Map MODERNIZATION

Federal Emergency Management Agency

FEMA's Flood Hazard Mapping Program

Guidelines and Specifications *for* Flood Hazard Mapping Partners

Appendix F: Guidance for Ice-Jam Analyses and Mapping

FEDERAL EMERGENCY MANAGEMENT AGENCY

www.fema.gov/fhm/dl_cgs.shtm

April 2003

All policy and standards in this document have been superseded by the FEMA Policy for Flood Risk Analysis and Mapping. However, the document contains useful guidance to support implementation of the new standards.

Summary of Changes for Appendix F,

Guidance for Ice-Jam Flooding Analyses and Mapping

The Summary of Changes below details changes to Appendix F that were made subsequent to the initial publication of these *Guidelines* in February 2002. These changes represent new or updated guidance for Flood Hazard Mapping Partners.

Date	Affected Section(s)/Subsection(s)	Description of Changes
April 2003	None	No changes representing new or updated guidance were made.

Appendix F

Guidance for Ice-Jam Flooding Analyses and Mapping

F.1 Introduction [February 2002]

An ice jam may be defined as an accumulation of ice in a river, stream, or other flooding source that reduces the cross-sectional area available to carry the flow and increases the water-surface elevation. Ice usually accumulates at a natural or manmade obstruction or a relatively sudden change in channel slope, alignment, or cross-section shape or depth. Ice jams are common in locations where the channel slope changes from relatively steep to mild, and where a tributary stream enters a large river. Ice jams often cause considerable increases in upstream water-surface elevation, and the flooding often occurs quite rapidly after the jam forms.

In the northern United States, where rivers can develop relatively thick ice covers during the winter, ice jams can contribute significantly to flood hazards. Although flow discharges may be low relative to free flow flood, the stages of ice jam flooding may be among the highest on the record. Ice jams typically occur repeatedly in the same locations and ice jam flooding tends to be local and highly site specific.

In areas likely to be selected for a detailed study by the Federal Emergency Management Agency (FEMA) or one of FEMA's Mapping Partners, historical documentation usually will indicate if ice-jam-caused flooding is a significant factor warranting consideration. In regions of the United States where ice jams are typical, the Mapping Partner that performs a detailed study for a FEMA-contracted Flood Map Project or community-initiated map revision shall investigate historical floods for evidence of ice-jam contribution as part of the reconnaissance effort.

F.2 Ice Jam Types [February 2002]

Ice jams have been classified in numerous ways by various investigators. In the U.S. Army Cold Regions Research and Engineering Laboratory Technical Note entitled "Methodology for Ice Jam Analysis" (1980), ice jams were classified as freezeup-, breakup-, floating-, or grounded-type jams. Each type is discussed in more detail in Subsections F.2.1 through F.2.4.

Additional information on the characteristics of ice jams is provided by the National Research Council of Canada in Chapter 10 of *Hydrology of Floods in Canada—A Guide to Planning and Design* (National Research Council of Canada, 1989), and by the U.S. Army Corps of Engineers in Engineering Pamphlet 1110-2-11, *Engineering and Design Ice Jam Flooding: Causes and Possible Solutions* (U.S. Army Corps of Engineers, 1994).

F.2.1 Freezeup-Type Jams [February 2002]

Freezeup-type jams are associated with the formation and accumulation of frazil ice, which eventually forms a continuous ice cover. Freezeup jams typically occur during early winter to midwinter. The Mapping Partner that performs the detailed study usually will not be required to address freezeup-type jams in performing a detailed study for National Flood Insurance Program (NFIP) purposes because freezeup-type jams are not associated with large discharge events. However, the Mapping Partner shall be aware of possible exceptions.

F.2.2 Breakup-Type Jams [February 2002]

Breakup-type jams are frequently associated with rapid increases in runoff and rises in river stage, resulting from rainfall and/or snowmelt. Breakup-type jams usually occur during the late winter or early spring. Because of the large volumes of ice that may be involved and the greater discharges associated with them, breakup-type jams are predominant in ice-jam-caused flooding. Therefore, breakup-type jams are the type that the Mapping Partner that performs the detailed study for a FEMA-contracted Flood Map Project or community-initiated map revision will typically need to investigate.

