Levees in Risk Rating 2.0

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FEMA

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1. Introduction

This document provides an overview of the levee data that supports Risk Rating 2.0. It offers a baseline understanding of the sources and methodology used to develop key levee data input for the catastrophic modeling and actuarial rating process. Computing the average annualized loss (AAL) from catastrophic loss models and setting insurance rates are not described in this document. Refer to https://www.fema.gov/flood-insurance/work-with-nfip/risk-rating# for additional information.

2. Background

FEMA is updating the National Flood Insurance Program's (NFIP) risk rating methodology through the implementation of a new pricing methodology called Risk Rating 2.0 to better serve the nation. By leveraging "industry best practices" and current technology, FEMA aims to deliver rates that are actuarily sound, more equitable, and easier to understand and that better reflect a property's individual flood risk. Risk Rating 2.0 allows FEMA to calculate premiums more consistently for all policyholders, based on the value of their home and their property's individual flood risk, by moving toward a graduated risk approach that expands beyond the binary depiction of flood risk centered around the 1%-annual-chance (100-year) flood event.

The graduated risk approach for Risk Rating 2.0 accounts for flood hazards larger and smaller than the 1%-annual-chance flood by leveraging additional data, beyond that depicted on Flood Insurance Rate Maps (FIRMs). The resulting rates more clearly and accurately identify and communicate the flood risk exposure of an individual building by accounting for multiple flood hazard sources (e.g., river, rainfall, coastal storms, and tsunami) and flood risk reduction measures such as levees.

It is important to note that not all aspects of the NFIP are changing. Community officials and lenders will continue to use effective FIRMs to determine if a building is located within a Special Flood Hazard Area (SFHA), an area that is subject to inundation by the base (1%-annual-chance) flood, to inform floodplain management and mandatory flood insurance purchase requirements. Lenders will also retain the prerogative to require flood insurance, even in the absence of the federal requirement to purchase coverage.

As part of Risk Rating 2.0, FEMA has not proposed any changes to the levee accreditation requirements established in the Code of Federal Regulations (CFR) at Title 44 – Emergency Management and Assistance, Section 65.10 (44 CFR 65.10), nor to the levee analysis and mapping procedures for non-accredited levees, which are documented in FEMA's guidelines and standards for the analysis and identification of the 1%-annual-chance flood hazard on a FIRM.

3. Levees in Risk Rating

FEMA included the impact of levee systems on flood risk reduction in Risk Rating 2.0. To do so, it partnered with the U.S. Army Corps of Engineers (USACE) to identify and use credible and consistently available information and methods to account for the level of risk reduction levees provide to the buildings located behind them. FEMA partnered with USACE to determine the key levee data needed to evaluate the impact of residual flood risk at the building level, identify readily available sources of levee information, and implement best practices to develop or refine data when possible.

Risk Rating 2.0 estimates the likelihood that a building will experience damage from flooding (and how much damage would occur), to set insurance policy rates. Levee data helps to inform the benefits and risks that a levee provides to businesses, communities, and the public for purposes of modeling the losses due to floods. A levee reduces – but does not eliminate – flood risk. The limitations of a levee system, in both its capacity to reduce flooding in leveed areas (informed by overtopping frequency) and its ability to perform adequately during flood events (levee performance) are fundamental to developing a graduated risk approach for Risk Rating 2.0. As such, more robust and better performing levees yield a quantifiable benefit to insurance policy holders.

In general terms, Risk Rating 2.0 follows three primary steps for areas with levees, as depicted in the simplified process graphic (Figure 1). The first step is the key levee data input, the second step uses catastrophic models that calculate average annualized loss at the building level, and the third step involves the actuarial rating process to set a base rate and rating factors. Levee data has an impact on the catastrophic modeling and the rating process (e.g. Levee Quality factor). This document focuses on the key levee data required to support Risk Rating 2.0 and explains the sources and/or methodology for developing the needed data.

