National Water Model (NWM) Tutorial

A 101 Guide to Understanding and Using the NWM

TABLE OF CONTENTS

* Please note that Sections 1 - 3 have an associated video tutorial linked at the beginning of each section.

2

Introduction: What is the NWM?

The National Water Prediction Service (NWPS) is the National Oceanic and Atmospheric Administration's (NOAA) online, map-based platform that provides access to a wide range of water data, including river forecasts, streamflow observations, precipitation, and flood maps. It can be found at https://water.noaa.gov.

One of the main sources of data shown in the NWPS is the National Water Model (NWM). The NWM is a hydrological model that simulates hydrological conditions over the continental United States, South-Central Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands, on both gauged and ungauged rivers. Behind the scenes, the model runs in several configurations to support different uses. These include retrospective simulations for the past 40 years, as well as near–real–time estimates of current conditions and future forecasts since 2016, the year the NWM became operational.

Important Note: The NWM serves as a valuable supplemental resource when seeking data and tools to support flood forecasting and improve understanding of hydrological conditions, particularly streamflow and flood risk. While powerful, it is subject to uncertainty due to the limitations of input data. The NWM output also provides supplemental guidance to the National Weather Service (NWS) forecasters and should not be considered an official NWS river forecast. Always refer to official NWS alerts and guidance from local authorities for real-time decision-making and emergency response. For more detailed information about the NWPS, NWM, or related resources, contact your nearest National Weather Forecast Office.

# What Types of Information are Available from the NWM?

What data does the NWM use to make its simulations?

- NOAA and NWS Weather Data: Including precipitation, temperature, and other meteorological inputs.
- USGS Gauge Readings: Observed river and stream conditions from a network of monitoring stations.
- Land Surface Models: Models that use and combine soil moisture, runoff, and snowmelt data.

What predictions can the model make?

- Return Intervals: Estimates of how frequently specific hydrological events (like a 1-in-25-year flood) are likely to occur.
- Maximum High Flow Magnitudes: The highest streamflow values forecasted or recorded for a specific river.
- Stage Exceedance Probabilities: The probability (expressed as a decimal or percentage) that a certain river stage will be equaled or exceeded within a given time frame.
- Retrospective Data: 40-year retrospective data on streamflow and water levels providing an indication of how rivers have behaved over time.

- Streamflow Forecasts: Estimates of how much water will be in rivers and streams (measured in cubic feet per second) based on forecasted precipitation.
- River Stage Heights: How high the water will rise (measured in feet).
- Flood Inundation Mapping (FIM): Visual maps showing where flooding is likely to occur at different water levels. These maps are typically generated using the Height Above Nearest Drainage (HAND) method, which uses terrain elevation data to estimate how far water will spread from nearby streams.
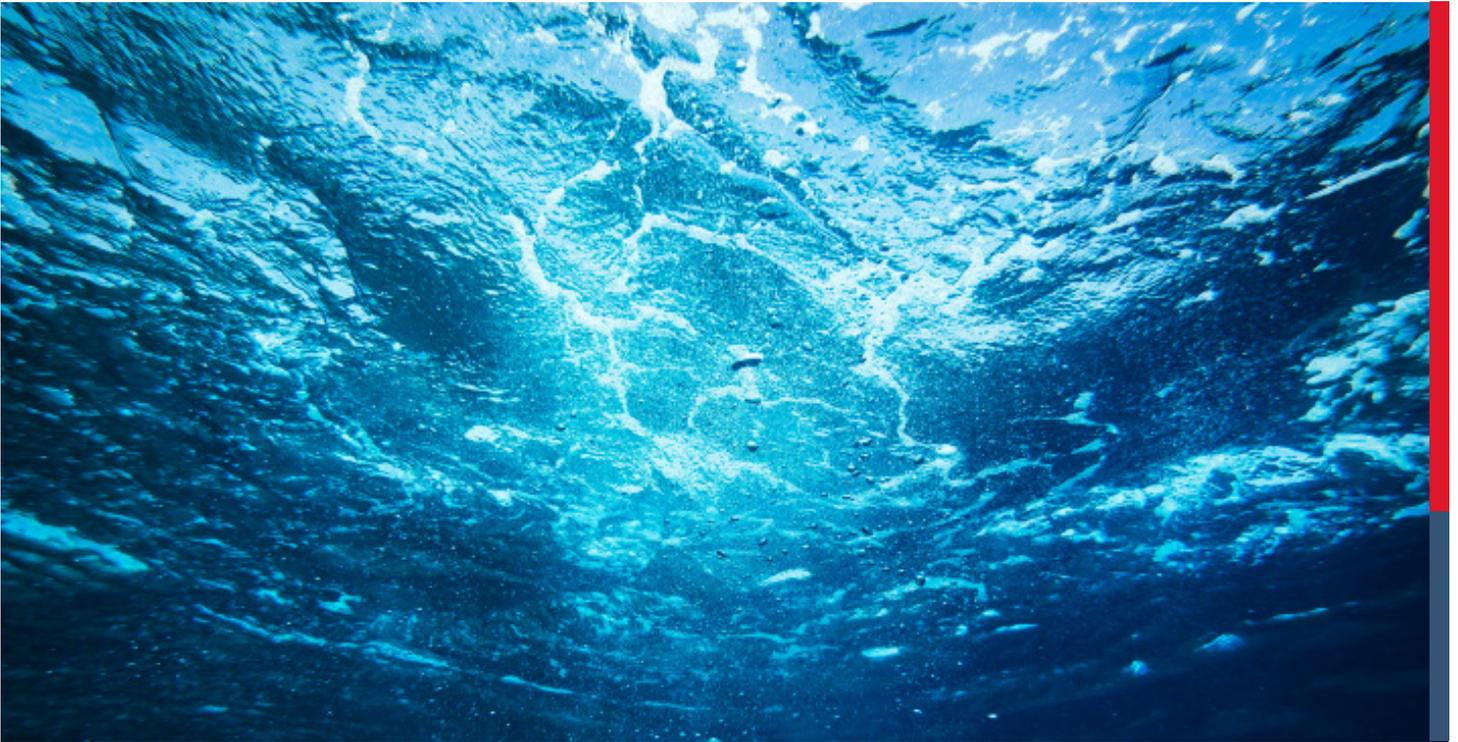
What Questions Can the NWM Help Me Answer?

The NWM is a valuable supplemental tool for understanding streamflow and water conditions in your area of interest. The model can help answer questions such as:

- Is my region forecasted to flood? (Section 2-3, 5)
- What does the streamflow near my home look like? (Section 2-3)
- What kinds of flood conditions could put my area at risk of flooding? (Section 2-3)
- How high, and how quickly, is the river expected to rise? (Section 2-3)
- What does streamflow look like on ungauged rivers and streams? (Section 3)
- How can I explore NWM estimates of streamflow for my area that were produced using historical, observation-based, meteorological inputs from past years? This retrospective record provides a 'what-if' baseline of how the NWM would have performed if it had been available prior to 2016 (Section 4)
- If my area is prone to flooding based on forecasted streamflow or historical peak values, which locations would be most affected by inundation flooding? (Section 5)

Step-by-Step: How to Evaluate Flood Risks Using the NWPS Website, NWM Data & FIM Services

This tutorial provides a step-by-step guide to: (1) navigate the NWPS website and find basic information on streamflow and flood risk; (2) access NWM near–real–time data and future forecasts and understand how to use and interpret this information; (3) access NWM historical & retrospective datasets; and (4) explore potential flood impacts using Flood Inundation Mapping (FIM) services.

This first two sections will help orient you to the NWPS homepage and walk through its core functions. You will learn how to: search for local streamflow information on gauged rivers, and view near–real-time (latest analysis) and forecasted flood risk alerts with predictions of what infrastructure could be impacted.

Section 1: Understanding NOAA's NWPS Website

Click here to view the **video tutoria**l on how to navigate the NWPS homepage.

