

Extreme Events, Insurance, and Resilience: Board on Atmospheric Sciences and Climate 2025 Fall Meeting

Modeling extreme events in a changing climate

Ed Kearns, Chief Science Officer, First Street

EXTREME EVENTS, INSURANCE, AND RESILIENCE: BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE
2025 FALL MEETING

A PRESENTATION FOR THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING AND MEDICIINE
NOVEMBER 3, 2025

Physical climate risk data products must be built on accuracy, resolution, and trust.

1

Purpose Built Models

We use Open Science to create physics-based, deterministic models that calculate property-level risk statistics today, and into the future in a changing climate.

2

Building Specific

We use structure characteristics to estimate a building's damage and downtime from any event. This asset-specific risk information is generally unavailable from government sources.

3

Beyond the Property

We quantify risk to nearby infrastructure, roads, and social facilities, along with projected population and demographic shifts, and changes in property valuations.

4

Validated Methodology

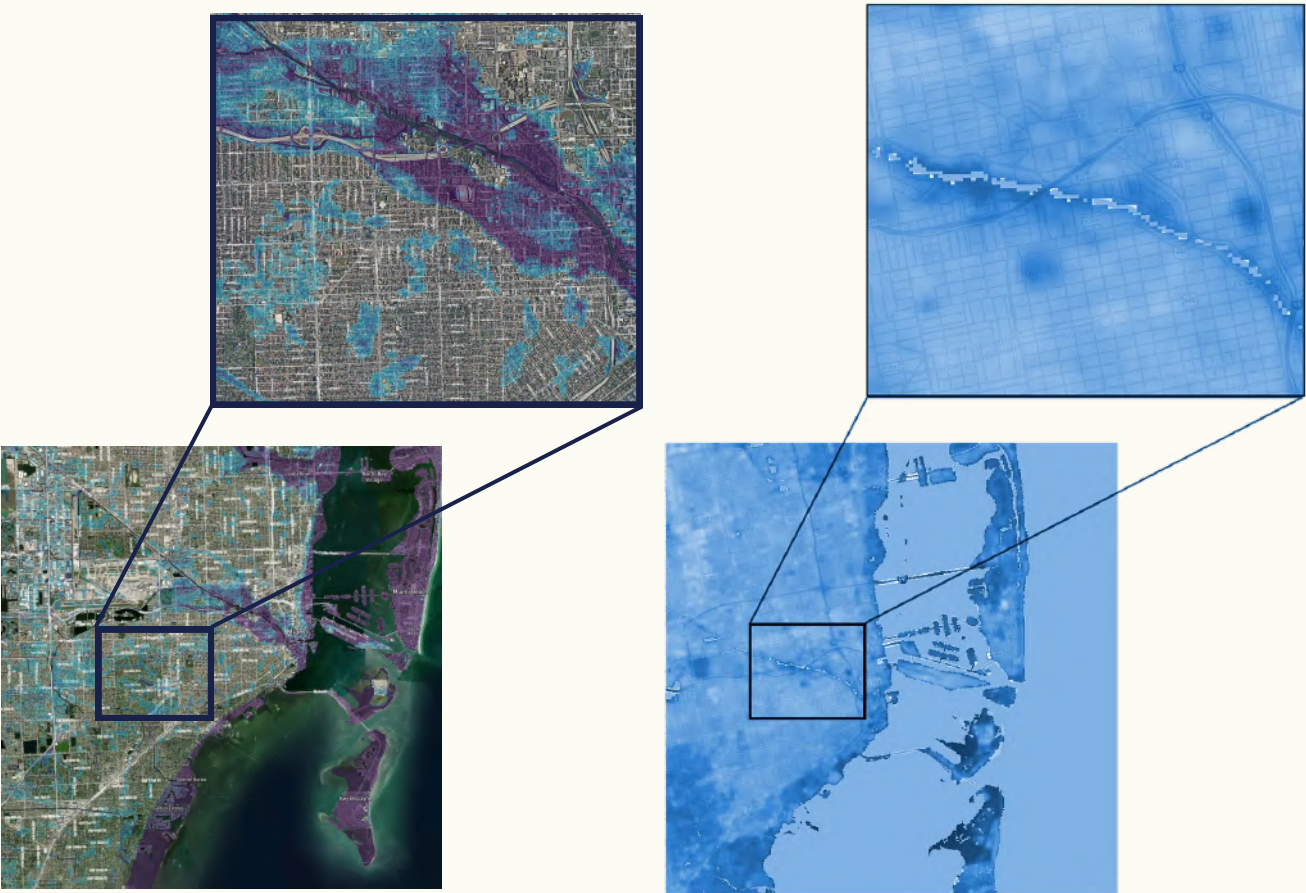
We created climate risk models that are peer-reviewed, transparent, and validated repeatedly against real-world events.

5

Translated to Financial Impacts

We translate the physical risk to financial risks for businesses, investors, governments, and individuals.

Approach: use climate model outputs *as **inputs*** to physics-based models to produce useful, high resolution risk information.



