

Guidance for Flood Risk Analysis and Mapping

Riverine Mapping and Floodplain Boundaries Guidance

November 2019



FEMA

Requirements for the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment, and Planning (Risk MAP) Program are specified separately by statute, regulation, or FEMA policy (primarily the Standards for Flood Risk Analysis and Mapping). This document provides guidance to support the requirements and recommends approaches for effective and efficient implementation. Alternate approaches that comply with all requirements are acceptable.

For more information, please visit the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage (www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). Copies of the Standards for Flood Risk Analysis and Mapping policy, related guidance, technical references, and other information about the guidelines and standards development process are all available here. You can also search directly by document title at www.fema.gov/library.

Document History

Affected Section or Subsection	Date	Description
Sections 8.0	November 2019	This guidance has been updated to clarify implementation of resolving mismatches across community boundaries, and to clarify floodplain boundary smoothing techniques.

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1.0 Riverine Mapping and Floodplain Boundaries Overview

This document provides guidance for riverine mapping and floodplains, and all the components that accompany it. FEMA prepares flood hazard mapping to create broad-based awareness of flood risk, provide data necessary for mitigation programs, and rate flood insurance for specific properties. Each floodplain or flood hazard area is divided into flood insurance rate zones that are based on the floodplain boundaries determined on a work map. Areas within the 1-percent-annual-chance (100-year) floodplain boundary are typically termed Special Flood Hazard Areas (SFHA). Areas between the 1- and 0.2-percent-annual-chance (500-year) floodplain boundaries are termed areas of moderate flood hazard. The remaining areas above the 0.2-percent-annual-chance floodplain are termed areas of minimal flood hazard.

For all types of riverine and floodplain mapping the assigned Mapping Partner should provide, in draft format, a neatly compiled work map that contains the flood hazard data necessary to produce the Preliminary version of the Flood Insurance Rate Map (FIRM). This will be included in a hydraulics or floodplain mapping submission. This will assist in outreach with the community through a flood risk review meeting. The Mapping Partner should coordinate with the region to determine work map specifications. The work map is typically the topographic map used to delineate the updated floodplain boundaries and/or the base map to be used for FIRM production. The assigned Mapping Partner shall submit the work map in digital form unless otherwise approved by the FEMA Lead. The assigned Mapping Partner shall submit the compiled work map (original copy) and/or plots of the digital files as part of the Technical Support Data Notebook (TSDN).

Whenever possible, the assigned Mapping Partner shall ensure that the work map, which shall be prepared in “FIRM-ready” format whenever possible, complies with the following guidelines:

- Use the same base map that FEMA will use for FIRM production for the base map.
- Use the proposed FIRM panel tiling and numbering scheme (this tiling applies only to hard copy maps).
- Prepare individual work map panels at the same scale as the FIRM panels.
- Use labels, legends, and notes that are compatible with the FEMA FIRM graphic specifications provided in the FIRM Panel Technical Reference and FIRM Graphics Guidance.
- Submit digital data in a seamless format (see FIRM Database Technical Reference).

If the assigned Mapping Partner is not required to prepare the work map in a “FIRM-ready” format, the Mapping Partner may submit the work map as strip maps, covering the revised floodplain areas. At a minimum, the work map should cover all areas with updated flood hazard data. Additionally, planimetric features and orthophotos should be compatible with those shown on the base map to be used for FIRM production.

The designated Mapping Partner shall ensure that the effective and revised flood hazard data are compiled into seamless data with no discontinuities. All inconsistencies between new/revised flood hazard data and unrevised flood hazard data should be identified during the Project Scoping

phase and resolved as appropriate in consultation with the FEMA Lead before work commences. The Mapping Partner responsible for the flood hazard data development shall ensure that revised flood hazard data ties in well to the effective flood hazard data. The potential mismatches should have been identified during the scoping phase and addressed at that time. Any problematic residual tie-in issues shall be brought to the attention of the FEMA Project Officer for review and resolution.

All floodplain mapping described in this Guidance Document contracted after September 2, 2005, should conform with Floodplain Boundary Standards (FBS). For Guidance on FBS see Guidance Document #49, Floodplain Boundary Standards.