1. **Access the NWPS homepage:** Open your browser and navigate to the National Water Prediction Service (NWPS) homepage: https://water.noaa.gov/
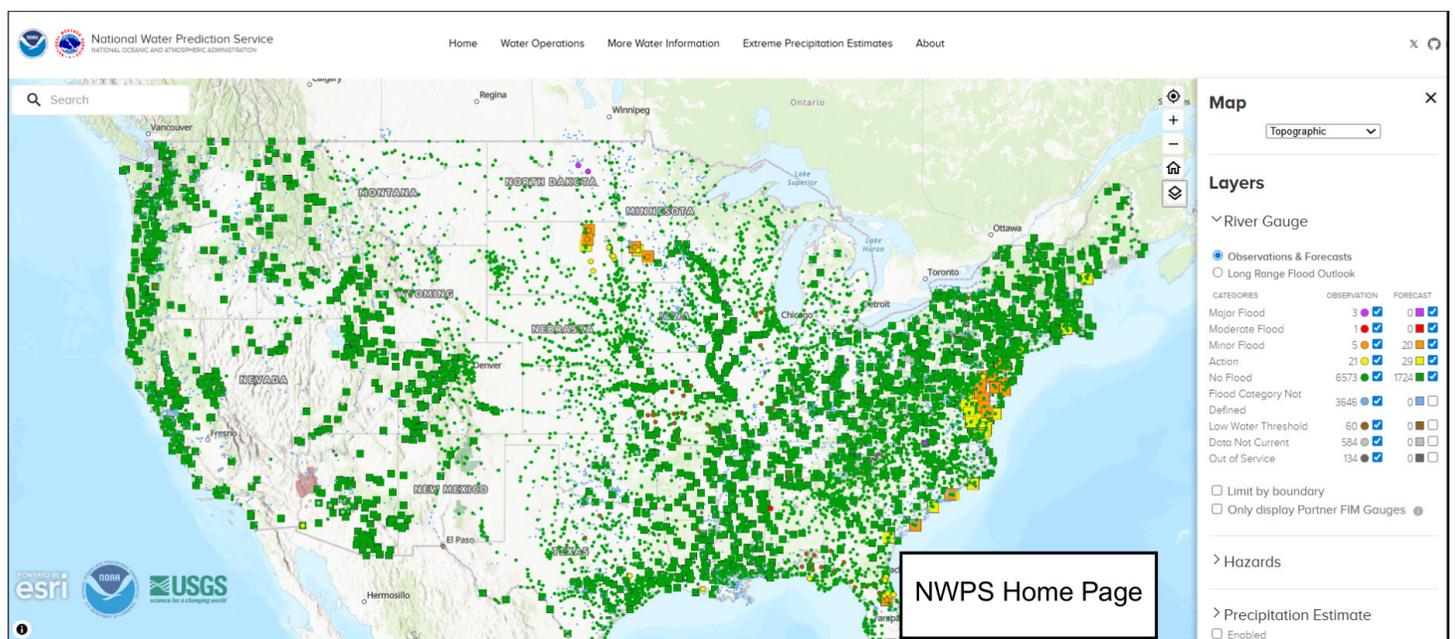

NWPS Home Page

2. **Understand the map view:** You'll arrive at an interactive map of the U.S. showing thousands of colored circles, squares and shaded areas. The circles and squares represent locations where there is an official NWS gauge.

**Squares**: Forecast points that provide future projections.

Circles: Observation-only gauges that show past or current conditions.

Shaded Areas: Active flood watches or warnings, often corresponding to squares and circles with forecasted and observed flooding.

Zoomed in NWPS Home Page displaying areas with observed and forecasted flooding (shaded in green)
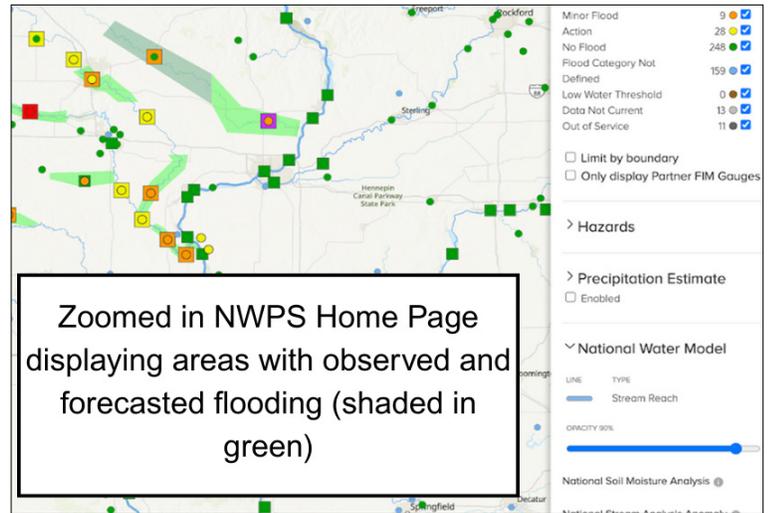
Colors: Indicate streamflow conditions
- Purple = Major Flooding
- Red = Moderate Flooding
- Orange = Minor Flooding
- Yellow = Action Stage
- Green = Normal Flow
- Other colors indicate areas where data is not available or low water

Zoomed in NWPS Home Page displaying different observations and forecasts
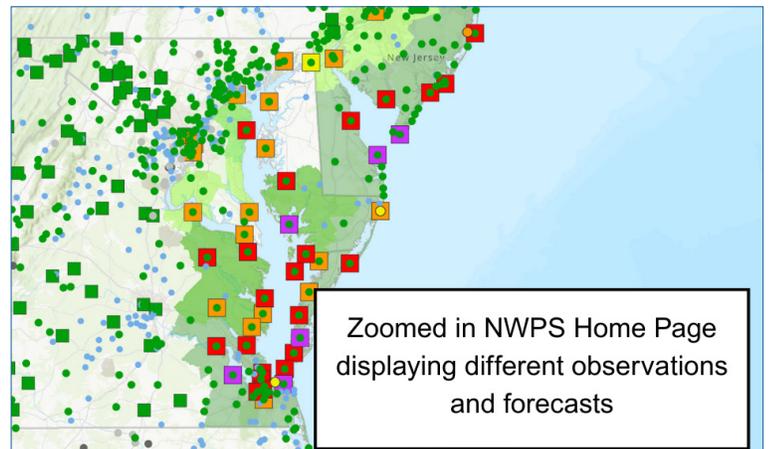
3. **Map Controls (top-right of the map):**
   a. The ⊙ button centers the map on your current location (if location services are enabled on your device).
   b. The ➕ and ➖ buttons allow you to zoom in and out respectively.
   c. The 🏠 button resets the map display to the default.
   d. The ⬙ button opens and closes the layers panel.
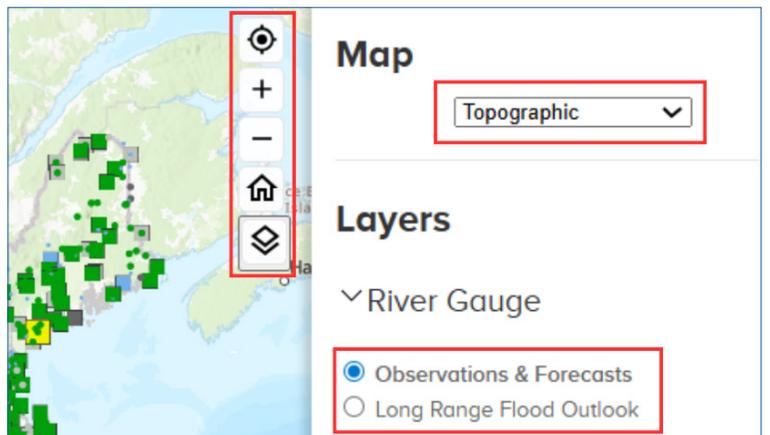
3. **Set your geography and terrain:** On the right, choose a base map to display your preferred landscape. By default, the 'Topographic' layer shows terrain, watersheds, and infrastructure, helping you see how water flow by elevation. See other base map options in the dropdown menu, including:
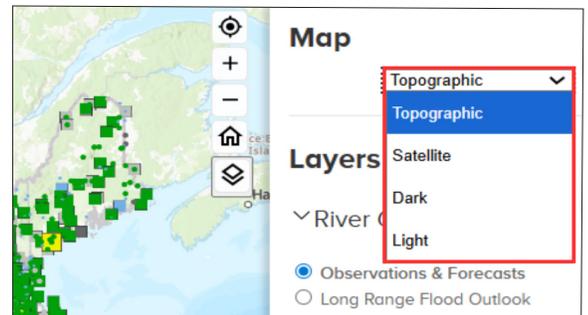
   a. **Satellite:** Uses satellite imagery and can be useful for identifying landmarks, including large water bodies.
   b. **Light:** Simple base map with high contrast and can be useful for to keep the information clear and share NWPS maps with others.
   c. **Dark:** Same as above – simple base map with high contrast.