3 METER RESOLUTION FSF
HYDRAULIC FLOOD MODEL

2 KM DOWNSCALED
PRECIPITATION CLIMATE MODEL

FLOOD MODEL LEVERAGES HYDRAULIC MODELS (HEC-RAS AND LISEFLOOD)

Riverine, Rainfall, and Coastal Flood Components.
Simulate the flow of water across the earth's surface.
Allows us to resolve water on the Surface at 3m-30m resolution.

WILDFIRE MODEL LEVERAGES A FIRE BEHAVIOR MODEL (ELMFIRE)

A Monte Carlo simulation of wildfires across the land surface to build up estimates of burn probability and flame length at 30m across the landscape.

Allows fire to penetrate into the Wildland Urban Interface (WUI) to assess risk to homes in those areas.

HURRICANE WIND MODEL LEVERAGES THE EMANUEL (2006) TECHNIQUE
FOR HURRICANE BEHAVIOR SIMULATIONS

Use synthetic hurricanes o increase the number of storms available for analysis.

Estimate the damage from 3-sec wind gusts on buildings.

Reliable input data are needed to drive physics-based models.

First Street uses US Government open data from NOAA, NASA, USGS, USDA, USFS, EPA, USACE, and FEMA for its hazard modeling, as well as data from the EU's Copernicus system.

CLIMATE FORECASTS

- WCRP CMIP6 simulation outputs (SSP245 (mid), SSP585 (high), SSP126 (low))
- Downscaled climate model data from NASA NEX-GDDP

HISTORIC

- USGS High Water Mark data
- NFIP flood claims (aggregate)
- FEMA significant flood hazard area designations
- FEMA Individual Assistance claims
- EPA Ozone and PM2.5 observations

IMAGERY

- USGS Landsat satellite data
- USDA NAIP aerial imagery
- EU Sentinel 2

TIDE & SURGE DATA

- NOAA Water Level and Tide Gauges

FUELS AND FIRE

- US Forest Service/DOI LANDFIRE Fuels
- US Forest Service Fire Occurrence Database
- US Forest Service Fire Suppression Difficulty Index

WINDS

- NOAA IBTrACS Historical Hurricane tracks
- ETCs from EU's ERA5

ELEVATION DATA

- USGS National Elevation Database, 3DEP lidar inputs
- Copernicus GLO-30

RIVER FLOWS

- USGS Stream Gauge data

PRECIPITATION

- NOAA ASOS rain data
- GloH20's MSWEP global precipitation*

When US Government data are insufficient we create new inputs to achieve model accuracy — and publish those methods.

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Assessment of the standard precipitation frequency of the United States

Jungho Kim ^{a,*}, Evelyn Shu, Kelvin Lai, Mike Amodeo, Jeremy Porter

^a First Street Foundation, Brooklyn, NY, USA

ARTICLE INFO

ABSTRACT

Keywords:

Extreme precipitation
Precipitation frequency estimate
NOAA Atlas
NEXRAD Stage-IV
Radar-based IDF curve

Study region: The Conterminous United States
Study focus: The NOAA Atlases have provided (PFEs) for over two decades in the United States. This study evaluates the Atlases compared Surface Observing System and Regional and examines a radar-based precipitation frequency post-Atlas.
New hydrological insights for the region: The study is highlighted as a significant factor in increasing the tendency to underestimate PFEs compared to the the ASOS-RFA increases as the return period is Atlases correlated with the difference, suggests estimates. The radar-based PFEs are well-matched but the uncertainties increased as the return period bias correction was limited in improving the accuracy used to pay careful attention to an increase in the durations.

1. Introduction

The intensity and frequency of extreme precipitation events have rapidly grown within two decades (NOAA, U.S. Climate Extremes Index, 2016; Wright et al., 2019). The continent has been considered in projecting dynamic atmospheric phenomena with many g Mallakpour and Villarini, 2015). There is a strong argument that flooding driven by infrastructure design criteria primarily based on Intensity-Duration-Frequency (IDF) curves (Sivini et al., 2020). Therefore, consistently updating IDF curves following an informed trend in the trend of extreme weather events, is essential to prevent substantial loss of life and Chu, 1957; Kidd et al., 2017; DeGaetano and Castellano, 2018; Sun et al., 2019). This study evaluates radar-based precipitation data as the primary data for developing the post-Atlas. An IDF curve describes precipitation intensity (e.g., precipitation frequency estimate

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2214-5818/© 2022 The Author(s). Published by Elsevier B.V. This is an open access article under the <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

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Atlas of probabilistic extreme precipitation based on 21st century records in the United States

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^a First Street Foundation, Brooklyn, NY, USA

ARTICLE INFO

ABSTRACT

Keywords:

Climate change
Non-stationarity
Extreme precipitation
Precipitation frequency estimate
NOAA Atlas

Study region: The Conterminous United States
Study focus: Extreme precipitation property defined Administration's Precipitation-Frequency Atlas of representativeness as the standard measure due to to spatially and quantitatively assess the change comparing the NOAA Atlas 14 with a new atlas developed in this study from early 21st-century records. **New hydrological insights for the region:** The NOAA recent 20-year records due to precipitation non-stationarity at Atlas 14 is characterized by more spatially smooth than employing the NOAA Atlas 14 could lead to local scale. As the "new normal" in the 21st century times more occurrences of extreme storms correspond 20th century. The recent 20-year extreme events in NOAA Atlas 14 is updated to account for climate resolve local effects better, it is recommended to middle bounds of PFE that capture the non-stationary underestimation of PFEs is highlighted in this study.