F.2.3 Floating-Type Jams [February 2002]

Floating-type jams are considered to be those where the ice is not grounded to the channel bottom and significant flow takes place beneath the ice cover. Floating-type jams are typical of deeper rivers. Because floating-type jams can cause significant backwater effects, the Mapping Partner that performs the detailed study must address them as part of the detailed study for a FEMA-contracted Flood Map Project or community-initiated map revision when such conditions exist.

F.2.4 Grounded-Type Jams **[February 2002]**

Grounded-type jams are characterized by an ice cover that is partially grounded to the bed of the channel, with most of the flow being diverted into the overbank and floodplain areas. Grounded-type jams are typical of shallow, confined stream sections. Because grounded-type jams can cause significant backwater effects, the Mapping Partner that performs the detailed study must address them as part of the detailed study for a Flood Map Project when such conditions exist.

F.3 Reconnaissance **[February 2002]**

When the Mapping Partner that performs the detailed study determines that ice jamming has historically resulted in flooding within the community that is the subject of the Flood Map Project, the Mapping Partner shall intensify the reconnaissance effort. Through the intensified reconnaissance effort, the Mapping Partner will be able to acquire as much data as possible concerning ice-jam events in the community, on the streams being studied, and in the region. Such data shall include, but not be limited to, the following:

- Locations of ice jams,
- Dimensions,
- Ice volumes,
- Causes,
- Associated river stages and discharges,
- Frequency of occurrence,
- Lateral and upstream extent of flooding, and
- Season of occurrence.

The Mapping Partner that performs the detailed study also shall investigate the nature of ice jamming common to the site; that is, whether freezeup- or breakup-type jams are typical and whether grounded- or floating-type jams are typical. Because very limited documented data are usually available, the Mapping Partner that performs the detailed study shall investigate all possible sources of information, including the following:

- Photographs;
- Local residents;
- Newspapers;
- Community officials; and
- State and Federal agencies.

During the field reconnaissance, the Mapping Partner that performs the detailed study also shall investigate physical evidence of ice jams (e.g., high-water marks, damage to structures, scars on trees) that may provide useful data for the analysis.

F.4 Analysis Approaches [February 2002]

Different methods may be used for establishing flood elevations in areas subject to ice-jam flooding, depending on the availability of data and the nature of the ice-jamming phenomena that occur at the site of interest. The methods outlined herein are applicable primarily to stationary-type ice jams that occur during periods of ice breakup. These types of jams historically have resulted in major flooding in certain regions of the United States. When conditions warrant alternate analytical methods, the Mapping Partner that performs the detailed study must seek approval of the alternate methods from the FEMA Regional Project Officer before proceeding.

The approaches in Subsections F.4.1 and F.4.2 are based on the development of stage-frequency relationships for two different populations (ice-jam flood stages and free-flow flood stages), which are then combined into a single composite frequency curve for flood stages at a site under study. Depending on the availability of ice-jam stage information, ice-jam stage-frequency relationships may be determined directly or indirectly as discussed in Subsections F.4.1 and F.4.2. For NFIP purposes, the direct method is preferred where sufficient data are available.

F.4.1 Direct Approach [February 2002]

If sufficient data exist at the site of interest, the Mapping Partner that performs the detailed study shall establish an ice-jam stage-frequency distribution directly by analyzing the historical ice-stage data. This approach is preferred where ice-jam stages are available for three or more significant events (i.e., overbank flooding) that span more than a 25-year period of record and where hydraulic conditions have not changed appreciably since those events.

Limited data on historical ice-jam stages are usually available at ungaged locations, and the Mapping Partner that performs the detailed study may obtain these data from a variety of sources, including:

- Community officials,
- Resident recollections,
- Newspaper accounts,
- High-water marks,
- Tree damage or scars,
- Vegetation trim lines, and
- Disturbed bank material.

If historical records of stage are sufficient, the Mapping Partner that performs the detailed study may use the graphical frequency analysis method to compute plotting positions and fit a frequency curve on probability paper. Because of their simplicity, FEMA recommends using the Weibull plotting positions for this purpose. However, the Mapping Partner shall be aware that any extrapolation beyond the range of observed data is risky when the graphical frequency analysis is performed, because the ice-affected stages are primarily governed by the regime of ice and its interaction with channel geometry. Additional guidance on graphical frequency analysis and the use of exceedance thresholds for ice-jam flooding is provided in *Hydrology of Floods in Canada—A Guide to Planning and Design* (National Research Council of Canada, 1989).