4. **Add specific data layers:** You can add layers to visualize different information. The default 'River Gauge' layer shows color-coded observations and forecasts. You can also enable additional layers:

   a. **Long-Range Flood Outlook:** Shows rivers with a minor, moderate, or severe flood risk over the next 3 months. By default, it shows rivers with at least a 50% chance of exceeding flood thresholds, but this percentage can be adjusted.
   b. **Limit by Boundary:** Focus results within a specific watershed, county, or custom boundary. Displays only the gauges visible in your current zoom level.
   c. **Only Display Partner FIM Gauges:** Displays gauges in areas with Flood Inundation Mapping available.
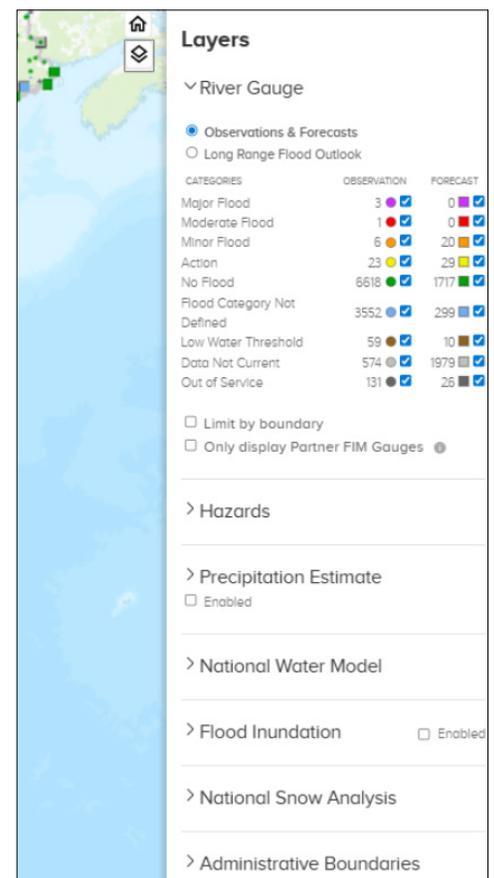
* Additional Layers on NWPS Website:
   a. Hazards (not covered in this tutorial)
   b. Precipitation Estimate (not covered in this tutorial)
   c. National Water Model (see Section 3)
   d. Flood Inundation (see Section 5)
   e. National Snow Analysis (not covered in this tutorial)
   f. Administrative Boundaries (not covered in this tutorial)

For more information on the layers not covered in this tutorial (c-e above), please refer to NOAA User's Guide.

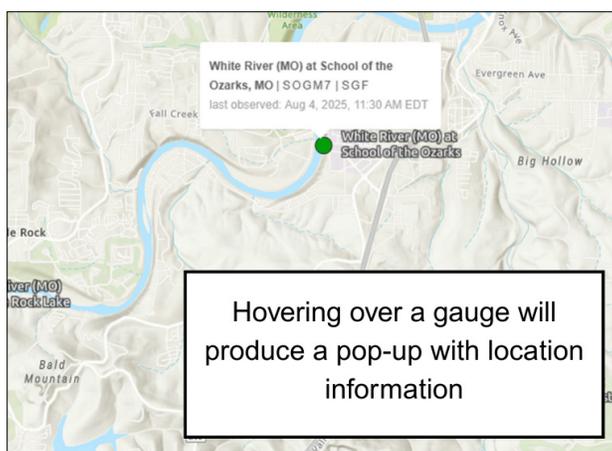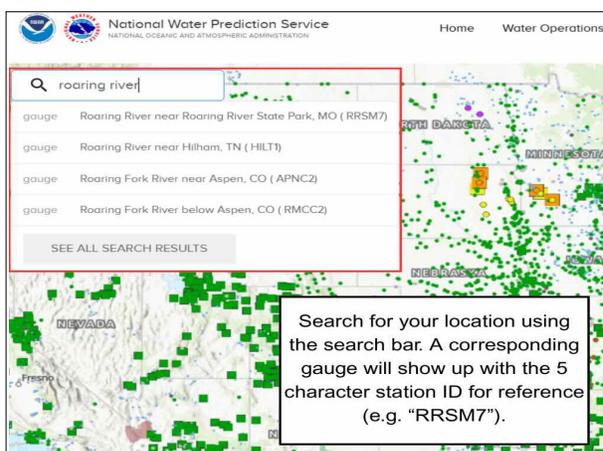5. **Share and save view:** The NWPS map URL (https://water.noaa.gov/map/) automatically saves your settings (layers, zoom level, and selected gauge), so you can bookmark or share with others.

Section 2: Using the NWPS to Access Gauged River Data

Click here to view the **video tutorial** on how to navigate the NWPS homepage. To check current and forecasted streamflow conditions from an official gauged point:

1. **Find a Gauge:**
   a. Enter your location in the search bar (at the top left of water.noaa.gov homepage)
   b. Click on a square or circle near your area of interest: When hovering over a square/circle, which represent river gauges with available streamflow data, a pop-up with location information will appear. Once you click on it, you can preview current and forecasted streamflow data. If there is no forecast available, it could be an observation-only location. For up-to-date information on gauges across the U.S., please visit the U.S. Geological Survey Water Data website.

Search for your location using the search bar. A corresponding gauge will show up with the 5 character station ID for reference (e.g. "RRSM7").

Hovering over a gauge will produce a pop-up with location information

2. **Interpreting the Hydrograph:** Once you click a circle or square, you will see a hydrograph page. The default view shows official, real-time data from gauged streams across the US. On the hydrograph you will find the following information:

   a. **Left side**: Observed water level data (past stage height in ft)
   b. **Right side**: Forecasted water level data (stage height in ft) of what the model predicts will happen in the next few days
   c. **Bottom**: A time slider to adjust the time window you'd like displayed for water level data
   d. **Flood Categories**: The shaded colors on the hydrograph correspond to Flood Thresholds from No Action (no color), Action (yellow), Minor (orange), Moderate (red), and Major (purple). For rivers experiencing unusually low streamflow, the graph may show the Low Threshold (brown). These flood categories are calibrated differently for each river based on streamflow.
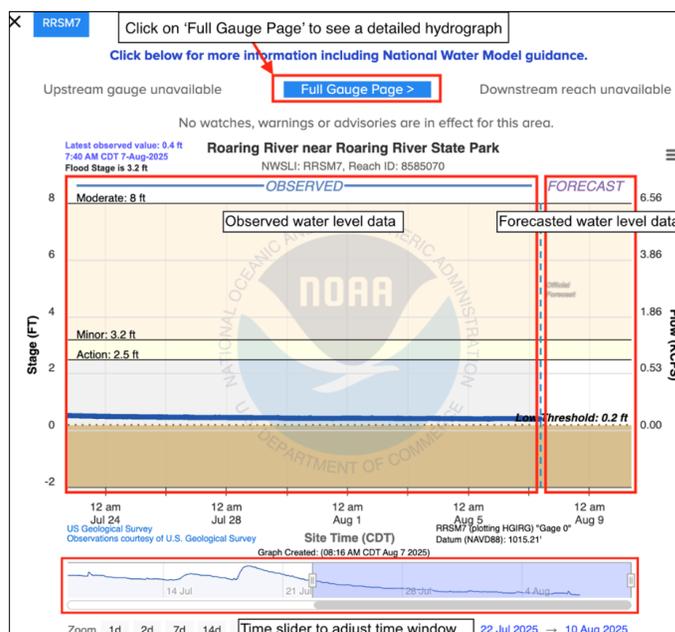
e. Click "**Full Gauge Page**" at the top of the preview page to see a detailed hydrograph and flood impact information.
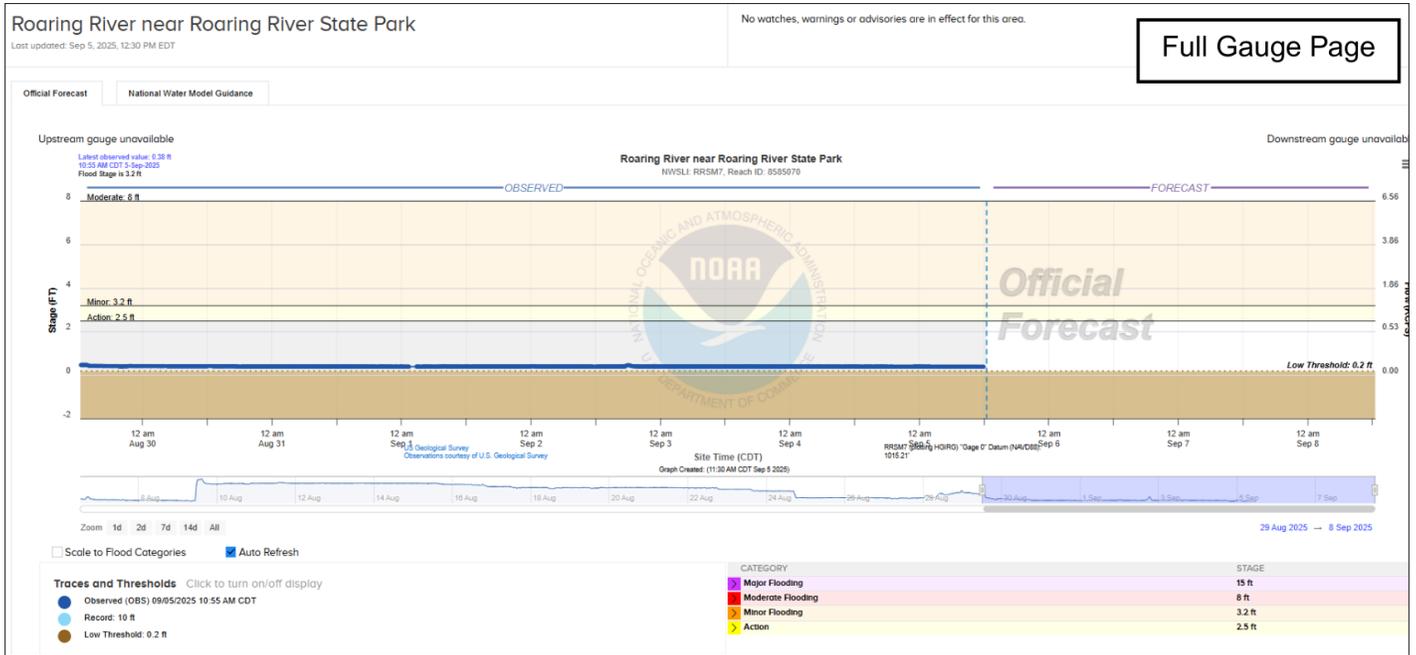
3. View Flood Impact Statements (if available):

a. Flood impact statements will be shown below the hydrograph on the full gauge page when flooding impacts infrastructure. For example:

Flood Impacts ⓘ

17.5 - Water reaches near the bottom of the bridge at the gage site. Most campsites and some park buildings flood.

9.5 - Highway 112 floods.

8 - Much of campgrounds 2 and 3 flood and portions of campground 1 near the tributary to Roaring River flood at Roaring River State Park.

SHOW MORE FLOOD IMPACTS

* Note: If you see streamflow on the hydrograph reach the "action" flood category, you may want to view the National Weather Service's Alerts Page and select your region to view more detailed hazard information, and contact your local Weather Forecast Office.

Section 3: Accessing the NWM within the NWPS website

Click here to view the **video tutorial** on how to navigate the NWPS homepage.

While NWPS defaults to showing gauge data, which provides real-time, observed measurements of water levels and flow, you can also view simulated streamflow and water-level forecasts from the NWM – even for ungauged rivers. These streamflow forecasts may be useful for assessing streamflow patterns and flood risk, particularly where there are no other sources of information available. This section describes the two ways (Option 1 and 2 below) to access NWM datasets within NWPS:

1. **Option 1: View NWM Forecasts from a Gauge Page**
   a. After clicking "Full Gauge page" (see steps above, image for reference below), you will see the detailed hydrohraph. Underneath your region's name you will see a "National Water Model Guidance." Click this tab to view the NWM datasets. You will then be able to review modeled streamflow and water level predictions for that reach.

After selecting a gauge in an area of interest (circle or square) and viewing the hydrograph, select 'Full Gauge Page'. You should land on a page like this.

Select this tab on the 'Full Gauge Page' to show NWM forecasted data on water levels and streamflow, if available.
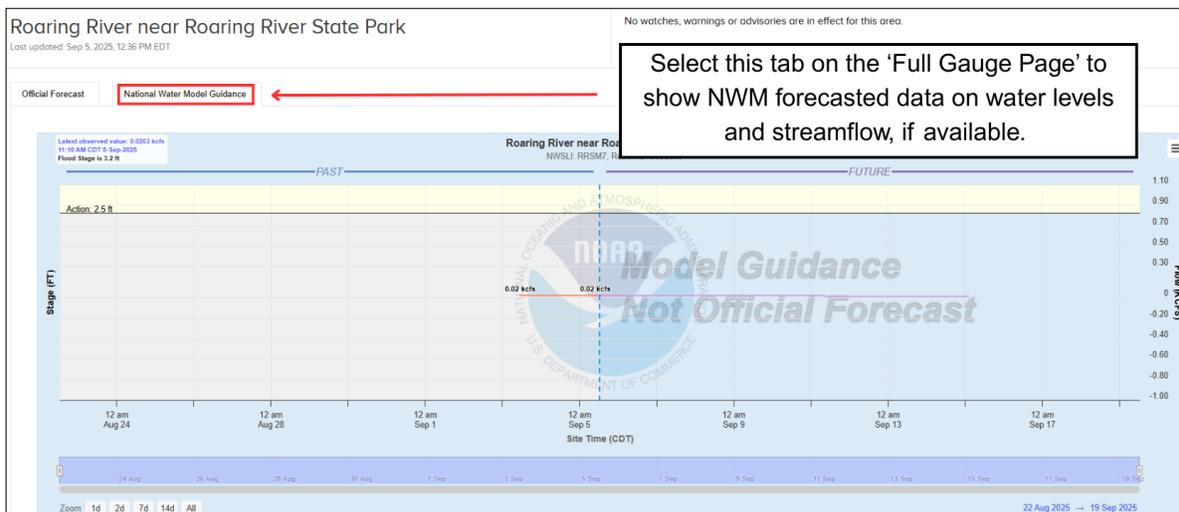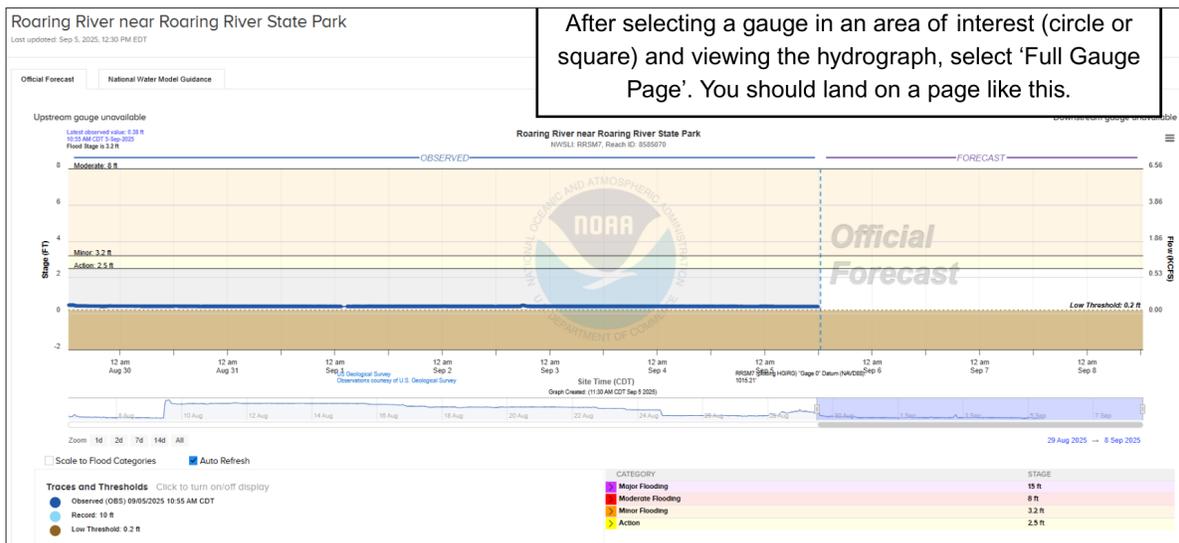
2. Option 2: Enable the NWM Layer from the NWPS Map

   a. On the main map (http://water.noaa.gov), open the Layer Panel.
   b. Enable the "National Water Model" layer by checking the box next to "Stream Reach."