2.0 Redelineation

Redelineation of riverine floodplains is a useful technique for updating flood hazard information for an effective riverine analysis that is considered valid. Redelineation is often used when effective discharges and Base Flood Elevations (BFEs) appear accurate, but the SFHA seems inaccurate (e.g., flooding losses in Zones B, C, or X; numerous Letters of Map Amendment; comparison with accurate topographic data). The flood boundaries are delineated by finding the intersection of the ground surface defined by the underlying digital terrain model and the flood surface. Redelineation involves using more detailed topographic data than what was used to prepare the effective FIRM, in order to remap the floodplain boundaries based on the flood elevations used in preparing the effective FIRM. Redelineation is to be limited to floodplains studied by detailed methods where BFEs or flood depths are designated on the effective FIRM. However, if elevation or depth data have been generated for a flooding source for which only approximate analyses were performed by FEMA, redelineation may be applied to the Zone A floodplain boundaries as well.

Prior to the redelineation of effective floodplain boundaries, the assigned Mapping Partner should perform the following activities to assess the appropriateness of this approach:

- Review the planimetric features surveyed during the topographic data development process to ensure that the horizontal accuracy is compatible with the selected FIRM base map.
- Review the effective 1- and 0.2-percent-annual-chance flood elevations to ensure that they are valid and usable for the floodplain boundary redelineation process. If conditions have changed such that the Flood Profiles included in the effective Flood Insurance Study (FIS) Report no longer represent existing conditions (e.g., if bridge or culvert construction has occurred), the assigned Mapping Partner may need to perform updated hydrologic and hydraulic analyses and/or investigate if a Letter of Map Revision (LOMR) has been performed at that location which would need to be taken into account. The assigned Mapping Partner shall obtain the required approval from the FEMA Lead before proceeding with such analyses.
- Investigate changes in planimetric or topographic conditions that indicate the need for updated analyses and may preclude the use of this method. Such situations would include significant possible floodplain violations by communities, discrepancies in planimetric

features, topography, or stream distance between Flood Profiles and topographic mapping. The assigned Mapping Partner shall bring these situations to the attention of the FEMA Lead.

Redelineation involves no new analyses. Redelineation uses effective information such as the flood profiles and floodway data tables from the FIS report, BFEs from the FIRM, and supporting hydrologic and hydraulic analyses and new topographic data that are more up-to-date and/or more detailed than those used to produce the effective FIRMs' floodplain boundaries. In many cases, mapping cross sections with interpolated water surface elevations (WSEL) should be derived to supplement effective cross section data, in order to ensure completeness of the resulting redelineated floodplain boundaries.

Possible sources of existing topographic data include local planning departments, Geographic Information System (GIS) coordinators, engineers, public works departments, FEMA archives, and state Departments of Transportation.

Detailed specifications for topographic data and field surveys are contained in FEMA Guidance Document No. 47, [Elevation Guidance](#). Guidance Document No. 47 is also accessible through the [FEMA Guidelines and Standards for Flood Risk Analysis and Mapping](#) webpage. In order to evaluate the suitability of existing topographic data, the Project Management Team shall consider the following factors:

- Contour Mapping or Digital Elevation Models: contour interval should be 4 feet or less (2 feet in flat terrain).
- Currency of data: if significant changes exist (e.g., highways, subdivisions, and/or mining). In some cases it may be possible to utilize only portions of updated topographic data in order to perform the redelineation. If a question about the currency/accuracy of topographic data exists, users should reference the metadata record, or contact the data owner for verification. Additionally, comparative analyses should be performed to verify the accuracy of topographic data in reference to past and present ground conditions.

The topographic data and the base map data used for the FIRM must be compatible. Features in both data sources must align and show current ground conditions. If suitable existing topographic data are not available, it will be necessary to develop new topographic and/or survey data. Guidance Document No. 47 provides the requirements for developing new topographic data and performing cross section and structure surveys.

When re-delineating effective flood hazard data, if WSEL are not available for all cross sections, the Mapping Partner must generate that elevation data from the corresponding streams' Flood Profile in the effective FIS report. The cross sections must traverse the floodplain and be oriented perpendicular to the direction of flow. The Mapping Partner must use the complete set of effective hydraulic cross sections to develop the required flood profiles. If the topographic data used in the redelineation differs significantly from the topographic data used to create the effective model indicating that the effective hydraulic analyses are no longer valid, the Mapping Partner must coordinate further actions with the FEMA Project Officer.

All data for redelineation must be submitted in digital format. The Mapping Partner performing "Floodplain Mapping" for redelineation is required to submit the data described in [Data Capture Technical Reference](#).

3.0 Mapping of One-Dimensional Riverine Analyses

Upon completion of a one-dimensional analysis the Mapping Partner, at a minimum, must delineate the floodplain and floodway boundaries of the base flood. The Mapping Partner must also delineate the floodplain boundaries associated with the 0.2-percent-annual-chance flood, if it is calculated.