If the detailed-study reach includes a gaging station where historical ice jams have occurred, the Mapping Partner that performs the detailed study shall perform a stage-frequency analysis using the stage data at the gaging station. The Mapping Partner shall obtain the stage data necessary for this analysis from streamflow records published by the U.S. Geological Survey and other agencies.

The annual-maximum stage can occur as the result of either a free-flow event or an ice-jam event. For the ice-jam events, the annual-maximum peak stage can occur at a different time than the annual-maximum peak discharge.

If detailed data are available, the Mapping Partner that performs the detailed study may follow two approaches for the direct analysis of stage data: (1) annual-event series and (2) annual-maximum series. The Mapping Partner shall use the annual-event series approach when data are available for both the maximum peak stage during the ice-jam season and the maximum peak stage during the free-flow season for each year (two values per year). The Mapping Partner shall use the annual-maximum series approach when only data for the annual-maximum peak stages are available for each year.

In both approaches, the Mapping Partner that performs the detailed study shall develop separate frequency curves for the ice-jam events and the free-flow events and then combine them to determine the percent chance that a given stage will be exceeded in a year. Weibull plotting positions are preferred for determining the individual stage-frequency curves. However, when there are more than 10 years of ice-jam or free-flow stages, the Mapping Partner may fit a frequency distribution such as the log-Pearson Type III to the stage data or their logarithms to help define or extend the stage-frequency curve based on plotting positions. An example of analyzing both annual-event and annual-maximum series is given in “Discussion of Techniques for Analysis of Ice-Jam Flooding” (Thomas, Crockett, and Johnson, 1998).

F.4.1.1 Annual-Event Series [February 2002]

To develop the annual-event series, the Mapping Partner that performs the detailed study shall develop peak stages for the ice-jam season and for the free-flow season for each year of record. However, most often, the available data will not be sufficient to develop the annual-event series. In many years, only a single peak stage is reported. To develop the annual-event series for these years, the Mapping Partner shall either estimate the peak stage for the missing season or, preferably, determine the peak stage through a search of the historical stage records. FEMA does not recommend estimating the peak stage because this approach introduces uncertainty in the analysis, particularly when estimating the missing ice-jam stages. Even though a search of historical stage records is usually time consuming, the Mapping Partner that performs the detailed study shall use this approach for developing the complete annual-event series.

For the annual-event series, the Mapping Partner that performs the detailed study shall compute stage-frequency curves for each season and combine them using the following equation:

$$P(s) = P(si) + P(sq) - P(si) * P(sq) \qquad (1)$$

where

P(s) = Probability of the annual-maximum stage exceeding a given stage "s" in any year, by either type of event

P(si) = Probability of the annual-maximum stage exceeding a given stage "s" in the ice-jam season (not all events in the ice-jam season will necessarily be affected by backwater from ice)

P(sq) = Probability of the annual-maximum stage exceeding a given stage "s" in the free-flow season

P(si) * P(sq) = Joint probability of the annual-maximum stage exceeding a given stage "s" in any year from both types of events

For the annual-event analysis, the Mapping Partner that performs the detailed study shall determine a peak stage for each season each year and combine the seasonal frequency curves assuming the two populations are independent of one another. The Mapping Partner shall not use Equation 1 if the two populations are not independent, if it is impossible to compile an annual-event series, or if it is impossible to segregate the peak stages into populations based on distinct hydrologic causes. When these conditions cannot be met, the Mapping Partner that performs the detailed study shall recommend an alternate approach that uses only the annual maximum peak stages in the frequency analysis to the FEMA Regional Project Officer (RPO) and receive approval for the alternate approach before proceeding with the analysis.

F.4.1.2 Annual-Maximum Series [February 2002]

In the annual-maximum series, the Mapping Partner that performs the detailed study shall identify the annual peak stage in each year of record as resulting from either an ice-jam or free-flow event. The Mapping Partner that performs the detailed study shall then develop a stage-frequency curve using all annual-maximum stages that are ice-jam events and a separate stage-frequency curve using all the annual-maximum stages that are free-flow events. Each frequency curve is called a "conditional-frequency curve."

The ice-jam conditional-frequency curve is "conditioned" in the sense that only annual-maximum peak stages that are ice-jam-related are used in the frequency analysis. To obtain the probability of an ice-jam event exceeding a given stage "s" in any year, the Mapping Partner that performs the detailed study shall multiply the exceedance probabilities from the conditional-frequency curve by the fraction of time that ice-jam events produce annual-maximum peak stages.

