. $2.00.
HA- 52 Floods at Columbus, Ohio. 1962. $2.00. (Scale 1:31,680.)
HA- 56 Floods on Crab Creek at Youngstown, Ohio. 1963. $2.00. (Scale 1:2,400.)
HA-324 Floods at Amesville, Ohio. 1969. $2.00. (Scale 1:12,000.)
HA-325 Floods at Jackson, Ohio. 1968. $2.00. (Scale 1:12,000.)

Oregon

HA-388 Floods on Elk Creek, Douglas County, Ore. 1971. $1.25. (Photomosaic, scale about 1:24,000.)

Pennsylvania

HA- 57 Floods at Harrisburg, Pa. 1961. $2.00. (Scale 1:31,680.)
HA-246 Floods at Easton, Pa.-Phillipsburg, N.J. 1967. $2.00.
HA-248 Floods on Schuylkill River from Conshohocken to Philadelphia, Pa. 1967. $2.00. (Scale 1:16,000.)
HA-483 Extent and frequency of floods on Schuylkill River near Norristown, Pa. 1973. $3.50. (Scale 1:16,000.)
HA-523 Flood of June 1972 in Wilkes-Barre area, Pa. 1973. $1.75.
HA-530 Floods of June 1972 in the Harrisburg area, Pa. 1973 [1974]. $1.75.
HA-541 Flood of June 22-23, 1972, at Loch Haven, Pa. 1975. $1.75. (Scale 1:12,000.)

Puerto Rico (all maps at scale of 1:20,000)

HA- 77 Floods at Bayamon and Catano, P.R. 1962. $2.00.
HA-128 Floods at Toa Alta, Toa Baja, and Dorado, P.R. 1964. $1.75.
HA-261 Floods in the Ponce area, P.R. 1967. $2.00.
HA-262 Floods at Barceloneta and Manati, P.R. 1967. $1.75.
HA-265 Floods at Humacao, P.R. 1967. $2.00.
HA-271 Floods at Arecibo, P.R. 1958. $2.00.
HA-288 Floods in the Mayaguez area of Puerto Rico. 1968. $2.00.
HA-289 Floods in the area of Vega Alta and Vega Baja, P.R. 1968. $2.00.
HA-375 Floods in the Anasco area, P.R. 1971. $1.75.
HA-382 Floods in the Yabucoa area, P.R. 1971. $1.75.
HA-414 Floods in the Guayanilla-Yauco area, P.R. 1971. $1.75.
HA-438 Floods at Caguas, Gurabo, Juncos, and San Lorenzo, P.R. 1972 $1.75.
HA-445 Floods in the Patillas-Maunabo area, P.R. 1971. $1.75.
HA-446 Floods in the Guayama area, P.R. 1971. $1.75.
HA-447 Floods in the Salinas area, P.R. 1971. $1.75.

Puerto Rico - continued

HA-448 Floods in the Santa Isabel area, P.R. 1971. $1.75.

HA-456 Floods in the Rio Guanajibo Valley, southwestern Puerto Rico. 1972 [1973]. $1.75.

HA-457 Floods in the Aguadilla-Aguada area, northwestern Puerto Rico. 1972. $1.75.

HA-532 Floods in eastern Lajas Valley and the Lower Rio Loco basin, southwestern Puerto Rico. 1974 [1975]. $1.75.

HA-533 Floods in the Carolina-Rio Grande area, northeastern Puerto Rico. 1975. $1.75.

HA-545 Floods in the Fajardo-Luguillo area, northeastern Puerto Rico. 1975. $1.75.

South Dakota

HA-511 Flood of June 9-10, 1972, at Rapid City, S. Dak. 1973. $1.75. (Scale 1:18,000).

Texas

HA-190 Flood on Big Fossil Creek at Haltom City, near Fort Worth, Texas, in 1962. 1965. $1.75.

HA-238 Floods on White Rock Creek at Dallas, Texas, in 1962 and 1964. 1967. $2.00.

