Service Description Document
Experimental Flood Inundation Mapping Services
September 24, 2024

Part 1 – Mission Connection

The demand for event-driven flood inundation mapping (FIM) as a high-value source of actionable information for emergency and water resource managers has increased recently. In response, the National Water Center (NWC) of the National Weather Service (NWS), in close coordination with NWS River Forecast Centers (RFCs) and Weather Forecast Offices (WFOs) along with Federal and other partners, has developed and demonstrated high-resolution inundation modeling capabilities. These methods leverage the Height Above Nearest Drainage (HAND) method to provide geo-referenced visualizations of approximated flooding extent at the continental scale.

These new experimental FIM services significantly increase coverage provided by existing static FIM libraries derived from detailed engineering scale hydraulic models at approximately 200 RFC forecast locations. New inundation mapping capabilities translate analysis and forecasts of streamflow into operational maps that communicate impact by showing where flooding may occur. When combined with flood and flash flood-related watches and warnings, these visualizations, which map the location of predicted water on the ground, will dramatically improve the NWS's Impact-based Decision Support Services, underscoring the significance of our work to our core partners.

Prototype services have been generated for internal NWS use in near real-time for the lower 48 states, Hawaii, Puerto Rico, and the U.S. Virgin Islands, using RFC official forecasts and forecast guidance from the National Water Model (NWM) for more than four years. These prototypes were critical components of demonstration for two Department of Commerce Agency Priority Goals: the FY 2018-19 demonstration led by the West Gulf River Forecast Center and the FY 2020-21 demonstration led by the Northeast River Forecast Center. Through these formal demonstration projects, NOAA successfully demonstrated the FIM capability for over 20 million Texas residents in 2018 and 2019 and an additional 95 million in the Northeast U.S. and other riverside areas in 2020 and 2021, instilling confidence in our capabilities. Key findings and recommendations from these demonstration and tabletop exercises conducted with emergency managers at the federal, state, and local levels, along with other state and regional water resources partners, have helped inform our pathway to public delivery of a suite of four experimental flood inundation services.

The experimental implementation of these revolutionary inundation services began in September 2023 for 10% of the nation's population, including much of eastern Texas and portions of the Mid-Atlantic and Northeast. In September 2024, these FIM services will be expanded and available for 30% of the national population, including significant portions of the Ohio and Mississippi River valleys, the mid-Atlantic, the Pacific Northwest, and Puerto Rico (Figure 1). Access to the data for this area is available to all users. Congress mandates these activities as part of the Bipartisan Infrastructure Law (BIL) and as part of the Department of Commerce Strategic Plan.