The free-flow conditional-frequency curve is "conditioned" in the sense that only annual-maximum peak stages that are free-flow events are used in the frequency analysis. To obtain the probability of a free-flow event exceeding a given stage "s" in any year, the Mapping Partner that performs the detailed study shall multiply the exceedance probabilities from the conditional-frequency by the fraction of time that free-flow events produce annual-maximum peak stages.

The Mapping Partner that performs the detailed study shall then combine the seasonal-frequency curves combined to obtain the probability of the annual-maximum stage exceeding a given stage "s" in any year due to either a free-flow or an ice-jam related event. For the annual-maximum series, the Mapping Partner that performs the detailed study shall compute the stage-frequency curves for each season and combine them using the following equation:

$$P(s) = (P(s) \mid s = \text{free-flow event}) * P(s = \text{free-flow event}) + (P(s) \mid s = \text{ice-jam event}) * P(s = \text{ice-jam event}) \quad (2)$$

where

P(s)= Probability of the annual-maximum stage exceeding a given stage "s" in any year, by either type of event

(P(s) | s = free-flow event) = Conditional probability of the annual-maximum stage exceeding a given stage "s" in any year, when only free-flow events that are annual-maximum peak stages are used in the analysis

(P(s = free-flow event) = Fraction of years for which the annual-maximum peak stage was a free-flow event

(P(s) | s = free-flow event) * P(s = free- flow event) = Joint probability of the annual-maximum stage exceeding a given stage "s" in any year and the seasonal free-flow event is an annual maximum

(P(s) | s = ice-jam event) = Conditional probability of the annual-maximum stage exceeding a given stage "s" in any year, when only ice-jam events that are annual-maximum peak stages are used in the analysis

P(s= ice-jam event) = Fraction of years for which the annual-maximum peak stage was an ice-jam event

(P(s) | s = ice-jam event) * P(s = ice-jam event) = Joint probability of the annual-maximum stage exceeding a given stage "s" in any year and the seasonal ice-jam event is an annual maximum

F.4.1.3 Summary [February 2002]

Equations 1 and 2 provide two different approaches for combining stage-frequency curves when stage data are directly available, when stage data are determined by the indirect approach described in Subsection F.4.2, or for a combination of the two approaches. For example, the Mapping Partner that performs the detailed study may use Equation 1 where limited historical stage data are available for ice-jam analysis and where the stage data for free-flow conditions are determined using the indirect approach. The Mapping Partner may estimate the probability of the annual-maximum stage exceeding a given stage "s" in any year from an ice-jam event (P(si)) from limited stage data such as three events occurring over at least a 25-year period.

As discussed earlier in this Appendix, the Mapping Partner that performs the detailed study shall perform a graphical analysis using Weibull plotting positions, and combine the probability (P(si) with the free-flow probabilities (P(sq)) using Equation 1. The Mapping Partner shall determine the free-flow probabilities (P(sq)) using discharge-frequency analysis for the free-flow season and standard hydraulic modeling procedures as described in Subsection F.4.2.

Equation 2 is more convenient for directly computing stage-frequency curves for detailed-study reaches where detailed information is available, such as at gaging stations. This approach requires the fraction of time that annual-maximum stages are caused by either ice-jam or free-flow events and uses just the annual-maximum stages for the two types of events. This information is usually not available or easy to determine for ungaged locations.

The Mapping Partner that performs the detailed study shall use the direct approach rather than the indirect approach as discussed below because the joint probabilities of various hydrologic and hydraulic factors (e.g., discharges, ice volumes, ice thickness) are inherently included in the frequency analysis. However, available data are often not sufficient for direct analysis or when hydraulic conditions in the detailed-study reach are different from gaging stations located upstream or downstream of the reach. In those instances, the Mapping Partner that performs the detailed study shall use the indirect approach.

F.4.2 Indirect Approach [February 2002]

The Mapping Partner that performs the detailed study may use the indirect approach to ice-jam stage-frequency analysis where available data are insufficient to establish a stage-frequency distribution directly.

F.4.2.1 Assumptions [February 2002]

The indirect approach to ice-jam stage-frequency analysis makes use of the following assumptions:

- Ice-jam stage frequency is a function of ice-jam season-discharge frequency.
- Ice jams are of the breakup type.
- Ice jams are of the stationary type.
- For all ice jams, the ice thickness will be given by the equilibrium relationship developed in "Formation of Ice Covers and Ice Jams in Rivers" (Pariset, Hauser, and Gagnon, 1966).
- For all ice jams, the stage-discharge relationship will be determined by adjusting the standard step-backwater technique for flow under an ice cover of equilibrium thickness.
- For grounded-type jams, the stage-discharge relationship at the point of ice-jam formation will be that resulting from complete or nearly complete blockage of the normal channel, with flow being carried in the overbank floodplain areas.