1. Introduction

A change in extreme precipitation (EP) and its non-stationarity have been accelerated by (2019). The regular occurrence of catastrophic flood events is no longer surprising in the United States and highlighted throughout recent history. The frequency of EP events has (Kunkel et al., 1999). An increasing trend of EPs was nationally observed from 1910 through United States presented significant increments of frequency up to 12% (Karl and Knight, 2002), annual maximum precipitation is about 6.9% per global warming degree (Barbero et al., 2018). A combination of thermodynamic and dynamic changes is the primary driver leading precipitation because warmer temperatures increase the atmospheric moisture content, cyclone frequency (2021). Atmospheric rivers in the western coastline regions, troughs in the desert Southwest,

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fire



Article

The Construction of Probabilistic Wildfire Risk Estimates for Individual Real Estate Parcels for the Contiguous United States

Edward J. Kearns ^{1,*}, David Saah ², Carrie R. Levine ², Chris Lautenberger ³, Owen M. Doherty ⁴, Jeremy R. Porter ¹, Michael Amodeo ¹, Carl Rudeen ⁵, Kyle D. Woodward ², Gary W. Johnson ², Kel Markert ², Evelyn Shu ¹, Neil Freeman ¹, Mark Esser ¹, Kelvin Lai ¹, Ho Hsieh ¹, Bradley Wilson ¹, Beth McClenny ¹, Andrea McMahon ² and Farrukh Chishtie ²

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Abstract: The methodology used by the First Street Foundation Wildfire Model (FSF-WFM) to compute estimates of the 30-year, climate-adjusted aggregate wildfire hazard for the contiguous United States at 30 m horizontal resolution is presented. The FSF-WFM integrates several existing methods from the wildfire science community and implements computationally efficient and scalable modeling techniques to allow for new high-resolution, CONUS-wide hazard generation. Burn probability, flame length, and ember spread for the years 2022 and 2052 are computed from two ten-year representative Monte Carlo simulations of wildfire behavior, utilizing augmented LANDFIRE fuel estimates updated with all the available disturbance information. FSF-WFM utilizes ELMFIRE, an open-source, Rothermel-based wildfire behavior model, and multiple US Federal Government open data sources to drive the simulations. LANDFIRE non-burnable fuel classes within the wildland-urban interface (WUI) are replaced with fuel estimates from machine-learning models, trained on data from historical fires, to allow the propagation of wildfire through the WUI in the model. Historical wildfire ignition locations and NOAA's hourly time series of surface weather at 2.5 km resolution are used to drive ELMFIRE to produce wildfire hazards representative of the 2022 and 2052 conditions at 30 m resolution, with the future weather conditions scaled to the IPCC CMIP5 RCP4.5 model ensemble predictions. Winds and vegetation were held constant between the 2022 and 2052 simulations, and climate change's impacts on the future fuel conditions are the main contributors to the changes observed in the 2052 results. Non-zero wildfire exposure is estimated for 71.8 million out of 140 million properties across CONUS. Climate change impacts add another 11% properties to this non-zero exposure class over the next 30 years, with much of this change observed in the forested areas east of the Mississippi River. "Major" aggregate wildfire exposure of greater than 6% over the 30-year analysis period from 2022 to 2052 is estimated for 10.2 million properties. The FSF-WFM represents a notable contribution to the ability to produce property-specific, climate-adjusted wildfire risk assessments in the US.

Keywords: fire model; property-level; climate; fuels; ignition

1. Introduction

The threat of increasing wildfire risk across the United States has been described by a number of studies that discuss both the increasing incidence of wildfire and the increasing threat to forests and communities [1–3]. The implications of this growing risk threaten the economic stability, natural resources, and quality of life for the affected communities and local residents, and there are a number of resources (e.g., <https://wildfiresearchcenter.org/>, accessed on 13 June 2022; <https://wildfirerisk.org/>, accessed on 13 June 2022) now available

Fire 2023, 13, 117. <https://doi.org/10.3390/fire5040117>

<https://www.mdpi.com/journal/fire>

1.RAINFALL CLIMATOLOGY

First Street calculated a new rainfall climatology for the US that properly resolves recent climate change impacts on rain-driven flood events. NOAA's Atlas 14 does not capture climate change impacts.

3.WILDFIRE FUEL LAYERS

First Street replaced nonburnable fuels in the USFS/DOI LANDFIRE database within the Wildland Urban Interface (WUI) to resolve fire risk to those communities. LANDFIRE was not built for WUI or urban issues.