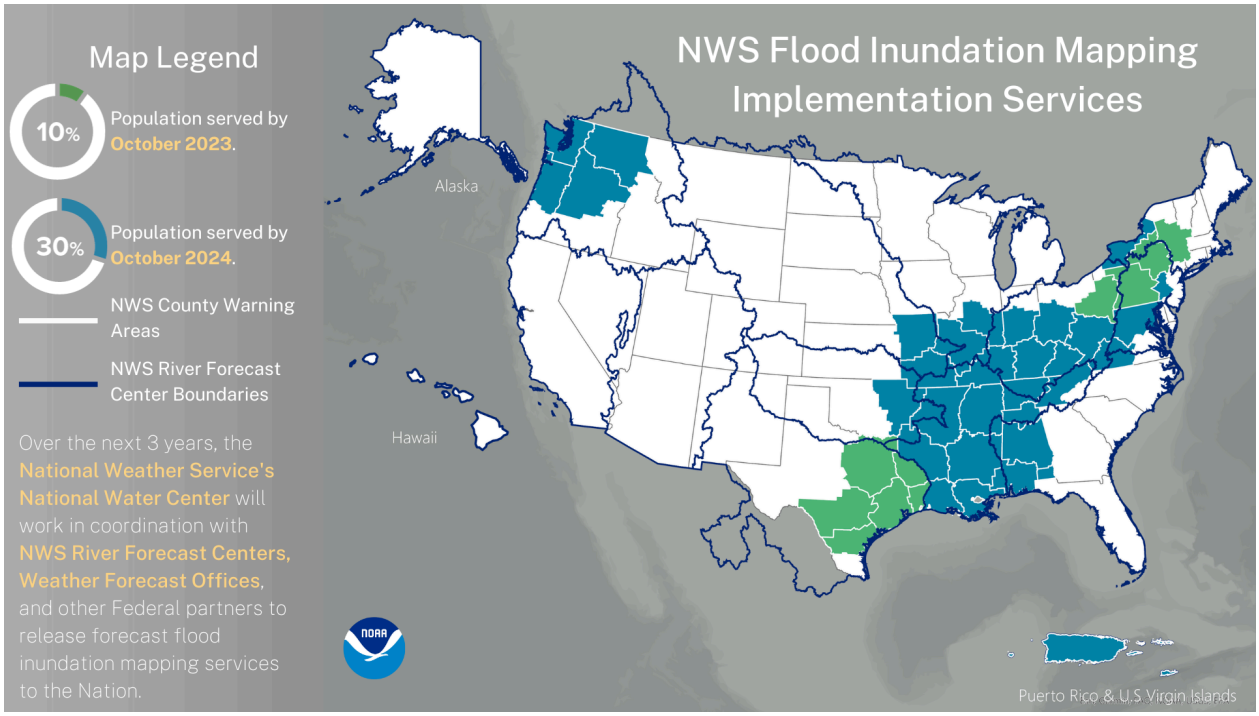


Figure 1: WFO Service areas for which FIM services and FIM-related IDSS will be delivered in phase 2 of implementation. These regions will bring services to 30% of the U.S. population.

Over a four-year period (2023-2026), NOAA will expand the spatial coverage to include nearly 100% of the U.S. population. This will thereby revolutionize U.S. water prediction capabilities by disseminating a new generation of event-driven, high spatial resolution forecast inundation maps and services. These capabilities will be complemented by services that depict the magnitude and timing of high-water events occurring for the identical river and stream network.

a) Product Description:

Experimental FIM Services include dynamic mapping services. FIM services will be provided as visualizations disseminated through the National Water Prediction Service (NWPS) (https://water.noaa.gov), the NWS National GIS Viewer – Water "site" section (https://viewer.weather.noaa.gov/water), and as a REST service through the Office of Water

Prediction's cloud-based system known as HydroVIS (https://maps.water.noaa.gov/portal/home/index.html).

The FIM methods deploy a model-agnostic approach to map the extent of inundation for rivers and streams cataloged in the National Hydrography Dataset (NHD) at a 10-meter spatial resolution. Synthetic rating curves, developed using the slope-area method for each river reach and the application of the Height Above Nearest Drainage (HAND) method, allow projection of the water surface elevation in the channel to the neighboring 10m cells in the digital elevation model (DEM).

The HAND method is a low-complexity, terrain-based approach for inundation mapping. It is described in detail in this publication: "Height Above the Nearest Drainage – a hydrologically relevant new terrain model," Journal of Hydrology; Volume 404, Issues 1–2, 29 June 2011, Pages 13-29, A.D. Nobre, L.A. Cuartas, M. Hodnett, C.D. Rennó, G. Rodrigues, A. Silveira, M. Waterloo, S. Saleska.

The method uses a 10m Digital Elevation Model (DEM) produced by the United States Geological Survey's (USGS) 3D Elevation Program (3DEP) and the NHDPlus Hydrography (stream network) dataset produced by the USGS to create a "hydrofabric." The hydrofabric represents the land surface elevations at the 10m resolution, consistent with the location of the stream and river channel network, represented as vectors or lines. As the name implies, the HAND method approximates the vertical distance between each 10 m cell and the nearest stream outlet for water flowing from each cell. In other words, the HAND model normalizes the topography with respect to the drainage network. The HAND method converts DEM elevation values referenced to mean sea level (MSL) into a Relative Elevation Model (REM) that no longer references MSL. To generate the forecasts of 5-day max inundation extents, forecast flows from the NWM and the River Forecast Center (RFC) are routed downstream through the NWM flowline network and passed through the HAND technique applied to individual stream reaches to generate these forecast map services. This technique is stream-reach focused and does not provide inundation for pluvial (i.e., intense local rainfall events with stormwater/urban runoff) based flooding.