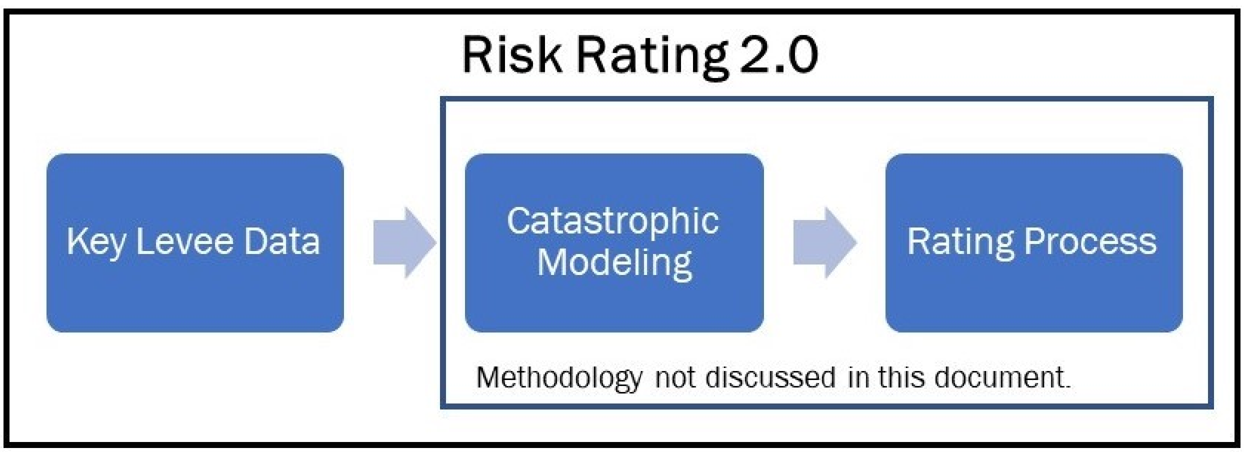

Figure 1. Risk Rating 2.0 simplified process graphic, including levee inputs

3.1. Risk Associated with Levee Systems

To identify the risk for communities behind levee systems, FEMA considers the likelihood of a flood hazard occurring, how a levee is expected to perform when exposed to that hazard, and the related consequences of a levee overtopping or a levee breach (Figure 2). For this document, hazard is defined as flooding from riverine sources and consequences are defined as damages a building may sustain from flooding. To incorporate the impact of levees in Risk Rating 2.0 one must understand the hazard, the anticipated performance of the levee, and the number of buildings that would be impacted if the levee is overtopped or does not perform as intended. Levees serve as a structural risk reduction measure to decrease the likelihood of consequences being realized. How well a levee reduces the consequences of flooding is an important factor for catastrophic loss modeling and rate setting in Risk Rating 2.0.

Figure 2. Risk Rating 2.0 data sources for key levee data

3.2. Anatomy of a Levee

The following section defines and describes the anatomy of a levee to provide a common understanding of the physical features used to evaluate the residual flood risk for buildings behind levees. Figure 3 illustrates common levee-related terms used in this document.

A levee is a man-made structural feature, usually an earthen embankment or concrete floodwall, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide risk reduction from temporary flooding. The levee's function is to exclude water from a portion of the floodplain – referred to as a leveed area – where houses, businesses, and assets may have a reduced flood risk because the levee exists. The levee crest is the top of the levee. The levee centerline is a line representing the highest points along the levee crest. The elevations of this centerline, when viewed in profile, yield a levee crest profile (Figure 4). Finally, the water surface profile represents the elevation of the water against the levee for a flood event of a particular frequency.