Enable 'Stream Reach' within National Water Model layer to show where forecasted NWM data is available.
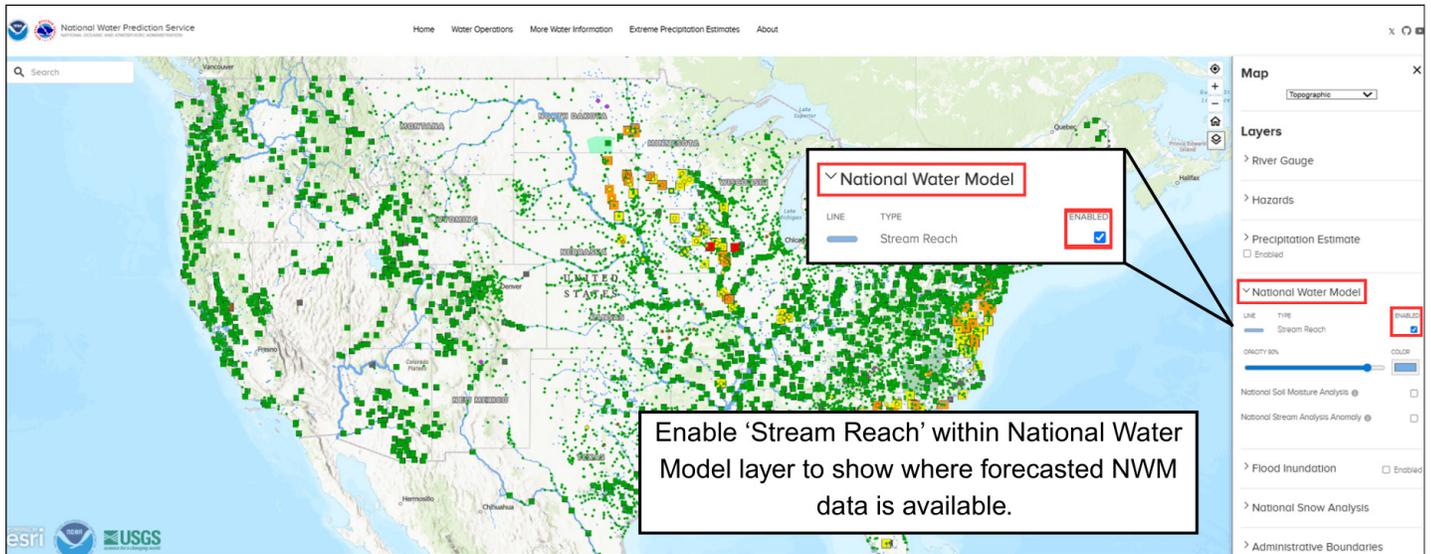
   c. A pop-up providing more information about the NWM will show on the map, click "Close" to continue.
   d. On the map, click on any blue stream segment to see NWM forecast data, even if there's no gauge. A side panel will display forecasted and historical streamflow, with options to change the time range (similar to the hydrograph page in Step 2).

(denoted by a square and/or circle marker), selecting the marker provides access to the official hydrograph ("Official" tab) for that gauge and a supplemental hydrograph ("National Water Model Guidance" tab) for the river reach that contains the gauge. This supplemental "National Water Model Guidance" hydrograph displays the NWM model output in addition to the official hydrograph. Selecting a section of river with no gauge marker (no official forecast) will provide the NWM guidance hydrograph for that river section.
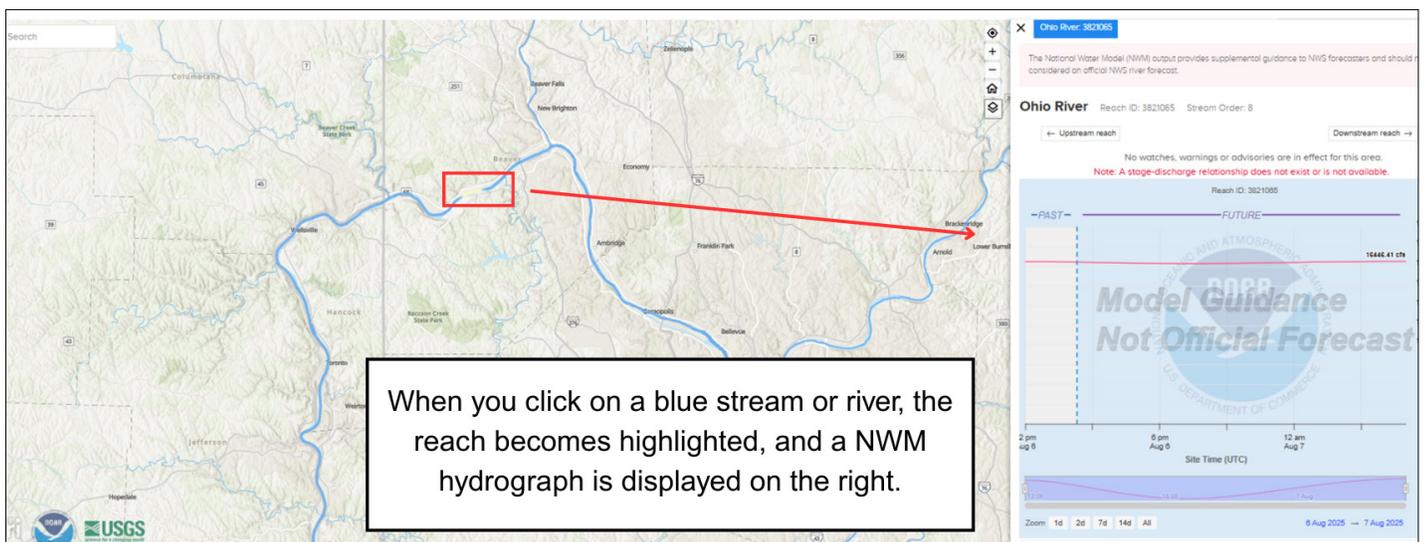
The NWM is currently undergoing extensive validation and verification to identify where scientific updates to the model can make the most improvement, and new versions are planned for release on a regular basis. The NWM output provides supplemental guidance to NWS forecasters and should not be considered an official NWS river forecast.

CLOSE

When you click on a blue stream or river, the reach becomes highlighted, and a NWM hydrograph is displayed on the right.

3. Interpreting NWM Data on Hydrograph: On both the 'NWM Guidance Tab' on the Full Gauge Page, and the hydrograph displayed after you click on a blue river reach, you will see options to view different types of NWM data. The Analysis (ANA) and Short Range (SR) lines are displayed by default on the graph and appear as orange and pink lines, respectively. You can view data from the 'Medium Range Ensembles' and 'Long Range Ensembles' by selecting these options in the dropdown menu. When these data points are selected, they will appear as purple or blue lines on the graph. Please note that not all ensembles may be available in your location of interest due to technical or performance issues. More information about each NWM data type is below:

This is the maximum amount of NWM forecasted datasets that users will be available to view.