Static services refer to FIM services that are available persistently and do not change with forecasts. They map inundation over short river reaches based on defined flow and stages at a gauge location.

Dynamic services refer to FIM services that update frequently and are derived from real-time RFC and NWM streamflow guidance. These services are only available when flow and/or stage

thresholds are reached, such as when the river forecast reaches action stage or higher at a river forecast point.

1. **Static Services**
   Static "Categorical" FIM (CatFIM) maps will be available for select NWS River Forecast Points within the FIM domain. CatFIM is a method developed by the National Water Center (NWC) to create a static inundation extent mapping library for the official NWS flood stage category thresholds [Action, Minor, Moderate, Major, and Record].

2. **Dynamic services**
   Dynamic services will include the NWM Analysis and Assimilation (AnA) FIM, the NWM Forecast 5-Day FIM, and the RFC Forecast 5-Day FIM.

   a. NWM Latest Analysis FIM
      The NWM Latest Analysis FIM service depicts the extent of inundation in the National Water Model (NWM) streamflow analysis, where the NWM signals "high water". High water is a term the Office of Water Prediction (OWP) uses to indicate elevated flows for a given NWM reach or stream. High water conditions are approximated regionally with an Annual Exceedance Probability (AEP) that aligns with the "Action" flood threshold of the RFC forecast points within each region. McCabe and Wolock, 2016 define regions based on a spatial analysis of variability in water-year runoff efficiency across HUC8 units.

      The NWM Latest Analysis FIM assimilates observed data into modeled streamflow conditions, then presents the most recent FIM in delayed real-time. The NWM Latest Analysis FIM uses observed rainfall data as a base for modeling runoff for the NWM domain. Flows are corrected by measurements taken at real-time gaging sites and routed downstream and are used to create FIM that reflects and approximates what is occurring. The NWM Latest Analysis FIM is not a forecast service and is therefore limited by the precision of its observed source data (e.g., Multi-Radar/Multi-Sensor System (MRMS) and the river gauge network). The NWM Latest Analysis FIM service runs hourly, with output available approximately 90 minutes after runtime.

   b. NWM 5-Day FIM
      The NWM 5-Day Max FIM Forecast depicts the maximum inundation extent over the next five days derived from the National Water Model streamflow forecast. This FIM is only generated where and when the NWM forecasts flows that meet or exceed the high water threshold for a given river reach.

This service is derived from the NWM's medium-range configuration. The NWM 5-Day Max FIM Forecast uses the NWM Analysis and Assimilation FIM configuration as its initial conditions.

The NWM ingests meteorological forcing data from the National Blend of Models (NBM), taking the first 36-hour quantitative precipitation forecast (QPF) from a blend of high-resolution meteorological models. After 36 hours through day five, the QPF, in 6-hour increments, is subdivided by the partial ratio of the 6-hour Unrestricted Mesoscale Analysis (URMA) Quantitative Precipitation Estimation (QPE) climatology (roughly 20 years). The forecast rainfall from the NBM for the upcoming five days is used in the NWM rainfall-runoff simulation to create a flood forecast.