F.4.2.2 General Procedures [February 2002]

To apply the indirect approach, the Mapping Partner that performs the detailed study shall use the procedures discussed below.

The Mapping Partner that performs the detailed study shall establish a free-flow stage-frequency distribution for each cross section by using standard backwater modeling to establish stage-discharge relationships. Usually, the four standard (10-, 2-, 1-, and 0.2-percent-annual-chance) flood discharges will provide sufficient points for establishing the stage-frequency curve for each cross section on normal probability paper.

The Mapping Partner that performs the detailed study shall separate the water year into an "ice-jam season" and a "free-flow season" based on the historical occurrence of ice jams in the region and, in particular, in the flooding source that is the subject of the detailed study. The season shall encompass the period when breakup-type ice jams normally occur and will likely vary with the latitude and elevation of the flooding source. Ice jams tend to be associated with one of the seasonal peak flows because ice jams typically form during rises in river stage that break up the ice sheet.

Where peak flow data are available at gaging stations, the Mapping Partner that performs the detailed study shall perform discharge-frequency analyses for the ice-jam and free-flow seasons using procedures described in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). If the logarithms of the peak-flow data do not fit a log-Pearson Type III distribution, then the Mapping Partner may use other frequency distributions or the appropriate plotting position formulas for this purpose. The reasons for deviating from Bulletin 17B procedures shall be documented.

For ungaged streams, the Mapping Partner that performs the detailed study shall establish seasonal discharge-frequency relations by performing a regional analysis of seasonal flows for the gaged streams in the region. Usually, the establishment of regional seasonal discharge-drainage-area relations will be sufficient for this purpose.

The Mapping Partner that performs the detailed study shall then use standard hydraulic techniques to establish corresponding stage-frequency curves for each cross section in the reach where ice jams are to be considered. Usually, the analyses of the standard percent chance of exceedance used for a FEMA-contracted Flood Map Project or community-initiated map revision (i.e., 10-, 2-, 1- and 0.2-percent-annual-chance) will be sufficient to establish the stage-frequency curves. For ice-jam analysis, this is typically accomplished using the ice-cover option in the U.S. Army Corps of Engineers (USACE) HEC-2 hydraulic program or the USACE HEC-RAS computer program. For additional information on the ice-cover option in the HEC-2 program, the Mapping Partner that performs the detailed study should refer to "Analysis of Flow in Ice Covered Streams Using Computer Program HEC-2" (USACE, 1979) on the use of this option.

These options take into account the hydraulic aspects of flow under ice, such as a reduction in flow area, increased wetted perimeter, and ice roughness. The inputs required to use this option include the following:

- Normal HEC-2 or HEC-RAS input;
- Thickness of the ice in the channel and overbank;
- Manning's "n" value for the underside of the ice cover; and
- Specific gravity of the ice.

The recommended ranges for "n" values are from 0.015 to 0.045 for unbroken ice and from 0.04 to 0.07 for ice jams. The specific gravity of normal ice is approximately 0.92 and is the recommended value for this analysis.

Where major floods are caused by ice jams, the assumption of equilibrium ice thickness is probably reasonable because sufficient upstream conditions exist to generate the ice volumes needed. Unless there is strong evidence to the contrary, the Mapping Partner that performs the detailed study shall use the approximate equilibrium thickness as defined in "Formation of Ice Covers and Ice Jams in Rivers" (Pariset, Hauser, and Gagnon, 1966) as the ice thickness for the analysis. Where equilibrium ice thickness is not appropriate, the Mapping Partner that performs the detailed study shall provide written justification to the RPO for the thickness used in the analysis.

The Mapping Partner that performs the detailed study shall calibrate for floating-type jams by assuming equilibrium ice thickness at the location where the ice-jam stage-frequency curve is needed and use a combination of discharge, equilibrium ice thickness, and roughness that would correspond to that stage. The Mapping Partner shall calibrate grounded-type jams by assuming complete blockage of the main channel at the point of obstruction, with equilibrium ice thickness, discharge, and roughness that would correspond to that stage. This will permit the Mapping Partner to use the ice cover option in the HEC-2 or HEC-RAS computer program to estimate corresponding ice-jam stages upstream or downstream of the point where historical data are available.