5.ELEVATION AND SURFACE ROUGHNESS

First Street constructed a digital terrain model (DTM) of all land use (built environment) and land cover (natural environment) for flood modeling and wind impact assessments.

2.FLOOD ADAPTATION

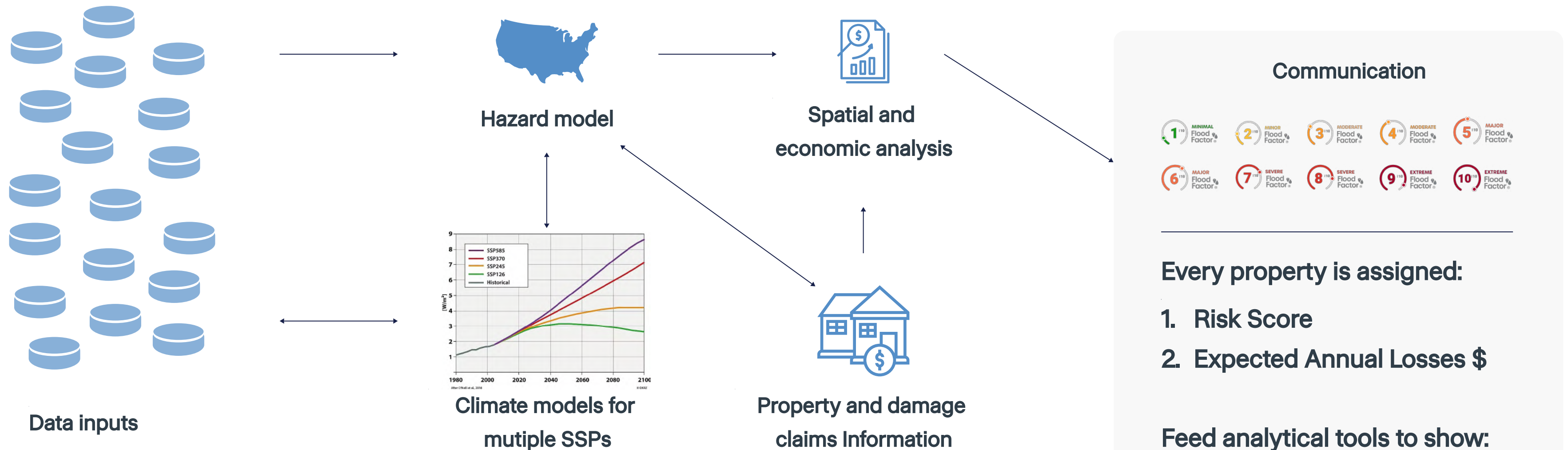
First Street assembled the first-ever database of over 23,000 US flood adaptation features (levees, seawalls, pumps) from local, regional, and Federal sources, the effects of which are incorporated into the hazard estimates. USACE's National Levee Database only has a subset of these features.

4.WILDFIRE MITIGATION

Annually, First Street compiles recent fuel treatments and disturbances, including fire breaks, prescribed burns, forest thinning, and any wildfires that have occurred, into its fuel estimates. LANDFIRE updates are not usually annual. Additionally, First Street calculates our own estimates of defensible space around each US building using aerial/satellite imagery.

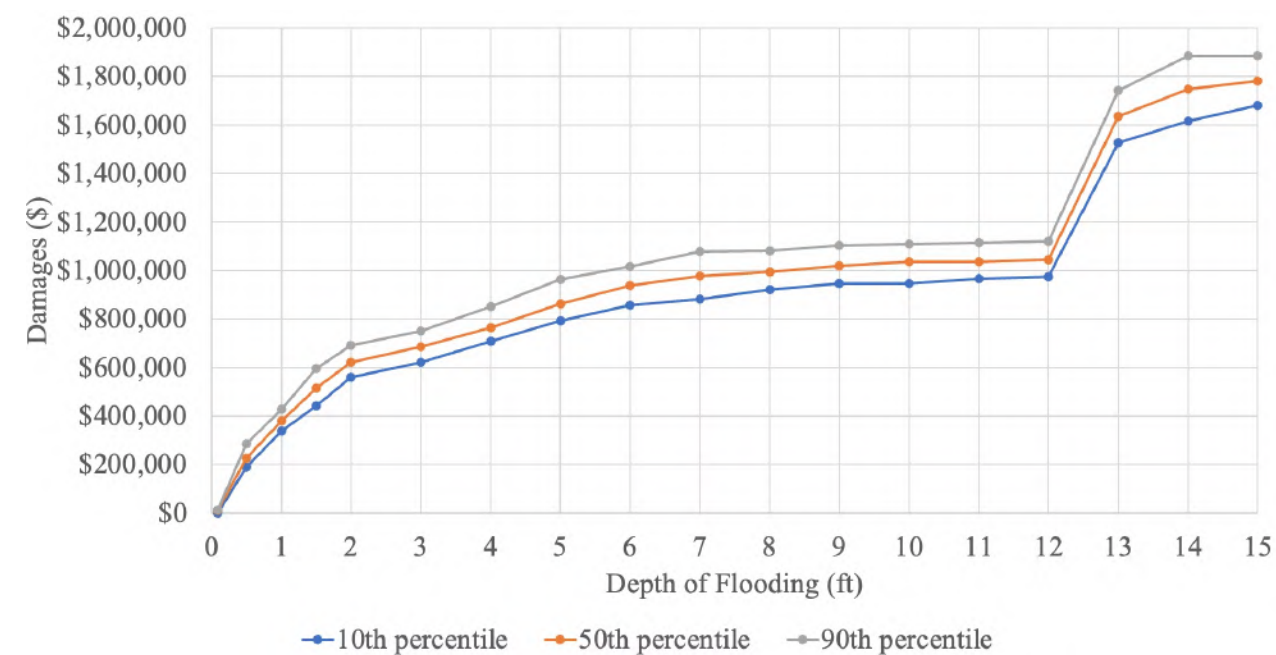
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Distill data into asset-specific climate risk statistics, using hazard models, and climate model outputs, for individual or groups of assets.