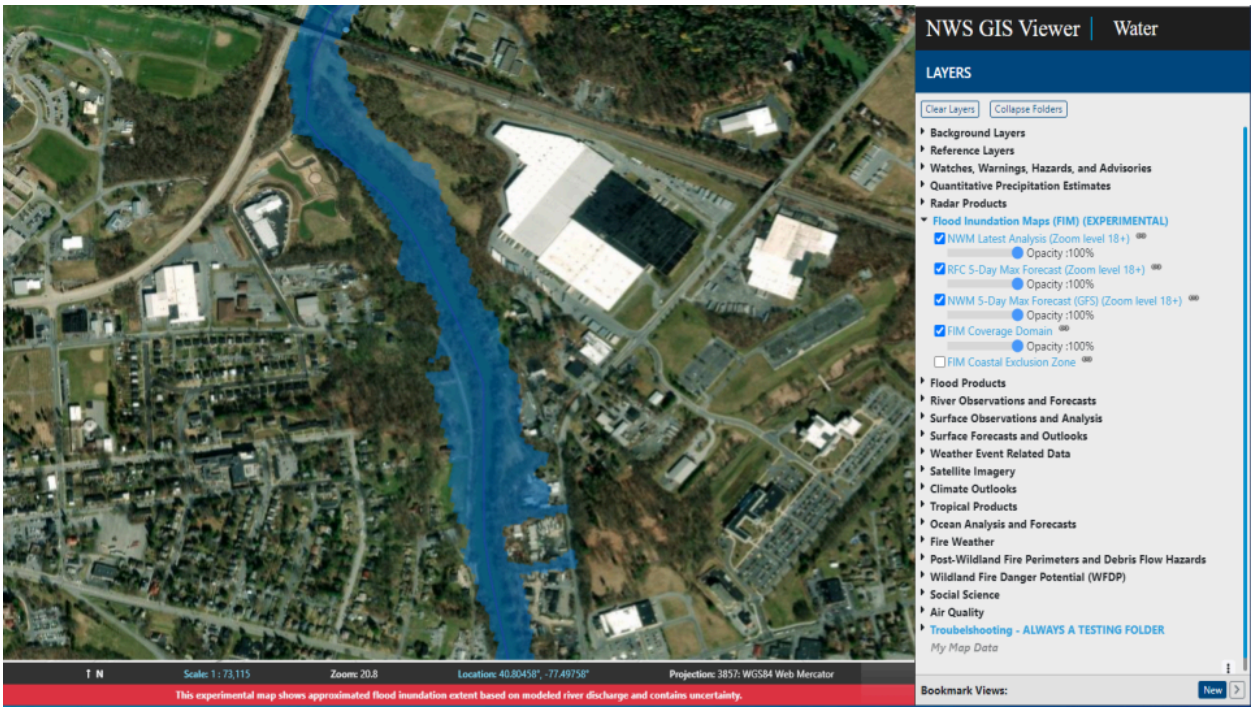
The FIM depicted by this service represents the maximum extent of inundation during these five days. NWM 5-Day FIM services will be available approximately 6 hours after model run time (i.e., the 12Z NWM cycle will provide FIM services by approximately 16Z).

c. RFC 5-Day FIM

RFC 5-Day Max FIM Forecast depicts the maximum inundation extent over the next five days, derived from the official River Forecast Center (RFC) forecast routed downstream of a forecast gauge location through the National Water Model (NWM) stream network. Forecasters at each RFC generate a Quantitative Precipitation Forecast (QPF) forecast several times daily. This QPF serves as the precipitation forcing in the Community Hydrologic Prediction System (CHPS), the modeling system used to produce the RFC streamflow forecasts for forecast points. The forecast flow from the RFC at a gage location is subsequently used to generate the 5-day Max FIM Forecast by routing the flow downstream through the National Water Model (NWM) stream network.

This forecast output provides inundation services along approximately 104,000 river miles downstream of the 3,600 RFC forecast points when the national implementation is completed in 2026. RFC 5-Day Max FIM Forecast is only available at and downstream of AHPS forecast points.

This service is generated anytime a forecast point location is predicted to reach or exceed the action stage. Services are updated within an hour of any forecast issuance.



b) Purpose/Intended Use:

These experimental visualizations and services are intended for local, regional, and national use to help inform decision-making before and during a flood event's life cycle. The experimental maps are approximate in nature and should be used with consideration of their uncertainty in representing actual inundation conditions. The maps provide complete coverage for the stream and river network in the domain area.

