National Risk Index Data Version and Update Documentation

To provide a consistent and accurate baseline risk assessment, the National Risk Index must periodically review and update source data and methods. Several changes have been made since the Phase 1 release of the National Risk Index on November 16, 2020. These changes incorporated new and better data and enhanced the methodology for several hazard types to improve the quality of risk results.

The National Risk Index is a dataset and online tool to help illustrate the United States communities most at risk for 18 natural hazards. It was designed and built by the Federal Emergency Management Agency (FEMA) in close collaboration with various stakeholders and partners in academia; local, state, and federal government; and private industry.

In the National Risk Index, risk is defined as the potential for negative impacts as a result of a natural hazard. The risk equation behind the Risk Index includes three components: *Expected Annual Loss, Social Vulnerability*, and *Community Resilience*. Expected Annual Loss represents the average economic loss in dollars resulting from natural hazards each year, and it is calculated using a multiplicative equation that includes three factors:

- **Annualized Frequency** represents the expected frequency or probability of a natural hazard occurrence per year.
- **Exposure** is the representative value of buildings, population, or agriculture potentially exposed to a natural hazard occurrence.
- **Historic Loss Ratio** represents the estimated percentage of the exposed population, building value, or agriculture value expected to be lost due to a natural hazard occurrence.

Over 80 subject matter experts representing 71 entities contributed to the development of the National Risk index by reviewing or providing data or supporting collaborative working groups to identify the best available and reputable data sources. All data supporting the components of the Index are nationwide in scope and able to be measured at minimum the Census tract level.

FEMA

Data Version v.1.17.0 (October 2020)

The Phase 1 release of the National Risk Index was on November 16, 2020. The release contained the initial *Risk Index*, *Expected Annual Loss*, *Social Vulnerability,* and *Community Resilience* results for each county and Census tract in the 50 states and the District of Columbia.

Data Version v.1.18.0 (August 2021)

The National Risk Index development team regularly meets with experts in specific hazard types, responds to user feedback, and keeps track of new or enhanced data sources to continually improve the product. Version v.1.18.0, which was publicly released on August 16, 2021, had significant enhancements in seven areas over the initial version v.1.17.0, released in November 2020. Table 1 illustrates the scope of the seven enhancement areas (numbered) by the hazard types and risk factors impacted by the change. The following correspondently numbered sections provide further details on each enhancement area.

Hazard Type	Frequency	Exposure			Historic Loss Ratio			Social Vulnerability	Community Resilience
		Population	Building	Agriculture	Population	Building	Agriculture		
Avalanche	1			N/A	6	6	N/A		
Coastal Flooding	2				6	6	N/A		
Cold Wave					6	6	6		
Drought		N/A	N/A		N/A	N/A	6		
Earthquake				N/A	6	6	N/A		
Hail					6	6	6		
Heat Wave				7	6	6	6, 7		
Hurricane				7	6	6	6, 7		
Ice Storm				N/A	6	6	N/A		
Landslide	3			N/A	6	6	N/A		
Lightning				N/A	6	6	N/A		
Riverine Flooding	4				6	6	6		
Strong Wind					6	6	6		
Tornado	5	5	5	5, 7	5, 6, 7	5, 6, 7	5, 6, 7		
Tsunami				N/A	6	6	N/A		
Volcanic Activity				N/A	6	6	N/A		
Wildfire				7	6	6	6, 7		
Winter Weather				7	6	6	6, 7		

Table 1 National Risk Index v.1.18.0 Enhancement Summary by Hazard Type and Risk Factor

1. Avalanche

The frequency factor for the Avalanche hazard type was updated to include three additional years from the source dataset, Arizona State University's (ASU) Spatial Hazard Events & Losses Database for the United States (SHELDUS). The period of record went from 1/1/1960 to 12/31/2016 in v.1.17.0 to 1/1/1960 to 12/31/2019 in v.1.18.0. Thus, the period of record went from 57 to 60 years.