The Mapping Partner that performs the detailed study shall document that grounded-type ice jams have occurred historically before grounded-type jam behavior is assumed. Grounded-type jams may occur at confined sections, such as bridges, and at shallow sections. The hydraulic analysis assumes that a high percentage of the normal flow area of the channel (or bridge) is obstructed and that most of the flow is in the overbank areas.

At the point of obstruction, the Mapping Partner that performs the detailed study shall use an actual or hypothetical bridge section to permit the special bridge routine the HEC-2 or HEC-RAS computer program to facilitate the analysis. The Mapping Partner shall then adjust the low chord of the bridge (HEC-2 variable ELLC) and the net flow area (HEC-2 variable BAREA) to achieve different degrees of blockage of the main channel.

The Mapping Partner that performs the detailed study shall normally assume between 95- and 100-percent blockage of the main channel unless sufficient evidence exists to support another assumption. In that case, the Mapping Partner shall document and justify the alternative. Upstream from the site of grounding, the Mapping Partner shall assume the equilibrium ice thickness, as computed according to the Pariset formulation (Pariset, Hauser, and Gagnon, 1966), unless alternative thicknesses can be justified.

The Mapping Partner that performs the detailed study shall establish a stage-frequency curve for the ice-jam and the free-flow events by plotting the stages from the HEC-2 or HEC-RAS analyses at each cross section. The Mapping Partner shall plot stages for the 10-, 2-, 1- and 0.2-percent-annual-chance floods on normal (or log-normal) probability paper and draw smooth curves through these points.

Not every flood event during the ice-jam season is affected by ice. If sufficient ice-jam data are available, then the Mapping Partner that performs the detailed study shall incorporate the fraction of time that ice-jam season peak stages are affected by ice in the analysis. If the discharge-frequency relation in the ice-jam season is independent of ice conditions, then the 10-, 2-, 1- and 0.2-percent-annual-chance flood discharges are essentially the same for those years when ice jams occur and when they do not occur.

Under these conditions, the Mapping Partner shall develop water-surface profiles for ice-affected and free-flow conditions in the ice-jam season. A modified version of Equation 1 for combining the stage-frequency curves is as follows:

$$P(s) = [P(sw)*P(si=\text{ice-jam event}) + P(so)*P(si=\text{free-flow event})] + P(sq) - [(P(sw)*P(si=\text{ice-jam event}) + P(so)*P(si=\text{free-flow event})) * P(sq)] \quad (3)$$

where P(s) and P(sq) are as defined in Equation 1

P(sw) = Probability of exceeding a given stage "s" in the ice-jam season developed using the discharge-frequency relationship for the ice-jam season and ice-affected hydraulic conditions

P(si=ice-jam event) = Fraction of years during the ice-jam season that peak stages are affected by ice jams

P(so) = Probability of exceeding a given stage "s" in the ice-jam season developed using the discharge-frequency relationship for the ice-jam season and free-flow hydraulic conditions

P(si=free-flow event) = Fraction of years during the ice-jam season that peak stages are free-flow events

The assumption in Equation 3 is that the conditional distribution of peak discharges for the ice-jam season is the same for ice-affected and free-flow conditions. If ice jams only occur when peak discharges are large or, conversely, if large peak discharges do not occur under free-flow conditions, Equation 3 is not applicable.

F.4.2.3 Summary [February 2002]

For the indirect approach, the Mapping Partner that performs the detailed study shall obtain the composite stage-frequency curve for the various percent-chance-exceedance floods at each cross section. This shall be done by combining the free-flow and ice-jam stage-frequency curves using Equations 1, 2, or 3, depending on the available data and analysis procedures used in establishing the discharge-frequency relationship. The various conditions are summarized below.

If the discharge-frequency analysis was performed using the annual-event approach (two discharge values per year), the Mapping Partner that performs the detailed study shall use Equation 1 to combine the ice-jam and free-flow stage-frequency curves. Equation 1 also applies for combining the stage-frequency curves if regional seasonal discharge-drainage-area relations are used to determine the discharge-frequency curves. Seasonal discharge-frequency curves developed in this manner represent the probabilities of the annual-maximum discharge exceeding a given discharge value during either the ice-jam or free-flow season. These exceedance probabilities are not conditioned or related to the fraction of time that the annual-maximum discharges are either ice-jam or free-flow events; therefore, the conditional-frequency approach of Equation 2 is not appropriate.