The dynamic and static FIM services, when fully deployed, will significantly enhance the IDSS provided by NWS field offices. These services will provide a spatial representation of visualized impacts to watches and warnings, offering more detailed and comprehensive depictions of the predicted flood footprint compared to existing impact statements. The use of the NWM FIM allows for a visualization of flood inundation and potential impacts on 3.4 million river reaches, extending for 2.7 million miles. As these services will be available as REST services, partners can integrate them into their own GIS systems, thereby dramatically improving their decision-making capabilities throughout the life cycle of a flood event.

c) Audience/Users:

These services are intended for core partners, water resources interests, floodplain managers, and the general public.

d) Presentation Format:
The dynamic inundation services will be provided as visualizations on the National Water Prediction Service (https://water.noaa.gov) web page and the NWS National Viewer—Water Tab ("site") (https://viewer.weather.noaa.gov/water). The user will be able to download the REST service for the desired inundation service for use in their own GIS system.

e) Feedback Method:
The NWS is accepting comments through September 30, 2025 on the provision of FIM services for 30% of the nation's population, including much of eastern Texas and portions of the Mid-Atlantic and Northeast, significant portions of the Ohio and Mississippi River valleys, the mid-Atlantic, the Pacific Northwest, and Puerto Rico via the online survey at:

https://www.surveymonkey.com/r/ExpFIMServices_2024

With the new services, users outside of those areas can provide comments. As the experimental FIM services are adjusted and expanded to other parts of the United States, there will be future opportunities for comment and review.

For further information, please contact:

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Part 2 – Technical Description

a) Format and Science Basis:
The Office of Water Prediction produces its Flood Inundation Mapping (FIM) services by deploying a model-agnostic approach to mapping the extent of inundation for rivers and streams cataloged in the NHD at a 10-meter spatial resolution. Synthetic rating curves and applying the Height Above Nearest Drainage (HAND) method allow the projection of the water surface elevation in the channel to neighboring cells in the digital elevation model (DEM).

The HAND method is a low-complexity, terrain-based approach for inundation mapping. It uses a 10m Digital Elevation Model (DEM) produced by the US Geological Survey's (USGS) 3D Elevation Program (3DEP) and the NHDPlus Hydrography (stream network) dataset produced by the USGS to create a "hydrofabric." The hydrofabric represents the land surface elevations at the 10m resolution, consistent with the location of the stream and river channel network represented as vectors or lines. As the name implies, the HAND method approximates the vertical distance between each 10 m cell and the nearest stream outlet for water flowing from each cell. In other words, the HAND model normalizes the topography with respect to the drainage network. The HAND method converts DEM elevation values referenced to mean sea level (MSL) into a Relative Elevation Model (REM) that no longer references MSL. To generate the forecasts of 5-day max inundation extents, forecast flows from the NWM and the River Forecast Center (RFC) are routed through the NWM, respectively, and passed through the HAND technique to generate these forecast services.

In addition to presenting inundation based on slope-area methods that represent the river reach coupled with the HAND representation of the location cross-section, a processing technique called "RAS-to-FIM" may be applied at and downstream of river segments, where detailed HEC-RAS models are available. Instead of leveraging the synthetically derived rating curves, the HEC-RAS-defined rating curves are leveraged to generate the flood inundation extents at and downstream of selected reaches, thereby complementing the HAND methodology.

These techniques are stream reach-focused and, therefore, do not provide inundation for pluvial (stormwater/urban runoff driven by high-intensity rainfall)- based flooding.

b) Availability:
Three dynamic inundation services will be provided. These include:

1. NWM Analysis and Assimilation (AnA) FIM – this service runs hourly with output available approximately 90 minutes after runtime.
2. NWM 5-Day FIM – this service is generated every 6 hours and is available approximately 6 hours after model runtime.

3. RFC 5-Day FIM – this service is generated whenever a forecast point is observed at or above the Action stage or is predicted to reach or exceed the action stage. The service is generated usually within an hour of forecast issuance by the RFC.

Static Categorical FIM (CatFIM) maps will be available for select NWS River Forecast Points within the FIM domain.

Visualization services will be available at the National Water Prediction Service (NWPS) webpage located at https://water.noaa.gov and hosted on the National Viewer – Water tab ("site") located at:
https://viewer.weather.noaa.gov/water.