HA-240 Flood of October 8, 1962, on Bachman Branch and Joes Creek at Dallas, Texas. 1966. $2.00.

Virginia

HA-326 Floods on Johns and Craig Creeks in Craig County, Va. 1968. $2.00. (Scale 1:12,000.)

HA-409 Flood of August 1969, Bon Air quad., Richmond, Va. 1969. $2.00.

HA-410 Flood of August 1969, Richmond quad., Richmond, Va. 1969. $2.00.

HA-411 Flood of August 1969, Drewrys Bluff quad., Richmond, Va. 1969. $2.00.

HA-412 Flood of August 1969 on Maury River at Buena Vista, Va. 1969. $1.25. (Photomosaic, scale about 1:12,000.)

HA-505 Flood of October 1972 at Petersburg and Colonial Heights, Va. 1973 [1974]. $1.75.

West Virginia

HA-427 Floods at Martinsburg and vicinity, W. Va. 1973. $1.25. (Scale 1:6,000.)

Wisconsin

HA-393 Floods on Rock River in northern Rock County, Wis. 1970. $1.75. (Scale 1:16,000.)

HA-394 Floods on Rock River in northeastern Jefferson County, Wis. 1971. $1.75.

HA-413 Floods on Rock River in southwestern Jefferson County, Wis. 1971. $1.75.

FLOOD HEIGHT-FREQUENCY RELATIONS FOR THE PLAINS AREA IN MISSOURI

By E. EUGENE GANN, Rolla, Mo.

Work done in cooperation with the Missouri Division of Geological Survey and Water Resources and Missouri State Highway Commission

Abstract.—Regional relations are defined for estimating the heights of floods having recurrence intervals ranging from 1.2 to 50 years at natural flow sites in the plains area of Missouri. Drainage-area size is the only independent variable required. Average standard errors of the relations range from 21 percent for the 50- and 25-year floods to 35 percent for the 1.2-year flood. A method is presented for utilizing the relations at ungaged sites.

Regional flood height-frequency relations defined for the plains area of Missouri (fig. 1) can be used to estimate flood heights corresponding to selected frequencies at ungaged sites where natural floodflows and stream channels exist. These relations will be useful in the preliminary planning of proposed flood-plain developments.

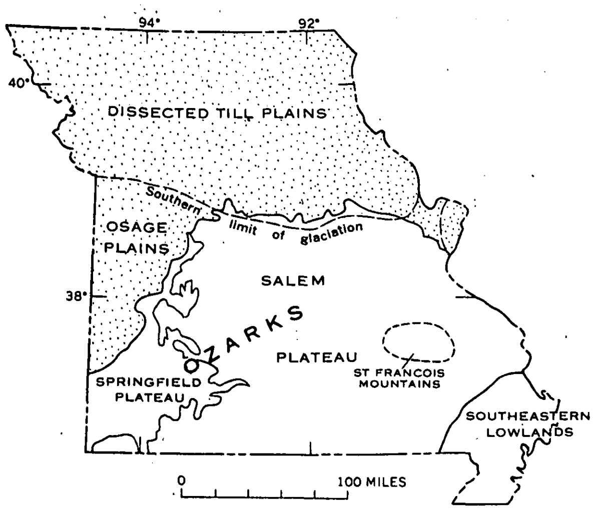

FIGURE 1.—Physiographic regions of Missouri. Area for which relations shown in figure 2 are applicable is shaded.

A study by Leopold and Maddock (1953) showed that for less than bankfull discharge a basin-wide relation exists between stream depth and discharge when discharge is of equal frequency of occurrence at all sites. They proposed a general equation of the form $d=cQ^f$, where d is the average cross-section depth, Q is the discharge of a given frequency at the section, and c and f are constants for a given frequency. Thomas (1964) found this type of relation applicable for greater than bankfull discharges in New Jersey, and for simplicity modified the equation to $h=cQ^f_{2.33}$, where h is the height of the water surface above the average channel bottom determined at time of median (50-percent duration) discharge, $Q_{2.33}$ is the mean annual flood discharge (recurrence interval of 2.33 years), and c and f are constants for a given frequency.