Depth, damage, and downtime calculations are used to translate hazards to losses.

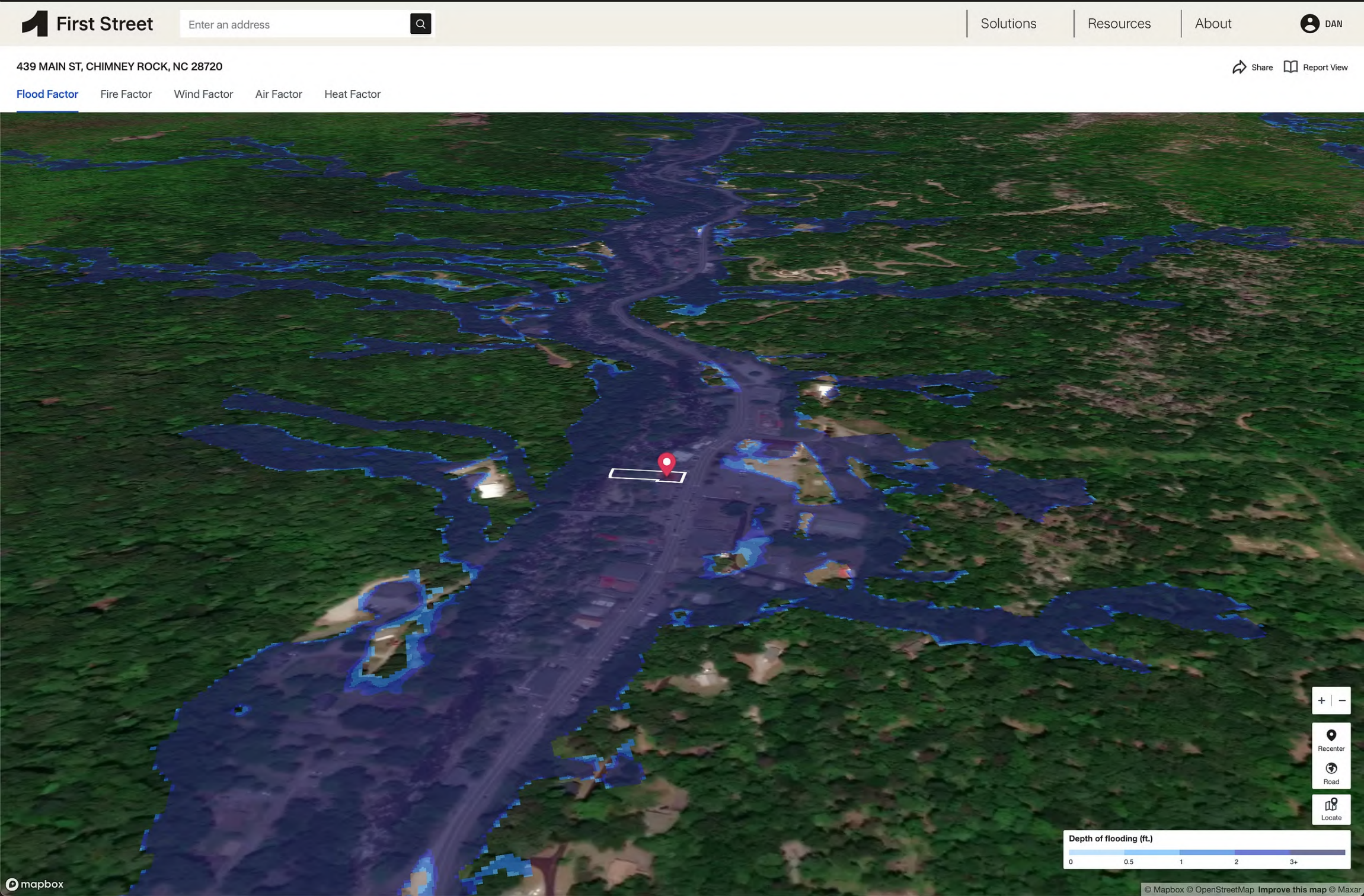
Leveraging our partnership with the world renowned consulting and engineering firm Arup, we have continued to build on the first principles of engineering approach to enhance our building archetypes and associated fragility curves. Using the known structure characteristics database to reverse engineer the building construction materials we identify the likely location of all critical components of the structure.