NWM forecasted datasets selected will be displayed on the corresponding graph. Medium Ensembles show forecasted data up to 8-10 days, and Long Ensembles up to 30 days.
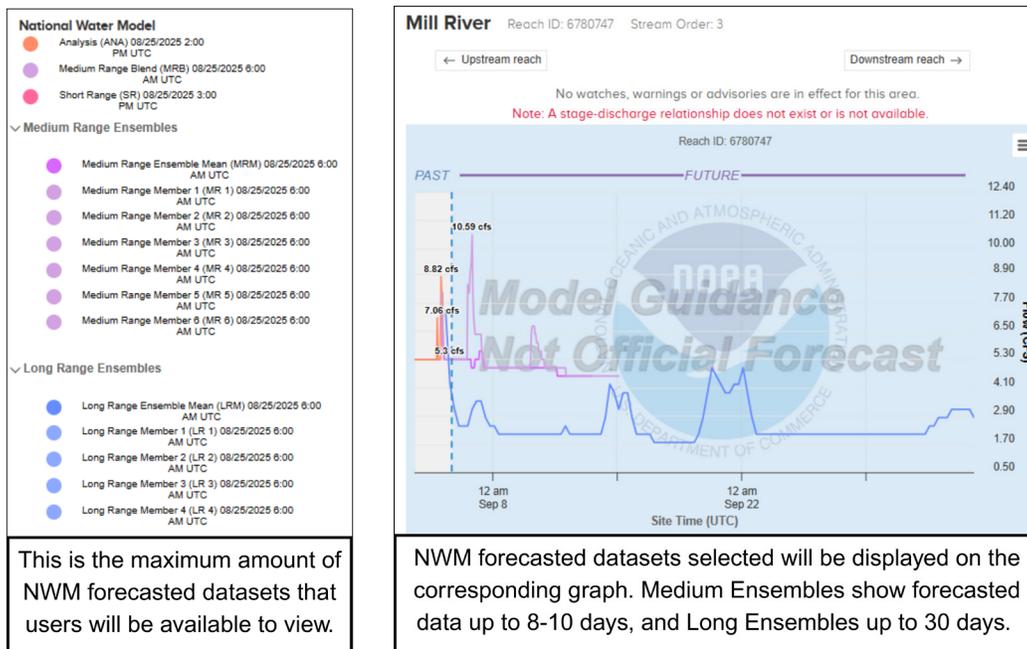
a. **Analysis (ANA):** Combines observed data with model simulations to produce the best estimate of current conditions. It serves as a starting points for short-, medium-, and long-range forecasts. Analysis cover the past three days.

b. **Short Range (SR):** Shows modeled streamflow for the next 18 hours using data from weather models, with hourly streamflow output. These are deterministic values, meaning they represent a single best-estimate prediction rather than a range of possible outcomes.

c. **Medium Range Ensembles:** The forecast is based on six slightly different model runs to account for uncertainty, with each run producing its own forecast called an ensemble member. Streamflow values are shown hourly. Users can choose to view any of the six individual ensemble members, the average of all six (mean ensemble), or a 10-day ensemble forecast.

d. **Long Range Ensembles:** For long-range ensembles, the forecast is based on four model runs. Streamflow values are shown every six hours. Users can view any of the four individual ensemble members, each extending 30 days, or the mean ensemble.

4. **View Additional National Water Model Layers:** Other layers that can be enabled in the National Water Model are shown below. Enable these layers in the Layer Panel under the 'National Water Model.'
   a. **National Soil Moisture Analysis:** Shows soil saturation (%) in the top 40cm of soil (updated hourly).
   b. **National Stream Analysis Anomaly:** Highlights whether current streamflow is unusually high or low for the time of year.
      • Example: A river may appear as purple if it is flowing higher than average in mid-July compared to previous years at the same time.

National Soil Moisture Analysis Layer

National Stream Analysis Anomaly Layer
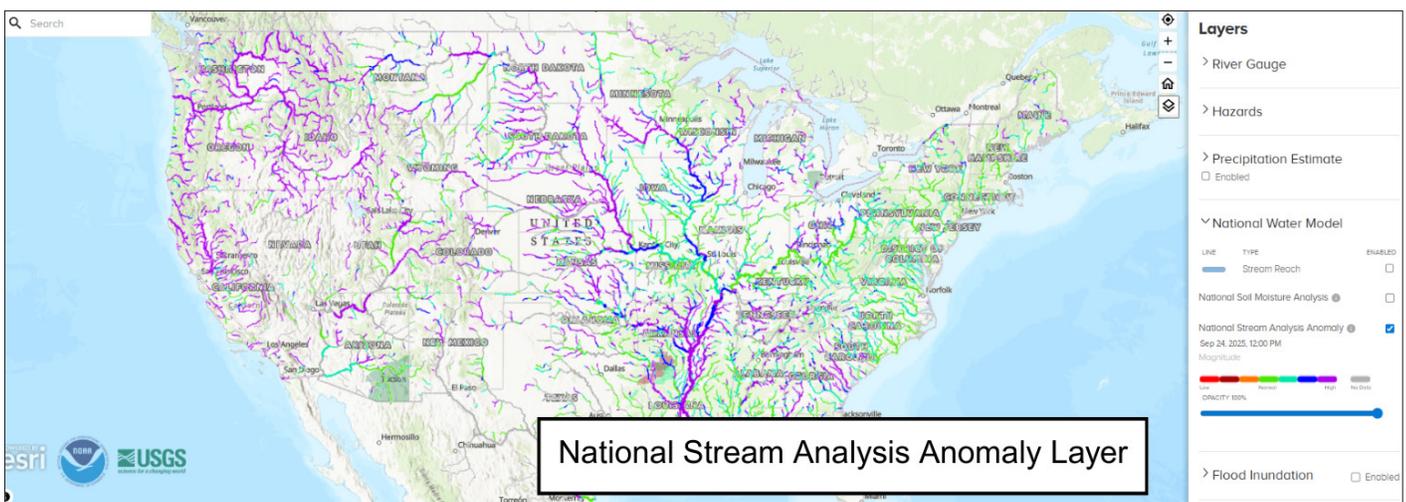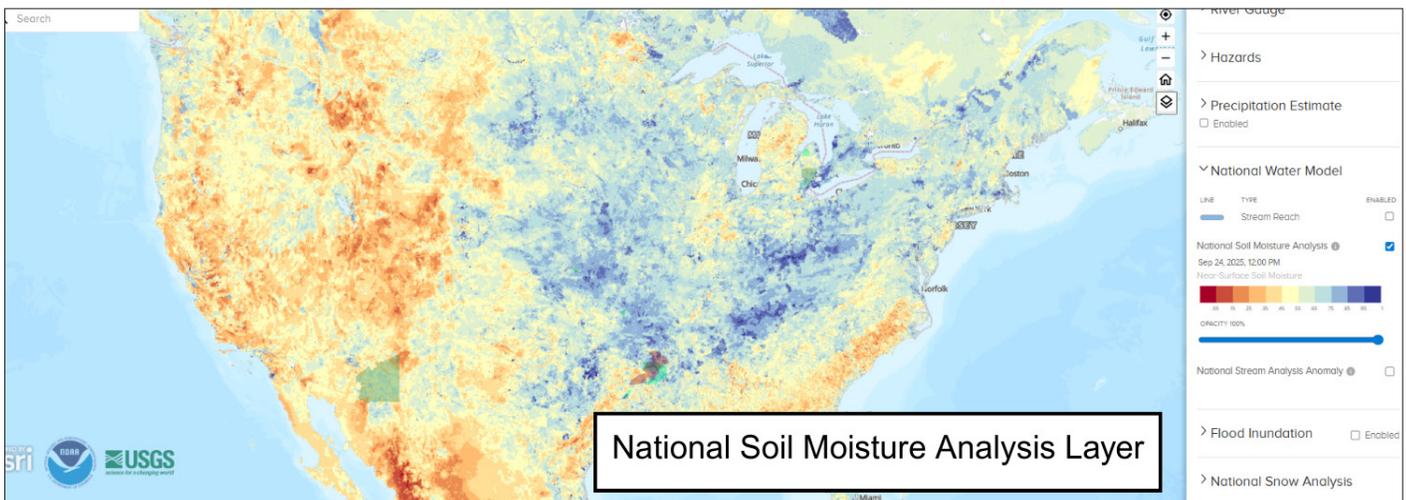
Section 4: Accessing NWM Retrospective Datasets