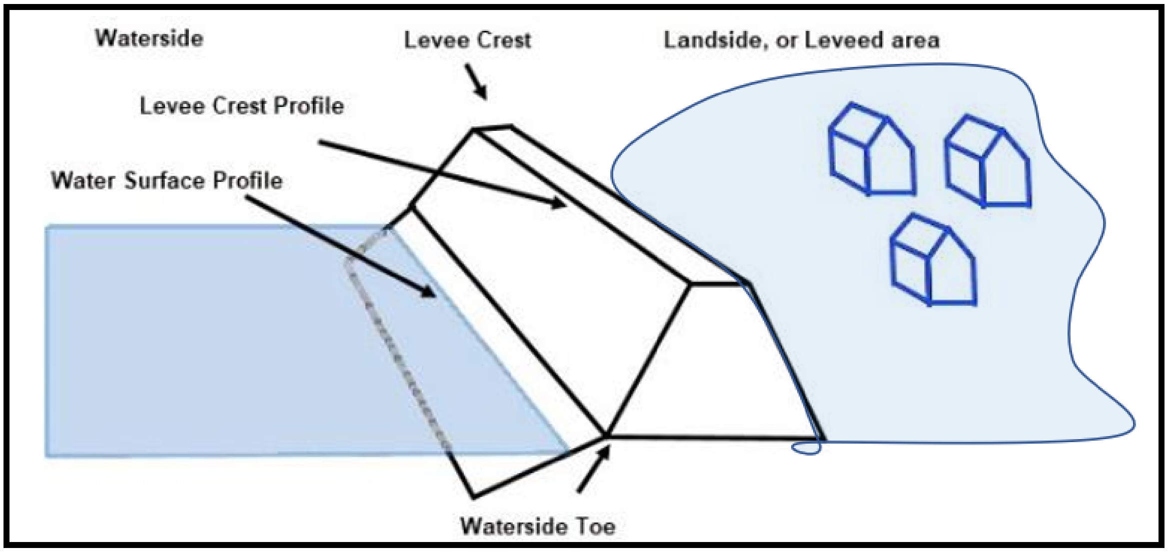

Figure 3. Generalized levee system labeled with common levee terminology

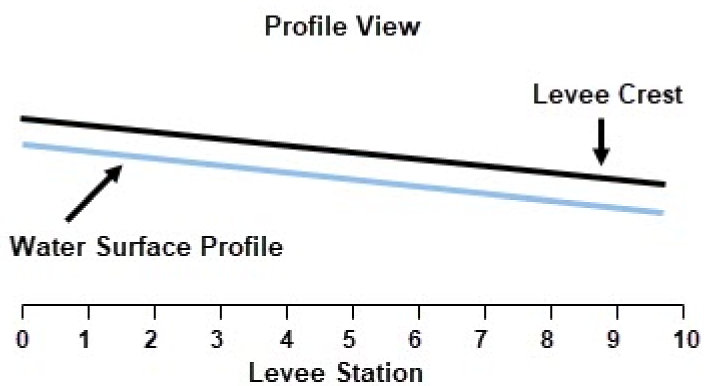

Figure 4. The levee crest profile and water surface profile, plotted along the levee in a profile view

The overhead (or plan) view in Figure 5 introduces two other important concepts: levee systems can be made up of discrete segments. The levee system as a whole creates a leveed area that represents the areas of reduced flood risk due to the presence of the system. While the segmentation of levees is typically used to designate different ownership or responsibilities, each segment is crucial for the entire levee system to function and reduce flood risk in the leveed area. The location where overtopping occurs most frequently sets the elevation at which water begins to flow over the levee and into the leveed area.

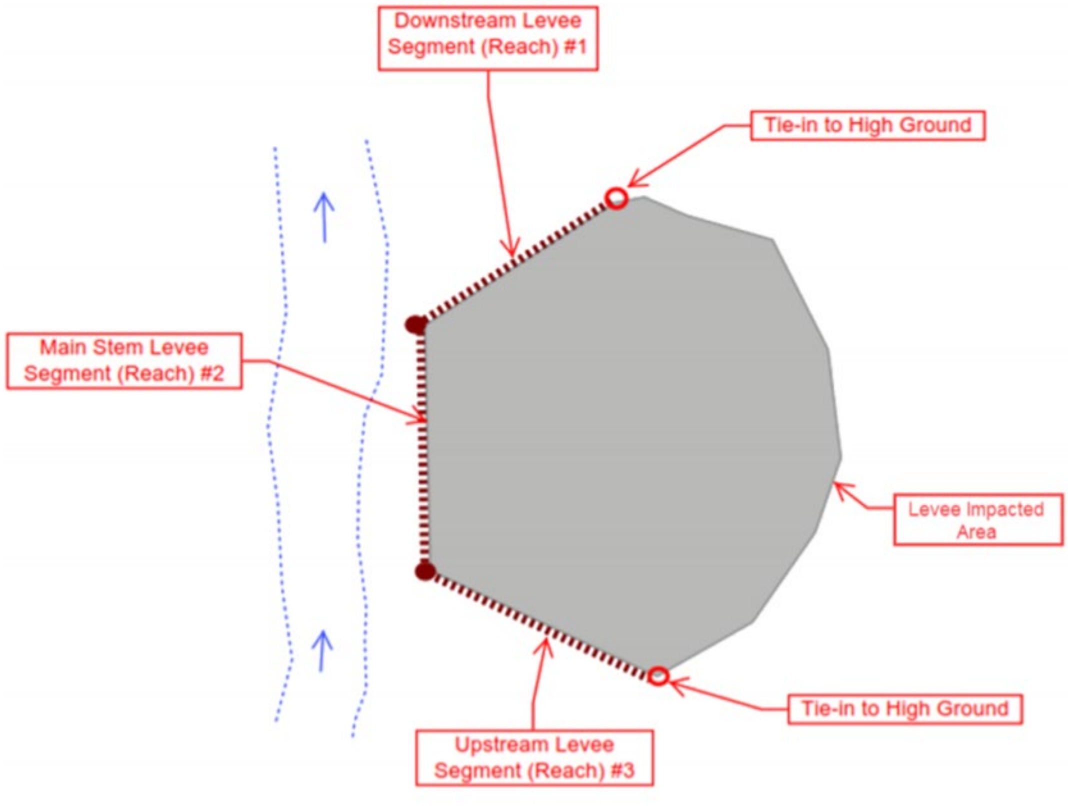

Figure 5. A levee system composed of a series of levee segments

3.3. Key Levee Data Overview

FEMA and USACE have a long history of partnering and developing complementary procedures related to levees. For Risk Rating 2.0, FEMA partnered with USACE to obtain credible and consistently available data and methods to determine a levee's level of risk reduction. Five key levee data elements were needed to support Risk Rating 2.0:

1. **Levee Centerline**: Defines the location of a levee in plan view. For Risk Rating 2.0, the levee centerline represents the top of the levee.
2. **Levee Crest Profile**: The elevation of the top of the levee along a levee centerline. For Risk Rating 2.0, the levee crest informs the overtopping frequency.
3. **Leveed Area**: A polygon representing the lands (and buildings) excluded from the floodplain by the presence of the levee (i.e. the area with a reduced flood risk due to a levee).
4. **Levee Overtopping Frequency**: The likelihood that a flood event will exceed the height of a levee, allowing flood water over the top of the levee (i.e. overtopping).