A further modification of Thomas' equation to $h=cA^f$, where A is the contributing drainage area, h is the height of the water surface above the elevation of the 50-percent duration discharge, and c and f are as previously defined, has been found to adequately describe the flood height–drainage area–frequency relation for the plains area in Missouri. These relations are presented graphically in figure 2.

The relations shown in figure 2 were defined from discharge-frequency and elevation-discharge curves at 81 stream-gaging stations. The higher frequency flood discharges were not defined for all 81 stations, and only 42 and 47 stations were used to define, respectively, the 50- and 25-year flood relations.

Drainage areas for the stations used in defining the relations ranged from less than 1 square mile to 8,000 square miles. The 50-year flood discharge is not defined for drainage areas of less than 50 square miles in the plains area of Missouri; therefore, the extended 50-

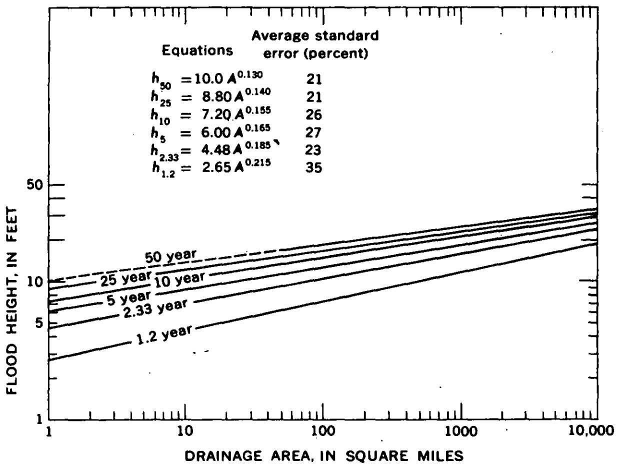

FIGURE 2.—Regional flood height–drainage area–frequency relations for the plains area in Missouri.

year relation is shown as a dashed line in figure 2 for drainage areas less than 50 square miles.

Values of the exponent f were found to range from 0.130 for the 50-year flood, to 0.215 for the 1.2-year flood, and values of the coefficient c ranged from 2.65 for the 1.2-year flood to 10.0 for the 50-year flood. Average standard errors, determined graphically, for the relations range from 21 percent for the 50- and 25-year floods to 35 percent for the 1.2-year flood.

The use of figure 2 requires knowledge of the elevation corresponding to the 50-percent duration discharge. This information must be estimated at an ungaged site. For most streams in the plains area of Missouri, the elevation of the 50-percent duration discharge is seldom found to exceed the elevation of zero flow by more than 1 foot. The elevation of zero flow corresponds to the lowest point at the upper end of the riffle just downstream from the point of interest, and it is suggested that the flood height be measured from the point of zero flow. When measuring flood height from the point of zero flow and for drainage areas larger than 100 square miles, add 1 foot to the values from figure 2 to adjust for the difference between the elevations of the 50-percent duration discharge and the point of zero flow.

The following examples will illustrate the use of figure 2.

Example 1: Assume that an estimate of the elevation of the 50-year flood is desired for a site on a stream draining 300 square miles in the plains area of Missouri.

Step 1: Determine the elevation of zero flow at the upper end of the first riffle downstream from the site. Assume an elevation of 600 feet above mean sea level for this example.

Step 2: Determine the flood height from figure 2 for a 300-square-mile drainage area and a 50-year flood to be 21 feet.

Step 3: Add 1 foot for drainage areas larger than 100 square miles. The desired elevation is therefore 600+21+1=622 feet above mean sea level.

Example 2: Assume that a profile of the 50-year flood is desired for a 5-mile reach of the stream in example 1.