1. Accessing additional retrospective simulations from the NWM on streamflow, as well as other hydrological conditions from the past 40 years, requires some experience in data science and modeling. As these datasets use simulated data, not the near-real-time analysis for forecast data explained above, they have limited utility in evaluating the NWM forecast accuracy in past events. These simulations are typically used for assessing overall model performance, calibrating parameters, or supporting hydrologic research. However, they can provide expansive datasets of NWM-based streamflow estimates which may be useful in areas where historical water-related data is limited. Below is some guidance for how you might be able to access this information:

   a. **Contact Experts:** Reach out to NOAA officials within your local National Weather Forecast Office who might be able to help you access this information. Please visit: https://www.weather.gov/srh/nwsoffices to see NWS offices.

   b. **Tutorials:** Below are some tutorials on how to access the NWM retrospective dataset developed in Jupyter notebooks. They will walk you through how to access the National Water Model (version 3) retrospective, simulated data, particularly the streamflow data. Note: The following resources assume that users have basic to intermediate knowledge and skills working with cloud-native data, Python, relevant packages such as x-array, and experience using Jupyter Notebook.

      - Garousi-Nejad, I., A. M. Castronova, K. B. Raub (2024). Demonstration of the National Water Model's Applicability to Community Resilience Planning: Cincinnati Use Case, HydroShare, http://www.hydroshare.org/resource/0ef4366e7711478fa2637f5049b4881a (For more information on how Cincinnati used NWM retrospective data to assess the vulnerability of their transport infrastructure projects, please view a report on their use case)

      - Garousi-Nejad, I., A. M. Castronova, K. B. Raub (2024). Demonstration of the National Water Model's Applicability to Community Resilience Planning: Minnesota Use Case, HydroShare, http://www.hydroshare.org/resource/3200bab682ec4c3287147cbe40e768ee (For more information on how Minnesota used retrospective data to provide flood insights in areas where existing water-related information was limited, please view a report on their use case)

   c. **Datasets**: This is recommended for those who are proficient in hydrologic modeling and data analytics. To access NWM raw data please visit: https://registry.opendata.aws/nwm-archive/

Section 5: Flood Inundation Mapping (Experimental)

For certain locations, you can view flood inundation maps based on NWM forecasts. Flood Inundation Mapping (FIM) shows where flooding may occur if water exceeds certain levels. Currently, FIM services are considered experimental, and they cover parts of the Midwest and Southeast, including flood-prone river systems like the Ohio, Mississippi, and Tennessee Rivers, as well as some major urban centers (e.g., Houston, Atlanta, St.Louis) as of September 2025. Coverage also extends to parts of the Northeast, West Coast, Alaska, Hawaii, and Puerto Rico. FIM is still under development and its network will be expanded through 2026.

Areas where FIM services are currently (available as of September 2025).

1. **To view flood inundation forecasts:**
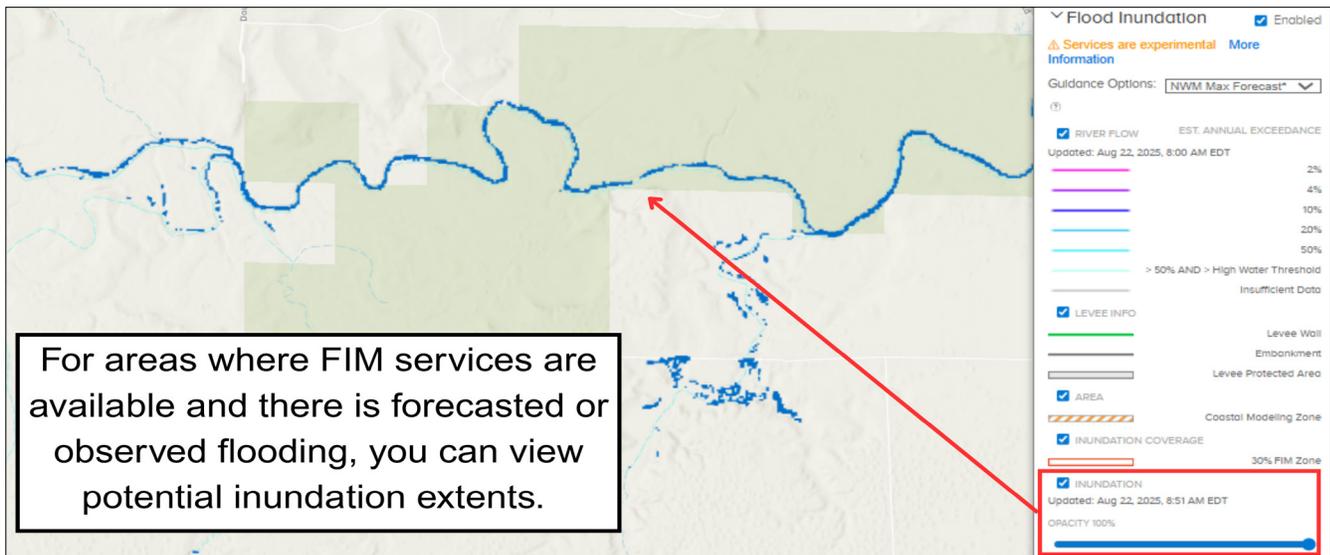   Enable the 'Flood Inundation' layer in the layer panel.

2. **Understand 'River Flow':** When 'River Flow' is enabled right below the Guidance Options, it displays only rivers that are currently experiencing streamflow at or above the thresholds associated with specific flood stages. River flow conditions are shown in different colors, with each color representing a specific threshold exceedance. There are several display options for 'River Flow.'

3. **Select display option:** A dropdown menu will appear when you click on 'Guidance Options.' By default, the display is set to "NWM Max Forecast," which is the most useful option for checking whether an ungauged river is exceeding high streamflow thresholds. Alternatively, some people may prefer to set the option to 'RFC Max Forecast' for a snapshot of flooding on major gauged rivers throughout the country. Specific information on the utility of each layer is provided below.
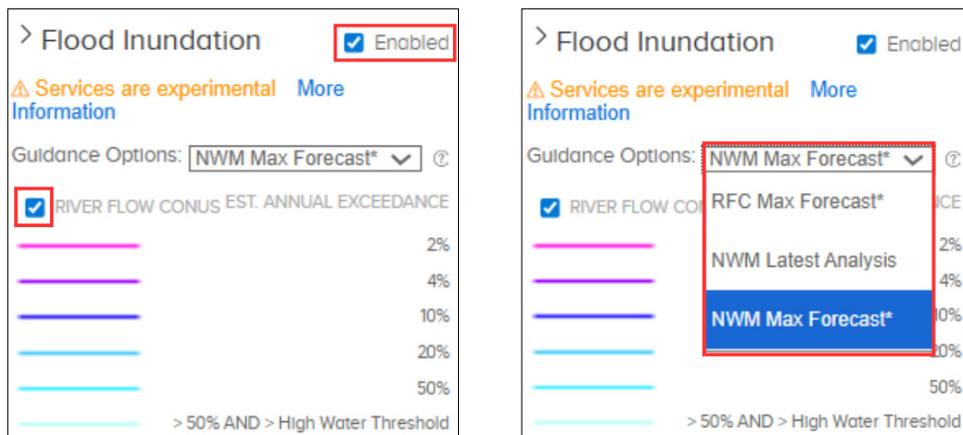

a. **RFC Max Forecast:** River Forecast Centers (RFCs) produce river and flood forecasts, while Weather Forecast Offices (WFOs) provide local weather forecasts and warnings. This layer shows inundated areas for rivers monitored by RFCs when streamflow reaches the "Action" stage, based on forecasts up to 5 days out. Streams are marked as exceeding minor, moderate, or severe thresholds. Since this layer sits above the rivers, you may want to adjust its opacity to see the river color beneath, which indicates its flood status as shown in the "River Flow" section.

b. **NWM Max Forecast:** This layer is based on a 5-day weather forecast and displays rivers, including those both covered and not covered by RFCs, that exceed the high streamflow threshold. These thresholds vary regionally and are determined by the NWM's 40-year retrospective data. The values are presented as recurrence intervals. For example, 2% flood represents a 2% chance of a flood occurring every year over a 100-year period, which corresponds to a 1-in-50- year flood.

c. **NWM Latest Analysis:** This displays the simulated data from the analysis run that is updated hourly based on recent observations for rivers where streamflow has exceeded the high streamflow threshold. It is intended to provide a snapshot of the most recent modeled floods. The values are also represented as recurrence intervals.

d. **Others:** Remaining options cover the U.S Virgin Islands and Puerto Rico only.