The flood boundaries are delineated by finding the intersection of the ground surface defined by the underlying digital terrain model and the flood surface. Floodplain boundaries are delineated on the best available topographic mapping using the water-surface elevations determined at cross sections. Between cross sections, WSELs are interpolated. The interpolation is linear along smooth lines following the general direction of the flow close to the boundary. The topographic mapping should be digital, accommodating an automated or semi-automated floodplain mapping algorithm; manual delineation should be used only if digital topographic data are not available. Final boundaries should be reviewed for hydraulic reasonableness based on the best topographic information, the hydraulic modeling results, photographs, flood profile information, and engineering judgment.

The floodplain boundaries must be shown in a georeferenced spatial file, as defined in section 6.9 of the [Data Capture Technical Reference](#), and in section 9 of the [FIRM Database Technical Reference](#). If inspection of this file does not demonstrate that the cross sections (and/or BFE lines) are aligned perpendicular to the flow, in the submittal special considerations documentation described in [Data Capture Technical Reference](#) the Mapping Partner must document why, contrary to what may be indicated, the flow direction is in fact perpendicular to each cross section.

4.0 Mapping of Two-Dimensional Riverine Analyses

Two-dimensional flood analysis results in a (regular or irregular) grid of flood elevation values. Each cell in the model is attributed with a flow direction and flood elevation or is designated as not flooded or dry. The floodplain is delineated using the collection of cells with flood elevations. Although rare, non-conveyance areas may be input into the two-dimensional model using artificially high roughness values. The Mapping Partner should ensure that non-conveyance areas that should be included in the floodplain are mapped as such.

If the flood elevation grid cannot be used directly in GIS software as a digital surface, the Mapping Partner should develop such a surface. Most GIS software contains options to develop such a surface. The floodplain boundaries are delineated by either finding the intersection of the ground surface defined by the underlying digital terrain model and the flood surface, or subtracting the ground surface grid from the WSEL grid and finding the boundaries of those cells with differences (i.e., flood depths) greater than zero. The Mapping Partner must fully document the methods used to develop the flood surface and to determine flood boundaries.

The Mapping Partner should delineate BFE contour lines using the digital flood surface. The contour interval should be sufficient to discern the flow direction at any point within the floodplain. The Mapping Partner should verify that the flow directions indicated by the contour lines agree with the flow directions in the output grid.

The flood boundaries and BFE lines must be provided in a georeferenced spatial file as defined in section 6.9 of the [Data Capture Technical Reference](#), and Section 9 of the [FIRM Database Technical Reference](#). If necessary for presentation purposes, the Mapping Partner should smooth the boundaries and contour lines. In lieu of Flood Profiles, the flood elevation grid may be utilized by map users to interpolate between the flood surface contour lines.

5.0 Floodway Mapping

The floodway is a tool to assist communities in balancing development within the floodplain against the resulting increase in flood hazard. The Mapping Partner should coordinate with the community when developing floodways as early as possible in the study process, and more detailed guidance can be found in the [Floodway Analysis and Mapping Guidance](#) document. A regulatory floodway is defined as the channel of a river or other watercourse and the adjacent land area that is reserved from encroachment in order to discharge the base flood without cumulatively increasing the water-surface elevation, or surcharge, by more than a designated height.

For one-dimensional riverine analyses, floodways are delineated at encroachment stations (limits of conveyance) at cross sections and delineated between cross sections. The floodway boundaries must be smooth lines following the general direction of floodwaters, gradually widening or narrowing to reflect the changes in width between cross sections. The floodway must be shown in a georeferenced spatial file submitted as part of the hydraulics and floodplain submittal described in Section 6.6 of the [Data Capture Technical Reference](#), and Section 9 of the [FIRM Database Technical Reference](#). Floodway boundaries should be mapped at the channel bank stations when the floodway surcharged elevation is lower than the channel bank elevation or the base flood is contained within the channel. If a floodway exists upstream or downstream of the study reach, the floodway data for the study reach must be contiguous with the floodway data for the existing study.

Regulatory floodways are not normally delineated in coastal high-hazard areas (i.e., Zones V1-30, VE, and V). For more information about mapping floodways near coastal zones refer to Section 2.2 of [Combined Coastal and Riverine Floodplain](#) guidance.

Where the floodway is mapped differently than the model results in order to meet state requirements, the Mapping Partner should document the state requirements and the location(s) that discrepancies occur.