Step 1: Plot the low-water profile of the desired reach of stream from a topographic map.

Step 2: Determine the flood height for the desired frequency of flood from figure 2.

Step 3: Add flood height to low-water profile elevations to obtain the estimated flood profile for the desired frequency.

The relations described in this article are applicable only to sites where the floodflow and river channel are virtually natural. Less confidence may be placed in estimates from these relations than from estimates based upon computations using open-channel hydraulics formulas and detailed flood-peak estimating relations (Sandhaus and Skelton, 1968). Despite these limitations of use and accuracy, flood depths can be quickly and easily estimated from the presented relations and they should be useful for solving many common engineering and land-use planning problems.

REFERENCES

Leopold, L. B., and Maddock, Thomas, Jr., 1953, The hydraulic geometry of stream channels and some physiographic implications: U.S. Geol. Survey Prof. Paper 252, 57 p.

Sandhaus, E. H., and Skelton, John, 1968, Magnitude and frequency of Missouri floods: Missouri Div. Geol. Survey and Water Resources, Water Resources Report 23 [In press].

Thomas, D. M., 1964, Height-frequency relations for New Jersey floods: Art. 167 *in* U.S. Geol. Survey Prof. Paper 475–D, p. D202–D203.

HEIGHT-FREQUENCY RELATIONS FOR NEW JERSEY FLOODS

By D. M. THOMAS, Trenton, N.J.

Abstract.—Regional relations among height, discharge, and frequency are defined for New Jersey floods having annual recurrence intervals of 1.5 to 50 years. Separate relations are shown for Coastal Plain and non-Coastal Plain streams, and they can be used to predict flood heights at sites where mean annual flood discharge is known or can be estimated.

Regional relations among height, discharge, and frequency have been defined for New Jersey floods. These relations, which were developed from a study of stream-gaging station records, can be used to predict flood heights at sites where mean annual flood discharge is known or can be estimated. The relations are similar to the depth-discharge-frequency relations found by Leopold and Maddock (1953).

Leopold and Maddock (1953) determined for less than bankfull streamflow that a basin-wide relation exists between stream depth and discharge when discharge is of equal frequency of occurrence at all sites. They showed this relation as a simple power function of the form $d=c\ Q^f$, where d is average cross-section depth, Q is discharge of a given frequency at the section, and c and f are constants for a given frequency.

The simple power function also proved satisfactory for defining the New Jersey flood relations. However, for ease of field application, different measures of the two variables were used. Flood height (h) was used rather than average cross-section depth (d) because it is simply measured as a vertical distance. Flood height is defined as height of the water surface above the average channel bottom determined at time of median (50-percent duration) discharge. Mean annual flood discharge ($Q_{2.33}$) was found to be a satisfactory index of flood sizes for the desired flood-frequency range, and it was used for all frequencies rather than actual discharge (Q). With these variables the equation of the New Jersey flood height-frequency relations is $h=cQ^f_{2.33}$.

Records of 46 stream-gaging stations were used to define the flood-height-frequency relations by evaluating the c and f constants for annual flood recurrence intervals of 1.5 to 50 years. These gaging stations, which have mean annual flood discharges ranging from 117 to 140,000 cubic feet per second, are located at sites where natural flood flows and flood heights could be determined. Thirteen of the gaging stations are in the Coastal Plain physiographic province of southern New Jersey. Different c values were determined for these gaging stations than for the gaging stations outside the Coastal Plain. For the Coastal Plain, c ranged from 0.49 for a 1.5-year flood to 1.35 for a 50-year flood, while for the non-Coastal Plain sites c ranged from 0.33 for a 1.5-year flood to 0.90 for a 50-year flood. The f values for both Coastal Plain and non-Coastal Plain sites ranged from 0.360 for a 1.5-year flood to 0.314 for a 50-year flood. Figures 167.1 and 167.2 show graphically the defined relations.