Reverse engineered building plan with location of critical components

Hurricane Helene, an unprecedented precipitation event in WNC

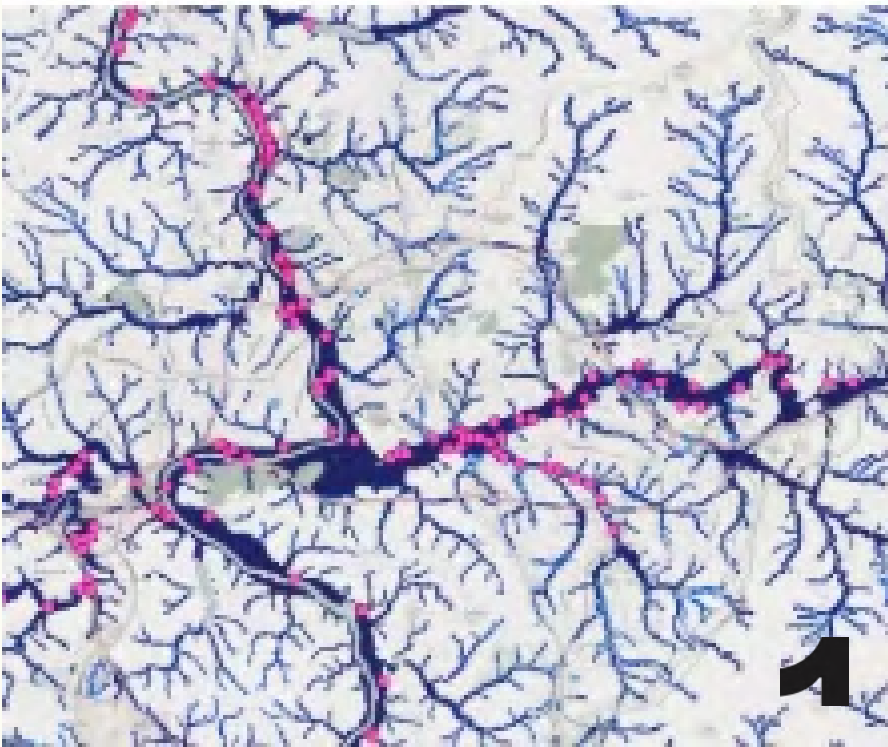
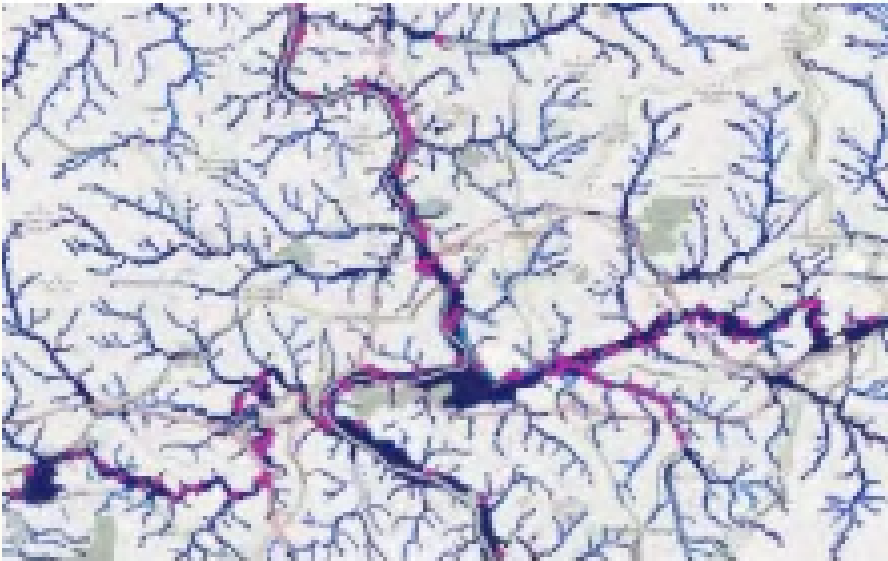
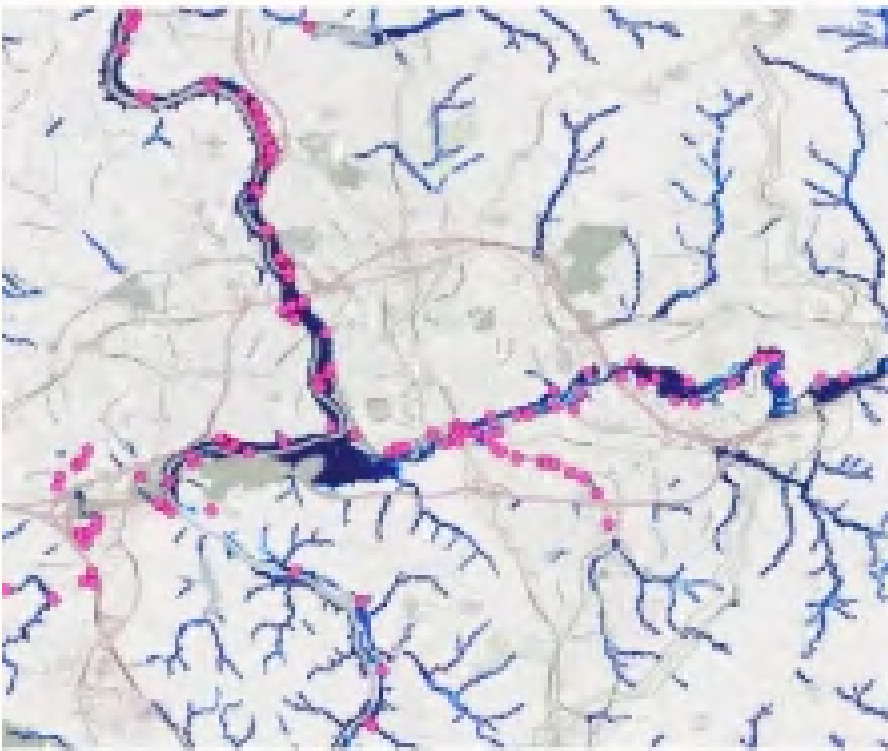
SEP 27, 2024 – FLOOD
IMPACTS HURRICANE HELENE