If the Mapping Partner that performs the detailed study based the discharge-frequency estimates of the 10-, 2-, 1- and 0.2-percent-annual-chance floods solely on annual-maximum discharge events, then the Mapping Partner shall use Equation 2 for combining the stage-frequency curves. This implies that the discharge-frequency curves used for this analysis are based on either ice-jam or free-flow annual-maximum discharges and that these frequency curves have NOT been adjusted for the fraction of time that the ice-jam or free-flow events are annual maximums.

If the discharge-frequency relationship during the ice-jam season is the same under ice-affected and free-flow conditions and sufficient ice-jam data are available, the Mapping Partner that performs the detailed study shall use Equation 3 to account for the fraction of time that the peak stages in the ice-jam season are actually affected by backwater from ice.

F.5 Presentation of Results [February 2002]

Requirements for presenting the results of the ice-jam analyses in the Flood Insurance Study (FIS) report and on the Flood Insurance Rate Map (FIRM) are presented in Subsections F.5.1 and F.5.2.

F.5.1 Flood Insurance Study Report [February 2002]

The information the Mapping Partner that performs the detailed study shall submit the information summarized in Subsections F.5.1.1, F.5.1.2, and F.5.1.3 for inclusion in the FIS report. The Mapping Partner that prepares the Preliminary and final versions of the FIS report shall, at the direction of FEMA, include this information either in the main body of the FIS report or as an additional subsection at the end of the FIS report. (For additional information on formats for FIS reports, see Appendix J of these Guidelines.)

F.5.1.1 Information To Be Included in Text [February 2002]

The Mapping Partner that performs the detailed study shall submit the information summarized below for inclusion in the text.

- The Mapping Partner that performs the detailed study shall provide a discussion of historic ice jams.
- The Mapping Partner that performs the detailed study shall provide a discussion of any discharge-frequency analysis for the ice-jam season, if used, and the statistical treatment of stage-frequency analysis for the ice-jam and non-ice-jam events. In this discussion, the Mapping Partner that performs the detailed study shall reference the historical data used in the analyses along with its source and how it was used.
- The Mapping Partner that performs the detailed study shall provide a discussion of how free-flow and ice-jam stages were computed and whether stages were computed directly from stage-frequency analyses or indirectly analyzed. The Mapping Partner that performs the detailed study shall include the following topics in this discussion:

  1. Approximate channel blockage and ice thickness assumed, if used;
  2. The relationship of the computed ice-jam stages to historic floods;
  3. An example of stage-frequency curves for combined floods for the point of obstruction, or a representative cross section within the community if the former is outside the corporate or county limits; and
  4. An explanation that regulatory floodways were computed only for free-flow conditions.

F.5.1.2 Information To Be Included in Tables [February 2002]

The Mapping Partner that performs the detailed study shall submit the information summarized below for inclusion in the data tables that appear in the FIS report.

- The Mapping Partner that performs the detailed study shall submit information for the Summary of Discharges Table that is based on an analysis of the full year and footnote the table to that effect.
- The Mapping Partner that performs the detailed study shall submit information for the "Regulatory" column of the Floodway Data Table using the 1-percent-annual-chance (100-year) flood elevations established from the composite ice-jam and free-flow season stage-frequency curves and footnote the table to that effect. All other columns in the Floodway Data Table shall be based on the 1-percent-annual-chance (100-year) floodflow conditions.

F.5.1.3 Flood Profiles [February 2002]

The Mapping Partner that performs the detailed study shall submit Flood Profiles that are based on the elevations established from the composite ice-jam and free-flow stage-frequency analysis.

F.5.2 Maps [February 2002]

The Mapping Partner that performs the detailed study and the Mapping Partner that prepares the Preliminary and final versions of the FIRM for FEMA shall ensure the information shown on the FIRM is based on the elevations established from the composite ice-jam and free-flow stage-frequency analyses performed at each cross section. The Mapping Partners also shall ensure that the regulatory floodways are established and plotted based on the 1-percent-annual-chance (100-year) flood discharges and hydraulics assuming free-flow conditions.

The Mapping Partner that performs the detailed study may indicate the lateral extent of a major historic ice jam on the work map if it is well documented, does not hamper interpretation, and is appropriately annotated as such.

F.6 References **[February 2002]**

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