Accuracy of the defined relations was checked by using them to estimate flood heights at the 46 gaging stations and comparing the estimated and measured values. As a check on the accuracies expected at ungaged sites, the flood heights were estimated using mean annual flood discharges computed from drainage-basin characteristics by preliminary methods developed in another study. Two out of three estimates at gaging stations agreed with measured flood heights within ± 23 percent for a 2.33-year flood, within ± 16 percent for both a 10-year and a 25-year flood, and within ± 21 percent for a 50-year flood. Maximum errors for a 2.33-year flood were $+54$ percent and -47 percent, and maximum errors for a 50-year flood were $+36$ percent and -49 percent. No significant accuracy differences appeared between estimates for Coastal Plain and non-Coastal Plain streams.

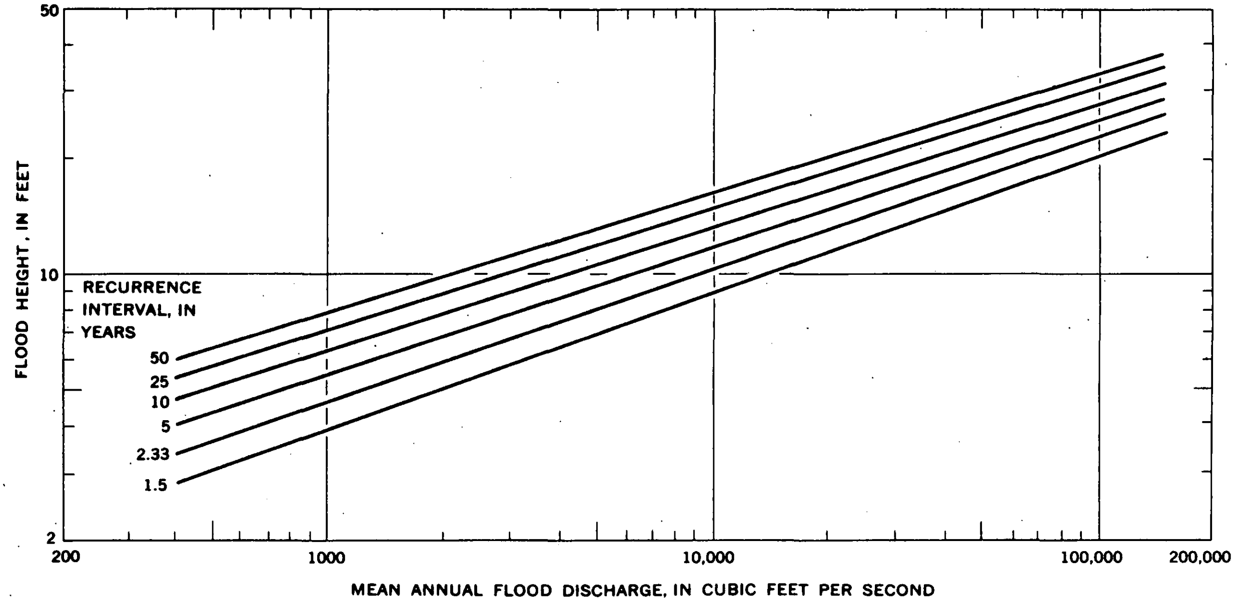

FIGURE 167.1.—Flood height-discharge-frequency relations for non-Coastal Plain streams in New Jersey.