4. **To view flood inundation extent:** Enable the 'Inundation' layer within 'Flood Inundation' to show flood inundation extents. When you zoom in to a river that is exceeding a threshold, you will be able to see the modeled extent of flood inundation represented by blue squares. You can also adjust the opacity of this layer using the slider.

For areas where FIM services are available and there is forecasted or observed flooding, you can view potential inundation extents.

5. **Additional Flood Inundation data:** Other layers you can enable within the Flood Inundation layer drop-down include:
   a. **Levee Info:** Displays locations and elevations of levees, embankments and protected areas that are within the National Levee Database.
   b. **Coastal Modeling Zone:** These are areas between 0m and 10m above sea level along the coast where inundation models should be viewed with caution as they do not account for coastal processes (e.g., storm surge).
   c. **Inundation Coverage:** These show areas that have Flood Inundation Mapping (FIM) coverage within a red line boundary. As of September 2025, FIM services currently provide partial national coverage (approximately 60% of the United States), with plans to continue expansion through 2025-2026.

Additional Flood Inundation Layers
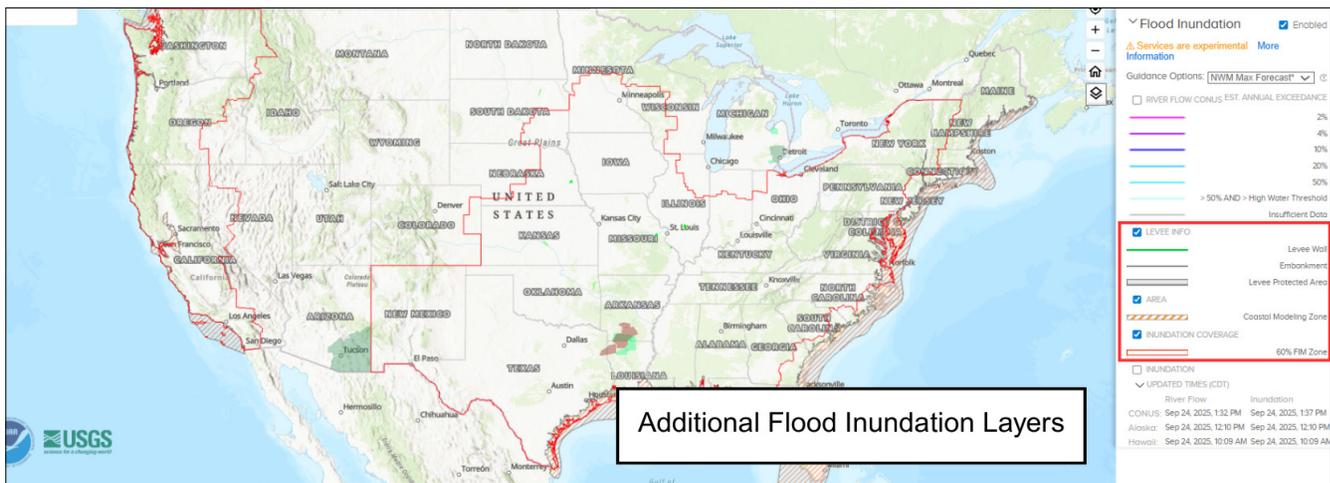
Glossary of Key Terms

- **Action Stage:** The level of a rising stream at which communities need to take some type of mitigation action to prepare for flooding (determined by the NWS).
- **Bankfull:** This is the point at which water begins to flow over the lowest natural banks.
- **Crest:** The highest stage or level of a flood wave as it passes a certain point.
- **Cubic Feet per Second (CFS):** A unit measuring the volume of water flow per second. To learn more about what the standard streamflow in cfs would be for a specific river, please visit USGS WaterWatch website. WaterWatch provides statistical information on streamflow based on historical data in graphs and tables. The NWPS flood categories and corresponding streamflow values for rivers with gages is also a useful reference point.
- **Datum:** Arbitrary reference elevation to help calculate stage. Datums differ regionally across the US, but a common datum is mean sea level.
- **Exceedance Probability:** The likelihood, expressed as a decimal (e.g., 0.01), that a streamflow or stage threshold is equaled or surpassed in a given time period.
- **HAND Method:** Stands for Height Above Nearest Drainage and is a model based on terrain analysis that estimates inundation using elevation and proximity to streams.
- **Hydrograph:** A graph displaying river levels over time, which is used for both real-time and historical comparisons.
- **Low Stage**: Water is low enough to cause disruptions to water supply, commerce and may damage property.
- **Major Flood Stage:** A flood category that indicates properties, including public utilities like hospitals and schools, may be at risk of extensive flooding. Evacuations may be necessary.
- **Minor Flood Stage:** A flood category that indicates some private property, roads and park land near rivers or streams may be a risk of flooding.
- **Moderate Flood Stage:** A flood category that indicates properties and major roadways may be at risk of flooding and evacuations may be necessary.
- **Return Interval:** Also known as recurrence interval, is an indicator of how frequent a particular hydrological event occurs on average. For example, a 1-in-100 year flood has a 1% chance of occurring every year.
- **River Reach:** A river reach is a stretch of a stream or river that behaves in a similar way (e.g., flood warning information would be consistent for the entire river reach as streamflow and other characteristics are similar).
- **Stage Height:** The height of the water surface above a reference point, usually in feet.
- **Time-Series Data:** A sequence of data points collected or recorded at successive in time, representing how a particular hydrologic variable changes over time. In hydrology, time series often describe measurements or estimates such as streamflow, precipitation and groundwater levels.
- **Water Depth:** Water depth is the height of the water from the surface to the river bed. As the river bed is uneven and fluctuates often, it is challenging to have a consistent measurement of water depth which is why stages and datums are used.

Where Can I Learn More About the NWM or Other NOAA Resources?

For more information on how to use the National Water Prediction Service interface, access National Water Model data, or other NOAA resources, please view these additional guides below:

- National Water Prediction Service
- User's Guide to the National Water Prediction Service (NWPS)
- Introducing the New National Water Prediction Service (NWPS)
- NWS National GIS Map Viewer
- NWS Products and Services
- NWS Flood Inundation Mapping Services
- Using the National Water Model within NWPS
- Flood Inundation Mapping, a recording of John Goff, Senior Service Hydrologist with NOAA/NWS in Burlington, VT hosted by Flood Ready Vermont

Acknowledgements

Project Background

This tutorial was developed through a collaboration between the Global Resilience Institute (GRI) at Northeastern University and the Consortium of Universities for the Advancement of Hydrologic Science, Inc.(CUAHSI), as part of a three-phase study funded by the Cooperative Institute for Research to Operations in Hydrology (CIROH). The project explored how NOAA's National Water Model (NWM) could be made more accessible to a broad group of potential end users – those engaged in local water-related planning and decision-making.

The three Phases of this study were designed to 1) better understand the landscape of how community-level resilience planning operates in practice and how communities can leverage the NWM to support their water-related decision-making, 2) co-develop a set of use cases that demonstrate the use of the NWM and increase its accessibility, and 3) further investigate the accessibility of the NWM for diverse end users, particularly those who lack specialized hydrology knowledge, and co-develop solutions for its use in resilience planning.

As part of this third phase, we collaborated with six communities in Vermont and Missouri to co-develop FloodSavvy, a customized web interface and flood scenario testing tool that provides simplified access and visualization of operational NWM forecast and historical data for these six regions. FloodSavvy intends to lower the barrier of entry for users who lack specialized hydrology knowledge. With the same goal in mind, this tutorial was created for first-time users of the NWM to contextualize NWM information and provide a simple connection to official NOAA services.

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