5. **Levee Performance**: A system response curve representing the estimated likelihood of breach under various flood levels. For Risk Rating 2.0, the system response curve was limited to levee performance prior to overtopping.

3.4. Data Sources

The long-term management of Risk Rating relies on key information from comprehensive data sources, including those related to levees. This allows FEMA to efficiently process and update rates at an individual building level. Risk Rating 2.0 used data that was either readily available or could be generated in a consistent and timely manner. Therefore, key sources of levee information, such as the USACE-maintained National Levee Database (NLD), were used to identify available levee data. USACE and FEMA are both committed to using the NLD as the authoritative and primary national resource for levee information.

3.4.1. NATIONAL LEVEE DATABASE AND LEVEE SCREENING TOOL

The NLD, developed and maintained by USACE, is the focal point for comprehensive information about all the nation's levees, as authorized by Congress. The NLD is a dynamic database that is continually updated to add or refine levee data from federal agencies, states, tribes, territories, and local sources.

The Levee Screening Tool (LST) is a web-based risk assessment tool that USACE uses to efficiently characterize levee risk. Users combine readily available information on hazards, conditions, performance, and consequences and apply engineering judgment to describe the performance of a levee and the potential consequences of flooding. At the time of the data pull for Risk Rating 2.0 (Section 3.4.5), USACE had applied the LST risk assessment process to more than 1,700 of the levee systems in the NLD. This subset of levees is referred to in this document as “screened levees.”

Levee information is shared between the NLD and LST. For screened levees, the LST is the primary source of levee performance data, and the NLD is the primary source for levee location information such as the centerline, crest profile, and leveed area. Estimates of levee overtopping frequencies for screened levees are contained in both the NLD and LST, with the estimate typically originating from the LST.

3.4.2. UNDERSTANDING DATA AVAILABILITY

The quantity and quality of levee information in the NLD and LST vary. FEMA used the data available from these sources as described in the sections that follow. Levees that USACE routinely inspects generally have more high-quality and detailed information available; that data was used for Risk Rating 2.0. For other levees where detailed information was not readily available, data from the NLD was used and enhanced using consistent methods. For some key levee data fields, a lack of readily available information required assumptions to be made.

The NLD is a dynamic database that is continually updated, so it may not yet contain any information for some of the nation's levees. USACE and FEMA are working together to learn more about these levees and will continue to collaborate to update levee information in the NLD as appropriate.

For Risk Rating 2.0, most of the screened levees (approximately 20% of the levee systems in the NLD) had the information to fulfill all five key levee data needs (levee centerline, levee crest profile, leveed area, overtopping frequency, and levee performance). The NLD reports that these screened levees mitigate the risk for approximately 60% of all buildings behind levees. Approximately 80% of the levee systems in the NLD had not been screened at the time of the data pull for Risk Rating 2.0 (Section 3.4.5).

The following steps were taken to develop data for unscreened levees in the NLD:

- Secondary data sources were identified and used.
- Existing data in the NLD was improved using consistent methodology.
- Assumptions were made in the absence of readily available data.

Not all levees have buildings behind them; thus, an absence of data for these systems is inconsequential for setting rates. Data refinement and improvements were prioritized for levees where high-quality Digital Elevation Model (DEM) data was readily available and where 50 or more buildings were in the leveed area.

3.4.3. OTHER DATA SOURCES

This section describes other national datasets used to develop supplemental levee data to support Risk Rating 2.0. FEMA used the Fathom dataset to calculate levee overtopping frequency where that data did not exist. Also, publicly available DEM from the USGS 3D Elevation Program (3DEP) were used to develop geospatial features such as levee profiles and leveed areas.

<u>Fathom</u>

FEMA used the national Fathom-US 2.0 dataset to estimate the overtopping frequency for levees that did not have data available from a previously discussed source. Fathom produces 10 frequency-based water surface elevation grids, based on nationwide regional frequency analysis, to establish stage relationships at critical sites throughout the nation. FEMA leveraged the Fathom data to provide expedient and consistent estimates of levee overtopping frequencies. The Fathom data was converted and associated to the levee centerline to compare the levee crest profile to the frequency-based water surface elevations. Water surface elevations were available for these 10 frequencies: 5-year, 10-year, 20-year, 50-year, 75-year, 100-year, 200-year, 250-year, 500-year, and 1,000-year floods. Section 3.7.1 describes the general methodology used for estimating overtopping frequencies from Fathom data, quality control, and validation.