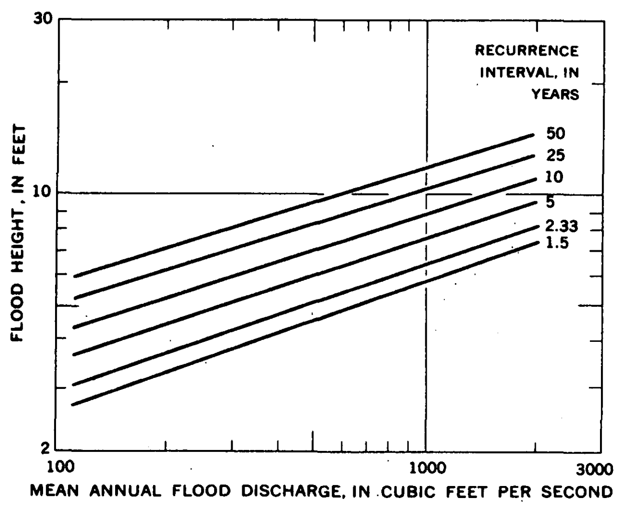

FIGURE 167.2.—Flood height-discharge-frequency relations for Coastal Plain streams in New Jersey.

Although flood heights estimated by the areal relations are considered less reliable than those obtained from field surveys and hydraulic computations, the ease and simplicity of their determination are expected to make them useful for many purposes.

REFERENCE

Leopold, Luna B., and Maddock, Thomas, Jr., 1953, The hydraulic geometry of stream channels and some physiographic implications: U.S. Geol. Survey Prof. Paper 252.

MAP OF FLOOD-PRONE AREAS

MAP OF FLOOD-PRONE AREAS

Flood-prone area prior to levee construction. Information on levees in this area available from Corps of Engineers, U.S. Army.

Flood-prone area prior to levee construction. Levees designed by Corps of Engineers, U.S. Army, to protect against year flood.

Coastal areas subject to tidal flooding have not been delineated

Floods delineated in this area in greater detail by the Corps of Engineers, U.S. Army

Floods delineated in this area in greater detail by the Tennessee Valley Authority

Base by U.S. Geological Survey

PRIOR TO RESERVOIR CONSTRUCTION

PRIOR TO LEVEE CONSTRUCTION

PRIOR TO CHANNEL DREDGING

FLOOD PRONE AREA

FLOOD PRONE AREA

PREPARED BY THE U.S. GEOLOGICAL SURVEY

1976

Flood boundaries were estimated from:
Photographs taken during a major flood

Soils maps, photographic interpretation, or other indirect information.

U.S. Geological Survey hydrologic atlas on floods available for this area

EXPLANATION

Flood boundaries were estimated from:
Profiles based on high-water marks.

EXPLANATION

Flood boundaries were estimated from:
Regional stage-frequency relations.

EXPLANATION

Flood boundaries were estimated from:
Photographs taken at time of flooding.
Profiles based on high-water marks.

EXPLANATION

Flood boundaries were estimated from:
Photographs taken at time of flooding.
Regional stage-frequency relations.

EXPLANATION

Flood boundaries were estimated from:
Profiles based on high-water marks.
Regional stage-frequency relations.

EXPLANATION

Flood boundaries were estimated from:
Photographs taken at time of flooding.
Profiles based on high-water marks.
Regional stage-frequency relations.

STICK-ON TYPE

Approximate boundaries of flood-prone areas are shown on this map. There is, on the average, about 1 chance in 100 that the designated areas will be inundated in any year. This information is important to public agencies and private citizens concerned with future land developments.

The flood-prone areas have been delineated through use of readily available information on past floods rather than from detailed field surveys and inspections. In general, the delineated areas are for natural conditions and do not take into consideration the possible effects of existing or proposed flood control structures except where those effects could be evaluated. Flood areas have been identified for: (1) urban areas where the upstream drainage basin exceeds 25 square miles, (2) rural areas in humid regions where the upstream drainage basin exceeds 100 square miles, (3) rural areas in semiarid regions where the upstream drainage basin exceeds 250 square miles, and (4) smaller drainage basins, depending on topography and potential use of the flood plains.

The 89th Congress, in House Document 465, recommended the preparation of flood-prone area maps to assist in minimizing flood losses by quickly identifying the areas of potential flood hazards. More detailed flood information may be required for other purposes such as structural designs, economic studies, or formulation of land-use regulations. Such detailed information may be obtained from the U.S. Geological Survey, other Federal agencies, or State, local, and private agencies.

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