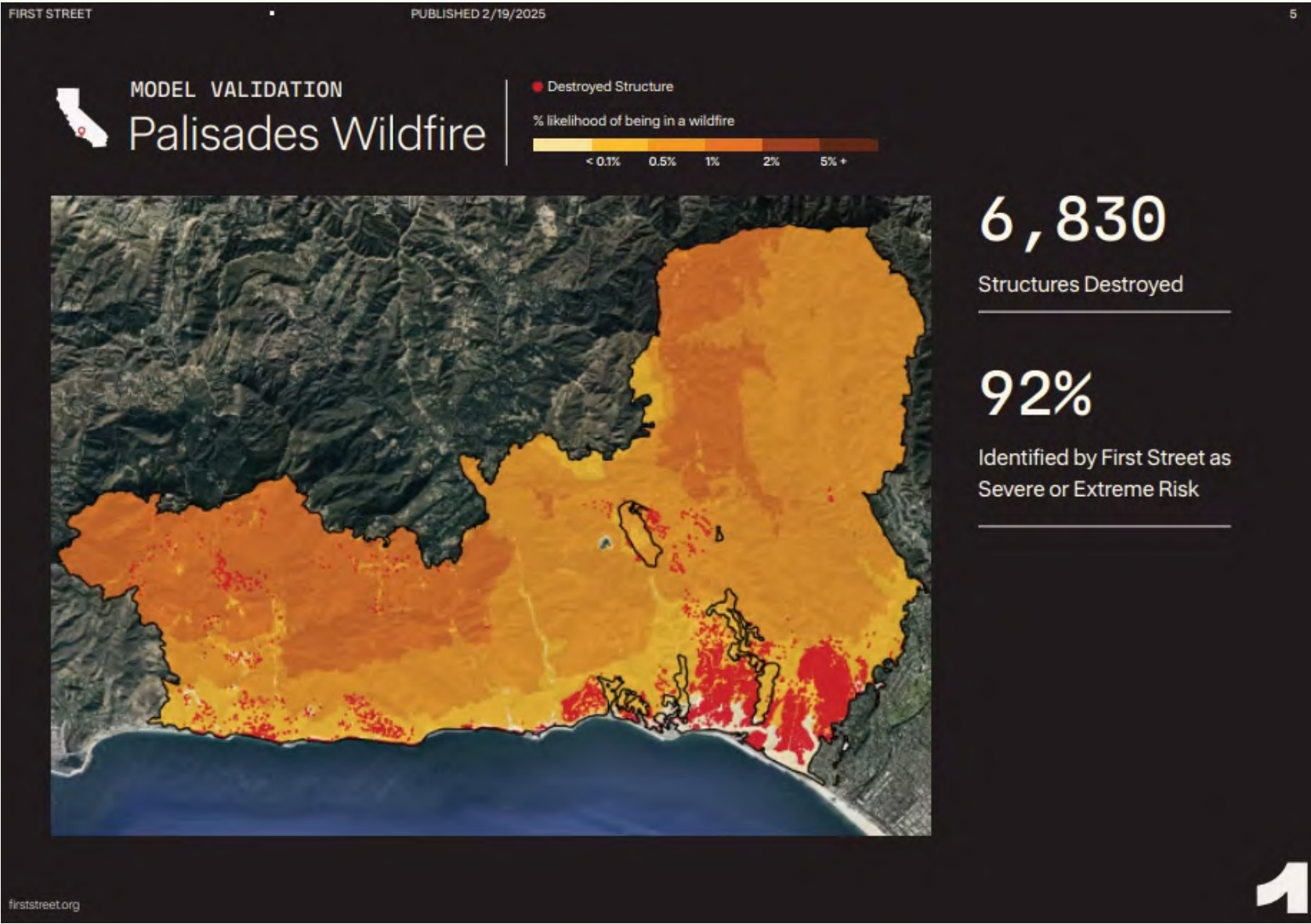
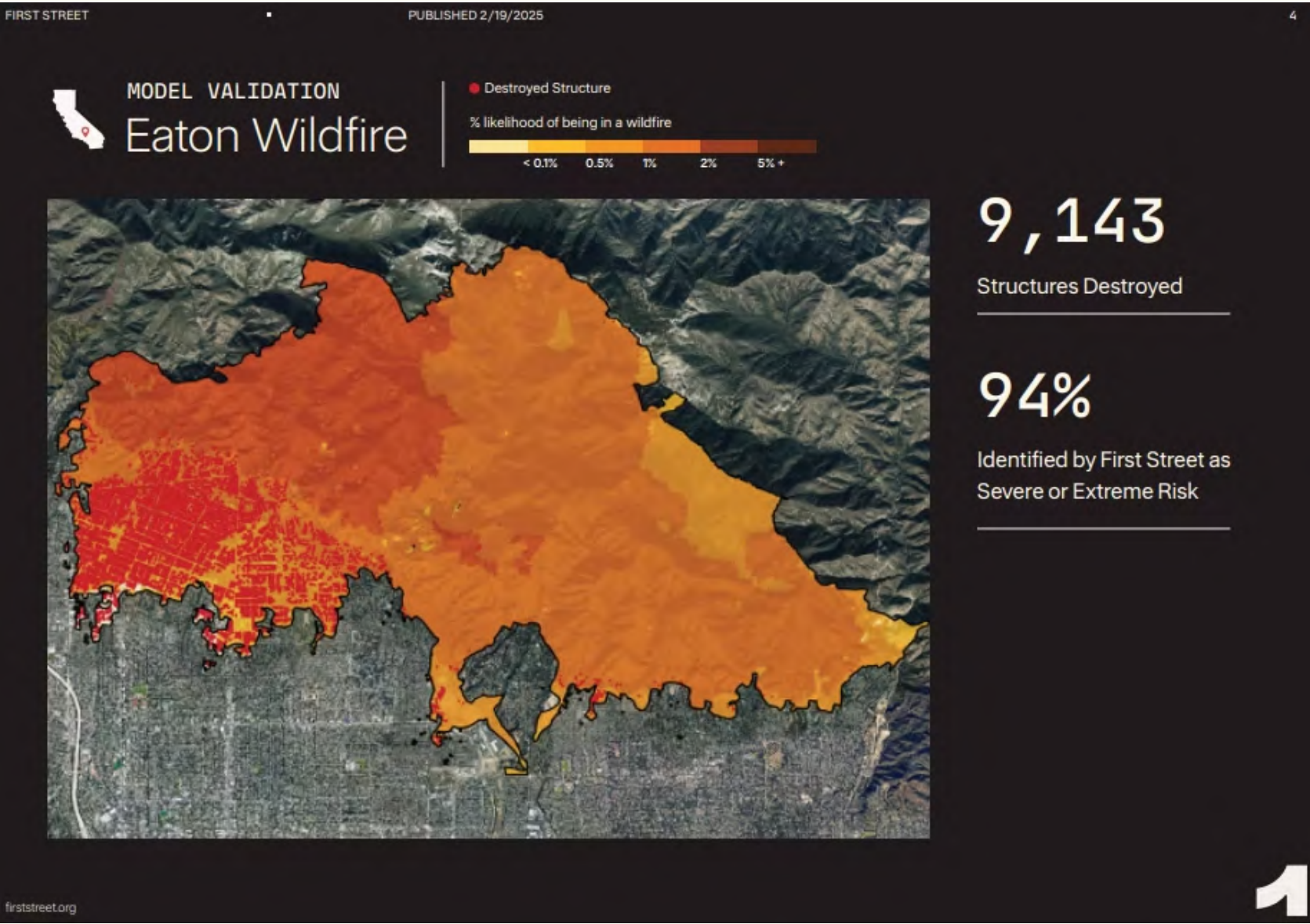
High Water Marks from Hurricane Helene and other recent extreme flood events

Key Takeaways: Comparisons of flood extent between the locations of USACE-surveyed High Water Marks and the projections of flood extents from the First Street Flood Model are useful in discerning the accuracy of those projections in real world conditions:

- The analysis of over 2,500 High Water Marks collected by surveyors from the US Army Corps of Engineers (USACE) within Western North Carolina and Eastern Tennessee following Hurricane Helene in Sep 2024 showed that First Street’s 1-in 500 year flood extent predictions had a 98% correspondence at 3m horizontal resolution with the USACE observations.
- For 22 recent extreme flood events across multiple US states, the First Street flood extent predictions were shown to have a 92% correspondence with over 2,400 high water marks collected by the US Geological Survey (USGS) and USACE.



LA Times 3rd Party Validation: 2025 Los Angeles County Wildfires





Thank you