2. Coastal Flooding

Expected Annual Loss (EAL) estimation for the Coastal Flooding hazard type is modeled in four subtypes: (1) sea level rise and high tide (SLRHT) flooding, (2) 100-year flood area, (3) 500-year flood area, and (4) hurricane surge. For v.1.18.0, the frequency factor of the SLRHT flooding subtype was updated. The previous approach used a simple national estimate of three flooding events per year for all areas susceptible to SLRHT flooding. This was refined in v.1.18.0 to derive *regional* frequency estimates by calculating average flood frequencies for each region from high tide flooding (HTF) recurrence intervals for 146 National Oceanic and Atmospheric Administration (NOAA) tidal gauges distributed throughout the continental U.S. and Hawaii. These regional frequencies are adapted from NOAA research on HTF patterns.[1]

The methodology was also updated to adjust SLRHT frequencies for areas designated by the source data as being protected by levees. These areas received a SLRHT frequency of 1/500 years rather than the average frequency for its region.

3. Landslide

The frequency factor for the Landslide hazard type was updated to utilize a new source dataset: National Aeronautics and Space Administration's Cooperative Open Online Landslide Repository (COOLR). v.1.17.0 used a predecessor of COOLR with a period of record from 1/1/2010 and 11/20/2018. v.1.18.0 uses COOLR data with a period of record from 1/1/2010 and 12/31/2019. Thus, the period of record went from 8.9 to 10 years.

4. Riverine Flooding

The frequency factor for the Riverine Flooding hazard type was updated to include three additional years from the source dataset, the National Centers for Environmental Information's (NCEI) Storm Events Database. The period of record went from 1/1/1995 to 12/31/2016 in v.1.17.0 to 1/1/1996 to 12/31/2019 in v.1.18.0. Thus, the period of record went from 22 to 24 years.

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[1] Sweet, V.W., Dusek, G., Obeysekera, J., and Marra, J.J. (2018). *Patterns and projections of high tide flooding along the U.S. coastline using a common impact threshold*. NOAA Technical Report NOS CO-OPS 086. Retrieved from https://tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf (accessed December 4, 2021).

5. Tornado

There was a major overhaul of the modeling approach for the Tornado hazard type that impacted all EAL factors. Foundationally, the methodology expanded from modeling all tornadoes of different magnitudes in the same way to modeling tornadoes for three subtypes based on the Enhanced Fujita (EF) scale: (1) EF-scale 0 and 1; (2) EF-scale 2 and 3; and (3) EF-scale 4 and 5.

The exposure and frequency factors for the Tornado hazard type were updated to include two additional years from the source dataset, the Storm Prediction Center's Severe Weather Database Files, compiled by the National Weather Service (NWS). The period of record went from 1/1/1986 to 12/31/2017 in v.1.17.0 to 1/1/1986 to 12/31/2019 in v.1.18.0. Thus, the period of record went from 32 to 34 years.

Modeling tornado frequency for communities is a challenge because tornadoes can happen almost anywhere but generally impact very small geographic areas. For instance, EF-0 and 1 tornadoes impact less than 1 km^2 on average. The v.1.17.0 methodology made very conservative frequency assumptions where both counties and Census tracts inherited frequencies by an approach that counted historic tornado occurrences where paths were buffered by 80 kilometers (regardless of EF-scale) for each cell they intersected in a national 49-by-49-km fishnet grid. This method effectively increased the influence of past tornado occurrence on nearby communities even if those areas had not been impacted by past tornadoes. After discussions with tornado experts, the National Risk Index team updated the frequency approach to be less conservative by calculating subtype frequencies, scaling tornado counts by subtype nationally, and area-apportioning subtype frequencies to counties and Census tracts. This resulted in a major reduction and more accurate estimate of tornado occurrence rates.

For the exposure factor, representative damage areas were developed for each subtype based on the average areas impacted by historical tornadoes within the subtype. The v.1.17.0 methodology utilized a single representative damage area of 2.0 km^2 that was applied to a county or Census tract average consequence value density. The v.1.18.0 methodology uses these representative areas: 0.78 km^2 for subtype 1, 13 km^2 for subtype 2, and 79 km^2 for subtype 3.

In v.1.17.0, the loss ratio per basis exposure calculation was based on historic tornado paths occurring in each county during the year-month in which SHELDUS-documented loss occurred. In v.1.18.0, HLRs were enhanced by matching historical tornado paths from NWS with the SHELDUS loss events for event-specific loss ratios. Subtype specific HLRs were generated.

The three EAL factors were modeled separately for each subtype. EAL was calculated for each subtype and then summed up for the Tornado EAL.

These enhancements significantly changed the Tornado risk profile. In particular, they reduced risk in high population density counties where severe tornadoes are rare, particularly in the Northeast and Great Lakes states.

6. Historic Loss Ratio

The Historic Loss Ratios (HLRs) for all hazard types were updated to include three additional years (2017-2019) from the source datasets:

- **Cold Wave:** NCEI's Storm Events Database

- **All Other Hazards:** ASU's SHELDUS

Thus, the period of record went from 21 to 24 years.

In addition, the National Risk Index team was granted access to SHELDUS's individual peril event loss records to develop v.1.18.0 HLR estimates. The v.1.17.0 version used summarized hazard county-month loss records. Access to the more granular data enabled development of more accurate loss ratio per basis estimates. These enhancements impacted the risk profile for all hazard types for all counties and Census tracts.

7. Expanded Agriculture Consequences to Five Additional Hazard Types

Within the National Risk Index, losses are estimated for three consequence types: building, population, and agriculture (crop and livestock). Each hazard type is modeled to have losses in one or more of these consequence types. Impacts to buildings and population were estimated for all hazard types except Drought, which only estimated agriculture losses. In v.1.17.0, agriculture losses were also estimated for those hazard types where historically agriculture losses contributed greater than 10% of the total reported losses.

In v.1.18.0, the loss contribution threshold was reduced to 1% resulting in agriculture loss estimation for five additional hazard types: Heat Wave, Hurricane, Tornado, Wildfire, and Winter Weather. This change resulted in a $292M increase of EAL nationally, a 7% increase in agriculture losses. The most significant impacts were from hurricanes in communities in the Southeast.

Data Version v.1.18.1 (November 2021)

Version v.1.18.1, which was publicly released on November 18, 2021, had one change from Version v.1.18.0, which was released in August 2021. Table 2 illustrates the scope of the enhancement area by the hazard type and risk factors impacted by the change. The number corresponds to the section below that provides further details on the enhancement.

Hazard Type	Frequency	Exposure			Historic Loss Ratio			Social Vulnerability	Community Resilience
		Population	Building	Agriculture	Population	Building	Agriculture		
Hurricane					8	8	8		

Table 2 National Risk Index v.1.18.1 Enhancement Summary by Hazard Type and Risk Factor

8. Corrected Hurricane HLR Calculations

In v.1.18.1, the HLR calculation process for the Hurricane hazard type was updated to correct a bug that was identified in the v.1.18.0 release.

HLRs are hazard-specific, county-specific estimates of the percentage of the exposed consequence type expected to be lost in a single hazard occurrence. A county's HLR could be the simple average of a county's loss ratios (losses divided by exposure) from past hazard occurrences. However, because there are often wide variances in loss ratios or not enough hazard occurrences for a statistically significant average, the National Risk Index methodology employs a Bayesian credibility approach that considers multiple geographic levels. Specifically, averages and variances of the individual hazard occurrence loss ratios are calculated for each consequence type for up to four levels depending on the hazard type: (1) county, (2) surrounding area (196-by-196-km grid), (3) regional, and (4) national.

The intent for the Hurricane hazard type in the v.1.18.0 release was to utilize county, surrounding area, and regional levels in the calculation of the Bayesian-adjusted HLR values; however, a bug was found that the county, surrounding area, and *national* levels were used instead. In v.1.18.1, this bug was corrected to the original intent.

This correction resulted in new Hurricane building, population, and agriculture HLR values that affect the Hurricane and composite EAL values and scores and risk scores for all counties and Census tracts where Hurricanes are deemed possible. The impact of this correction is most noticeable in inland counties, particularly in the Midwest and Southwest where hurricanes are deemed possible but have not had many loss causing events in the 24-year period of record. As part of the update, these counties now receive contribution from the regional level, which for inland areas, is generally lower than the national average that includes loss ratios from coastal counties where loss ratios are generally much higher.