3.4.4. DATA SOURCE HIERARCHY

The data source hierarchy indicates the key sources of levee data that were used and which sources were considered to have a higher quality than others. When data was available from multiple sources, the highest quality data (as determined by the hierarchy) was used in Risk Rating 2.0. However, if Fathom estimated levee overtopping to be more frequent than the 1% annual exceedance probability (AEP) for an accredited levee on a FIRM, the overtopping frequency was assumed to be the 1% AEP. Levee centerlines, crest profiles, and leveed areas were sourced from the NLD. In some cases, the levee centerline and leveed area were improved and updated in the NLD.

Table 1: Risk Rating 2.0 key levee data source hierarchy

Key Levee Data	Hierarchy
Levee Centerline	National Levee Database
Levee Crest Profile	National Levee Database Refinement Process (Section 3.5)
Leveed Area	National Levee Database Refinement Process (Section 3.6)
Levee Overtopping Frequency	Levee Screening Tool National Levee Database Fathom Assumed Values
Levee Performance	Levee Screening Tool Assumed Values

3.4.5. DATA PULL

Data to support Risk Rating is pulled annually from its data sources to coincide with the planned annual update cycle. Each iteration of Risk Rating represents a snapshot in time of the information available from the key levee data sources. For Risk Rating 2.0, levee risk reduction benefits were considered for every feature identified as a levee system in the NLD in early March 2020. This is important to note, as the NLD is a dynamic database that is continually updated. Current NLD information may reflect changes made since the data pull for Risk Rating 2.0. FEMA will continue working with USACE to leverage the highest quality levee data readily available in support of future rate updates and a risk-informed NFIP.

Table 2 provides a summary of the data sources and methods used for each key levee data field for Risk Rating 2.0. It also summarizes the approximate percentage of levee systems and buildings associated with each data source or method. These percentages will change over time as more levee data becomes readily available in the future.

Table 2: Risk Rating 2.0 data sources for key levee data

DATA SOURCES FOR KEY LEVEE DATA USED IN RISK RATING 2.0

KEY LEVEE DATA FIELDS	DATA SOURCE/METHODS	% OF LEVEE SYSTEMS	% OF BUILDINGS BEHIND LEVEE SYSTEMS
LEVEE ALIGNMENT/ CENTERLINE	NATIONAL LEVEE DATABASE*	100%	100%
LEVEE CREST PROFILE	• NATIONAL LEVEE DATABASE	22%	78%
	• DEVELOPED WITH HIGH QUALITY DEM	20%	8%
	• NO PROFILE AVAILABLE (< 50 BUILDINGS OR HIGH-QUALITY DEM NOT AVAILABLE)	58%	14%
LEVEED AREA	NATIONAL LEVEE DATABASE*	100%	100%
LEVEE OVERTOPPING FREQUENCY	• LEVEE SCREENING TOOL	19%	60%
	• NATIONAL LEVEE DATABASE	<1%	4%
	• FATHOM FLOOD DATA	17%	11%
	• ASSUME 1% ANNUAL CHANCE FLOOD *(FOR ACCREDITED LEVEES WHERE HIGHER QUALITY DATA NOT AVAILABLE)*	6%	15%
	• ASSUME 2% ANNUAL CHANCE FLOOD *(<50 BUILDINGS OR INSUFFICIENT INFORMATION AVAILABLE)*	57%	10%
LEVEE PERFORMANCE	• LEVEE-SPECIFIC SYSTEM RESPONSE CURVE FROM SCREENING	19%	60%
	• AVERAGE LEVEE PERFORMANCE BASED ON USACE INCIDENT DATA	81%	40%

**Some Levee Alignments and Leveed Areas were refined and incorporated back into the NLD as part of Risk Rating 2.0.*

3.5. Levee Centerline and Crest Profile

The levee centerline and crest profile are required to derive additional key levee data. The levee centerline is needed to develop the crest profile, and the levee crest is needed to assess the likelihood of levee overtopping and to derive a leveed area.

The NLD contains geospatial levee data, including the levee centerline and crest profiles. All levee entries in the NLD have a levee centerline that locates the levee geographically, but not all levees in the NLD currently have a crest profile associated with the centerline. This can hinder users' ability to assess the likelihood of levee overtopping. The NLD centerline and profile data may be derived from survey information (as is the case for most screened levees) or terrain-based methods. Risk Rating 2.0 used terrain-based methods when centerline and profile data were not available from the NLD.

3.5.1. METHODOLOGY

In the absence of surveyed levee crest elevations, existing levee centerlines in the NLD were topographically adjusted to improve the spatial location and ultimately derive a levee crest profile. The terrain-based method uses DEM with a spatial resolution of 3 meters or better to improve the location of the levee centerline and the crest elevation profile. The primary source of DEM was USGS 3DEP, supplemented by data from state repositories as needed. The levee centerline was refined by cutting cross-sections along the existing centerline and shifting the centerline vertices to the highest point at each levee cross section (Figure 6). The crest profile was developed from the elevations pulled from the DEM at each new vertex along the updated centerline. The quality of resultant levee profiles was reviewed and rejected if anomalies were present in the data. Levee centerlines were improved using the assumption that all levee segments in the system were identified and the levee extents (the start and stop points) did not require adjustment. A total of 130 levee system centerline and profiles were updated with this method.

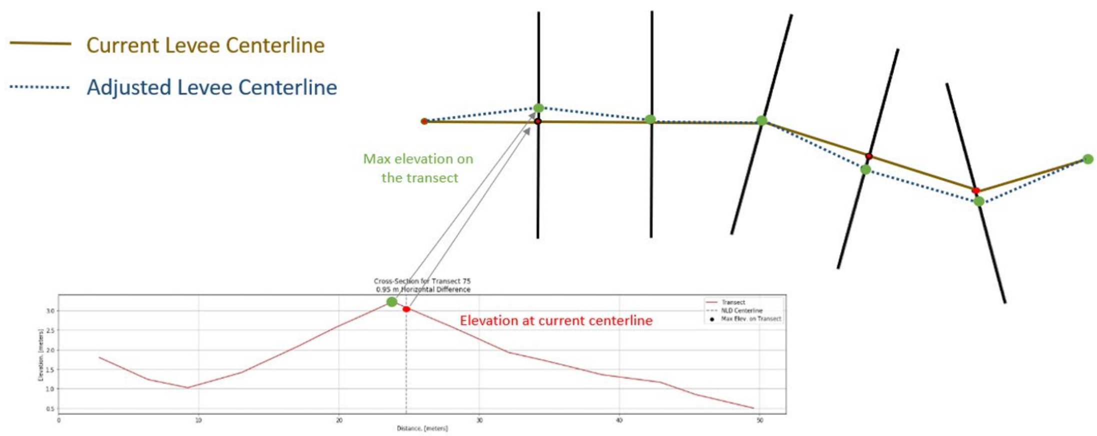

Figure 6. Centerline adjustment procedure

3.6. Leveed Area

The leveed area represents the lands from which the levee system excludes flood water. Geospatial data was used to identify buildings with a reduced flood risk due to the presence of a levee. The leveed area is separate and distinct from the regulatory Special Flood Hazard Area, because it is based on flood loading to the levee crest and not a discrete flood frequency event (i.e. 1%-annual-chance flood). Similar to levee centerlines, all levee systems in the NLD have a leveed area. The leveed area in the NLD may be developed by various methods.

3.6.1. METHODOLOGY

The Risk Rating 2.0 effort included refining leveed areas where sufficient data was available. This required a levee crest profile and a high-quality DEM. Leveed areas were developed using a "flood fill" method that creates a polygon around all areas in the DEM below a target elevation. The target elevation is typically the lowest elevation in the levee crest profile, which represents the extent of flooding for a flood event at the capacity of the levee. This leveed area method only applies to levee systems with a relatively flat levee crest profile in relatively flat terrain. Engineering judgment was applied to determine if the modified leveed area was an improvement over the existing leveed area in the NLD. Ninety leveed areas were modified using this method.

3.7. Levee Overtopping Estimates

A levee overtopping estimate is required to support Risk Rating 2.0. This estimate was made by comparing the levee crest profile elevations with the frequency-based flood water surface elevations. For screened levees, an overtopping frequency was estimated following USACE's levee screening process and entered in the LST. For non-screened levees, overtopping frequency was estimated using the methodology and assumptions described in the following paragraphs

3.7.1. METHODOLOGY

Levee overtopping estimates are sourced and selected for use based on a hierarchy (discussed in Section 3.4.4) that uses the most precise method for which data is readily available. If a levee segment or levee system did not have an overtopping estimate from an available source, such as the LST or the NLD, the overtopping estimate was derived by comparing Fathom data to the levee crest profile (Figure 7). The selected overtopping frequency was the most infrequent Fathom flood frequency water surface profile that is wholly below the levee crest profile. For example, in Figure 7, the levee centerline crest profile can wholly contain the 100-year (1%-annual-exceedance probability) flood event, but not a greater Fathom profile, without overtopping.

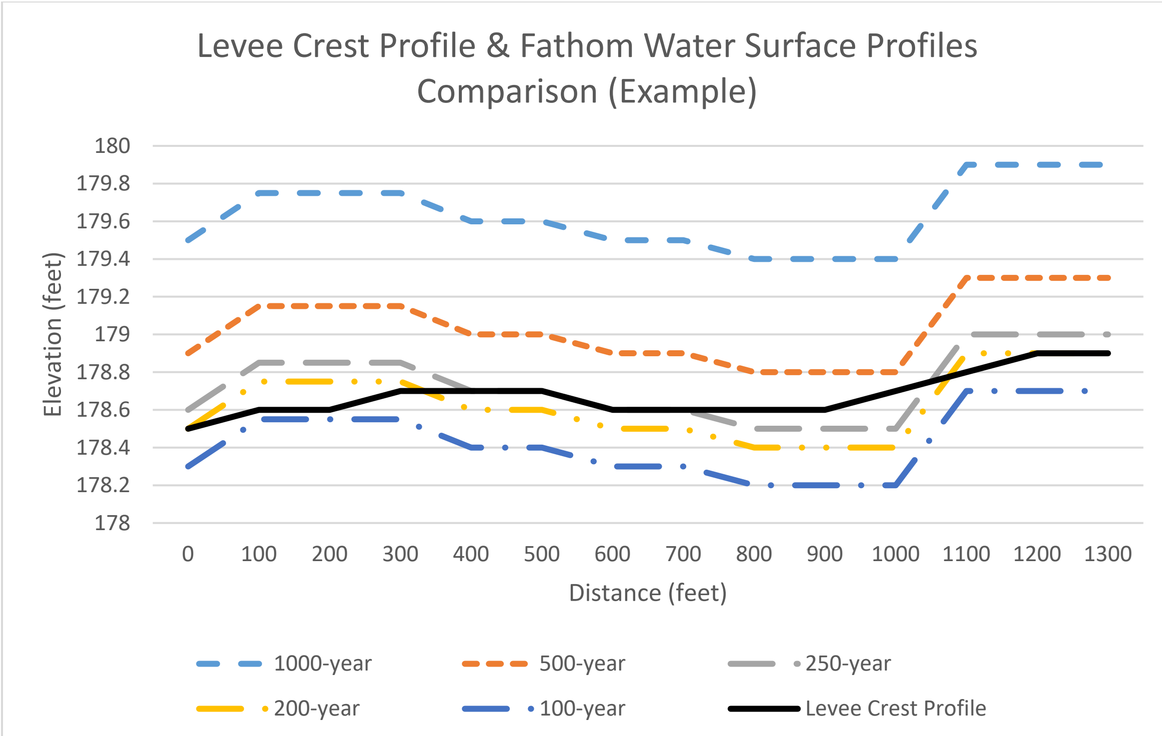

Figure 7. Example of Fathom water surface profiles for recurrence intervals (shown: 5 of the 10 available) compared to the levee crest profile

Before using Fathom data, FEMA conducted a series of quality checks and then validation. Quantitative and qualitative data analysis checks were used to verify the quality of the data. Data that did not conform to expected patterns, such as predictable increasing river stage with less frequent flood events and generally monotonic water surface profiles, and data having excessive data anomalies, were discarded. Next, Fathom-derived levee overtopping estimates were validated to give confidence that the data source could reasonably predict overtopping frequency when there is no LST or NLD data. The validation compared levee systems where both Fathom and NLD or LST data were available, to understand the potential bias. No significant data bias was identified; however, the Fathom data generally skewed to overstate the risk reduction (estimating a less frequent overtopping value than established LST or NLD estimates).

3.7.2. DATA DEVELOPMENT

Fathom data was used to calculate overtopping frequency estimates for 17% of levee systems, all of which were unscreened. As a result, 37% of levee systems considered in Risk Rating 2.0 have an overtopping estimate derived from either the LST, NLD, or Fathom data, and they cover 75% of the buildings behind levees.

3.7.3. ASSUMPTIONS

Assumptions for overtopping frequency were required for levee systems that did not have available or reliable information from the LST, NLD, or Fathom. One of two assumptions was applied in these cases. First, if a levee system was identified as accredited on a FIRM, the assumed overtopping frequency was a 1% annual exceedance probability (AEP) flood event. In situations where Fathom data estimated a more frequent overtopping for an accredited levee system, the 1% AEP overtopping frequency was still assumed. However, if Fathom estimated levee overtopping to be less frequent than the 1% AEP for an accredited levee, then the overtopping frequency derived from Fathom was used. Second, FEMA assumed the levee overtopping frequency as a 2% AEP flood event for the remaining 57% of levees (and associated 10% of buildings in leveed areas).

3.8. Levee Performance (System Response Curve)

A measure of the anticipated levee performance during flood loading is represented by a system response curve. The system response curve is a curve denoting the likelihood of a levee breach under various flood heights. Generally, a levee has an increased likelihood of breach as flood water surface elevations increase. Figure 8 illustrates examples of system response curves for three categories of levee quality or performance. For Risk Rating 2.0, the levee overtopping frequency, levee toe loading frequency, and levee performance factors are needed to create a system response curve. The shape of the curve varies based on available levee incident data. System response curves and overtopping frequencies are used in FEMA's catastrophic modeling and during the rate-setting process. The "Levee Quality" factor used in rate setting is derived from the system response curve. Additional information on the application of the "Levee Quality" factor in "Risk Rating 2.0 Methodology and Data Source" (April 16, 2021) is available at https://www.fema.gov/flood-insurance/work-with-nfip/risk-rating#.

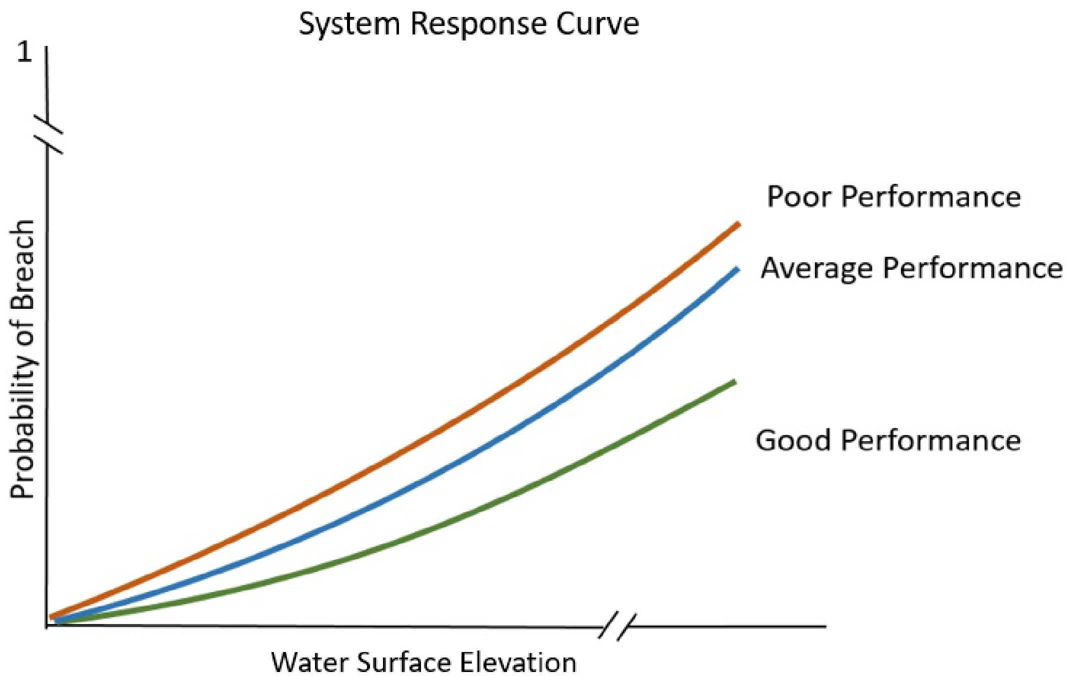

Figure 8. Examples of system response curves with different evaluated levee performance

3.8.1. METHODOLOGY

For all screened levees, system response curves were developed from risk assessment information in the USACE LST. The probability of a breach with water at the top of the levee (P-Top) is calculated for each potential failure mode evaluated in the LST and then combined to estimate a P-Top for the levee system. With the levee crest and levee toe loading frequencies, the P-Top value is used to estimate the levee system response curve. Once the system response curve is developed, a rating variable indicating levee performance is calculated from the area under the curve. The performance indicator value is a probability weighted average. The system response curve is also adjusted for the likelihood of flood-fighting efforts to intervene and mitigate levee performance issues during a flood event.

In the absence of a LST risk assessment-based system response curve, the USACE incident data statistics on average performance of a typical levee were used to derive an “average” levee system response curve for the remaining levees.

For Risk Rating 2.0, all segments in a system were evaluated together to identify residual risk at the system level. The segment with the highest likelihood to overtop and most likely to experience poor performance governs system performance and was used to derive the system response curve. The curve was applied to the entire system’s leveed area.

4. Further Study

A key element in understanding the level of risk reduction provided by levees is having credible and readily available data that describes the location, leveed area, likelihood of overtopping, and the performance of levees. FEMA will continue working with USACE to improve levee data and to refine risk assessment methodologies in support of future iterations of Risk Rating and a risk-informed NFIP. FEMA and USACE are committed to further collaboration and alignment around a shared methodology for assessing levee risk across the nation, communicating flood risk in a consistent and comprehensive manner, and equipping the public to make risk-informed decisions.