6.0 Base Flood Elevation Line Placement

WSELs of the 1-percent-annual-chance (base) flood are called BFEs. The BFEs may be designated on the FIRM using BFE lines or cross sections. The use of BFE lines is only required in special cases. Whole-foot BFEs (i.e., 1-percent-annual-chance WSEL values located with BFE lines) are shown at appropriate locations to allow map users to estimate 1-percent-annual-chance flood elevations. BFE lines must traverse the floodplain and be oriented perpendicular to the direction of flow. BFE lines must not cross each other or cross sections delineated in the georeferenced spatial file. BFE lines are to be plotted at significant profile inflection points (profile

breaks) where flood elevations are not reported at modeled sections, or as close to them as possible. The [Mapping Base Flood Elevations on Flood Insurance Rate Maps Guidance](#) provides placement rules for BFE lines and mapped cross sections. Static BFEs will be shown under the zone labels (e.g., in areas of ponding or coastal areas).

7.0 Future Conditions Flood Mapping

Communities experiencing urban growth and other changes often use future-conditions hydrology in regulating watershed development. While some communities regulate based on future development, others are hesitant to enforce more restrictive standards without FEMA support. For those communities experiencing urban growth and to assist community officials, FEMA decided to include flood hazard data based on future-conditions hydrology on FIRMs and in FIS reports for informational purposes at the request of the community. This decision was documented in a Final Rule published in the Federal Register on November 27, 2001.

Because multiple options exist for presenting future-conditions floodplains and related data on the FIRM and in the FIS report, interested community officials should contact the FEMA Project Officer to discuss available options and agree on the approach to be taken. For information on these options, FEMA encourages interested community officials to review the November 27, 2001, Final Rule and the FEMA report titled [Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using Future-Conditions Hydrology for the National Flood Insurance Program](#) (FEMA, 2001). That report contains one possible scenario/example of depicting future-conditions flood hazard information on a FIRM and in an FIS report and may be downloaded from the FEMA web site by searching the title of report.

At the request of a community and with the approval of FEMA, FIRMs and FIS reports may include, for informational purposes, flood hazard areas based on projected or future conditions hydrologic and hydraulic analyses. If community officials request that FEMA show the future-conditions base floodplain on the FIRM, the future-conditions floodplains and flood insurance risk zone should be shown on the FIRM and referenced in the accompanying FIS report. The future-conditions flood insurance risk zone is shown as a shaded Zone X area and labeled as "Zone X (Future)."

FEMA opted to use a Zone X (shaded) screen, in lieu of a new flood hazard zone designation, to depict the future-conditions base floodplain to minimize confusion by users of the FIRM who make determinations regarding federal mandatory flood insurance purchase requirements. Those users now recognize that areas designated as Zone X (shaded) are flood prone, but that the mandatory flood insurance purchase requirement does not apply.

Once future-conditions flood hazard data have been included on the FIRM and in the FIS report for a community, all revision submittals should incorporate the future-conditions data developed by the community. The community is entirely responsible for developing and maintaining this data layer on a FIRM.

8.0 Floodway and Flood Hazard Tie-Ins; Boundary Post-Processing

FEMA Standards #70 and #71 establish criteria for tying in floodway data across jurisdictional or Flood Risk Project boundaries. For more information on requirements for matching floodway data across various boundaries, refer to Guidance Document 45, [Contiguous Community Matching Guidance](#). Guidance Document No. 45 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.

Per FEMA Standard #306, any existing differences in flood hazard data across boundaries of adjacent jurisdictions must be identified and resolved as part of a FIS Report/FIRM update. This includes gaps or overlaps in flood hazard data between communities, counties, or states as well as consistency between adjacent FIRM panels. For more information on requirements for matching flood hazard data across various boundaries, refer to Guidance Document 45. Guidance Document No. 45 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage. This guidance for tying in flood hazard data across boundaries applies to all mapped flood hazard return periods, not just the 1-percent-annual-chance-flood hazard. The guidance regarding flood hazard boundary tie-ins applies to both one-dimensional and two-dimensional riverine boundaries.

Refer to the FEMA Best Practice: [Floodplain Boundary Processing](#) for information on common GIS methodologies and strategies for smoothing One- and Two-Dimensional floodplain boundaries. These methodologies may include, but are not limited to: smoothing boundaries to reduce line complexity, simplifying and generalizing boundaries to reduce boundary vertex count, or other strategies using commonly available simplification algorithms in GIS software. The [Floodplain Boundary Processing](#) Best Practice is accessible through the FEMA Knowledge Sharing Site, accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.

Any boundaries that are smoothed, generalized, or otherwise post-processed must still meet Floodplain Boundary Standards. Refer to Guidance Document No. 49, [Floodplain Boundary Standards \(FBS\) Guidance](#) for full details on FBS requirements. Guidance Document No. 49 is accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage.