National Weather Service Flood Inundation Mapping

National Weather Service
Des Moines, IA

Agenda

.01
Flood Inundation Mapping Overview

.02
Flood Inundation Mapping and Impact-Based Decision Support Services

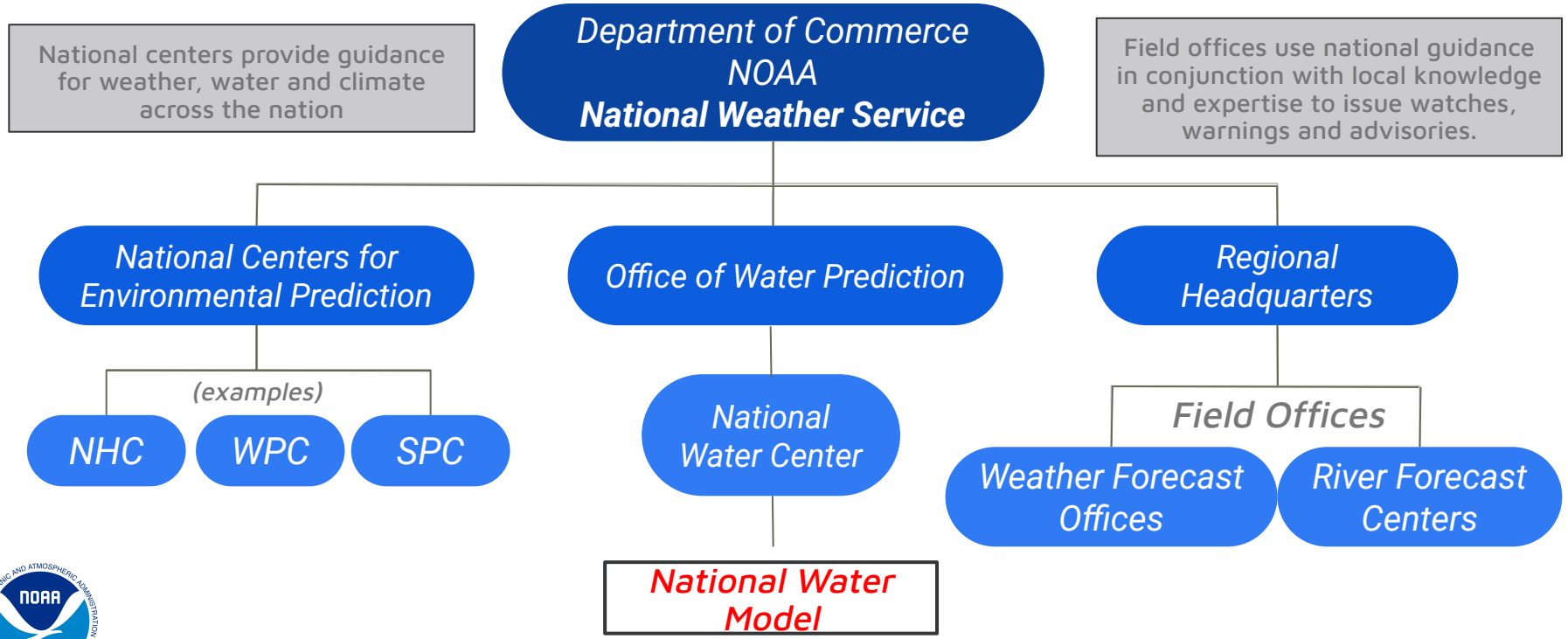
.03
Implementation Process

.04
Viewing FIM

Flood Inundation Mapping Overview

National Weather Service

Mission accomplished by multiple levels



Why Use Flood Inundation Mapping?

- Change the way we communicate flood forecasts and associated impacts
- Improve how we can protect lives and property

Map vs. Text

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FLC097-292345-
/O.EXT.KMLB.FL.W.0006.000000T0000Z-220930T1926Z/
/SHIF1.3.ER.220929T0557Z.220929T1200Z.220930T1326Z.NR/
735 AM EDT Thu Sep 29 2022

...FLOOD WARNING NOW IN EFFECT UNTIL TOMORROW AFTERNOON...

* WHAT...Major flooding is occurring and major flooding is forecast.
  This approaches the flood of record.

* WHERE...Shingle Creek At Campbell.

* WHEN...Until tomorrow afternoon.

* IMPACTS...At 62.3 feet, Water enters many homes in Good Samaritan
  Village. Water approaches Sherwood Forest manufactured homes.
  Streets in Camelot and Sherwood Forest not navigable by regular
  vehicles. Property and roads in southern Old Town receiving water.

* ADDITIONAL DETAILS...
  - At 7:15 AM EDT Thursday the stage was 62.2 feet.
  - Recent Activity...The maximum river stage in the 24 hours
    ending at 7:15 AM EDT Thursday was 62.2 feet.
  - Forecast...The river is expected to fall below flood stage
    late tomorrow morning and continue falling to 58.6 feet early
    Saturday morning.
  - Flood stage is 60.0 feet.
  - http://www.weather.gov/safety/flood

&&

             Fld   Observed        Forecasts (8 am)
Location     Stg   Stg   Day/Time  Fri   Sat   Sun   Mon   Tue

Shingle Creek
Campbell     60.0  62.2  Thu 7 am  60.8  60.1   MSG   MSG   MSG
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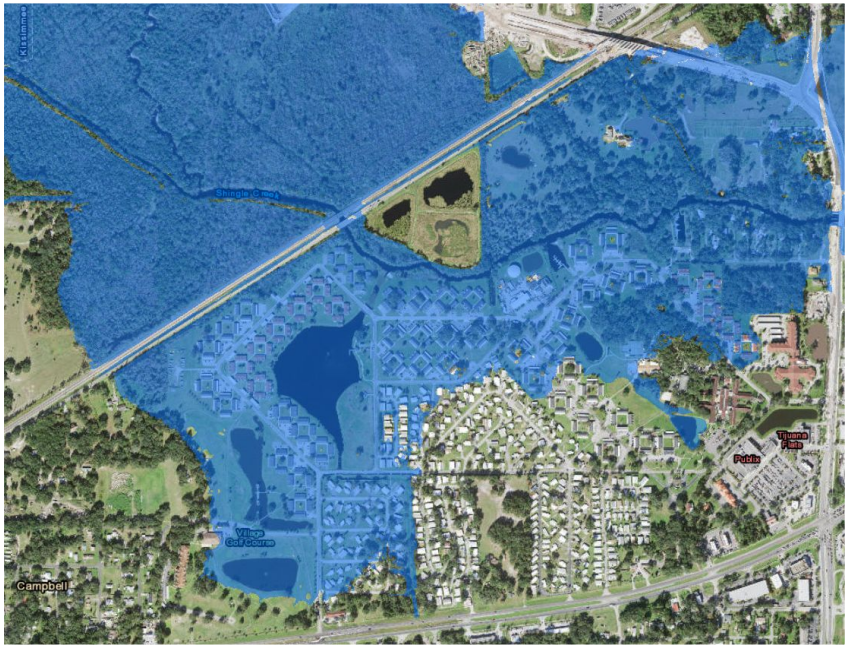
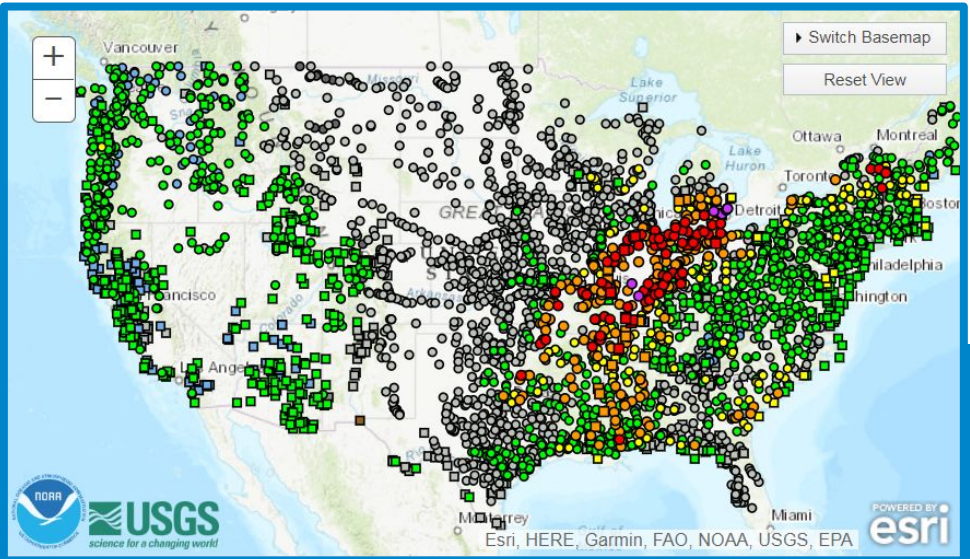
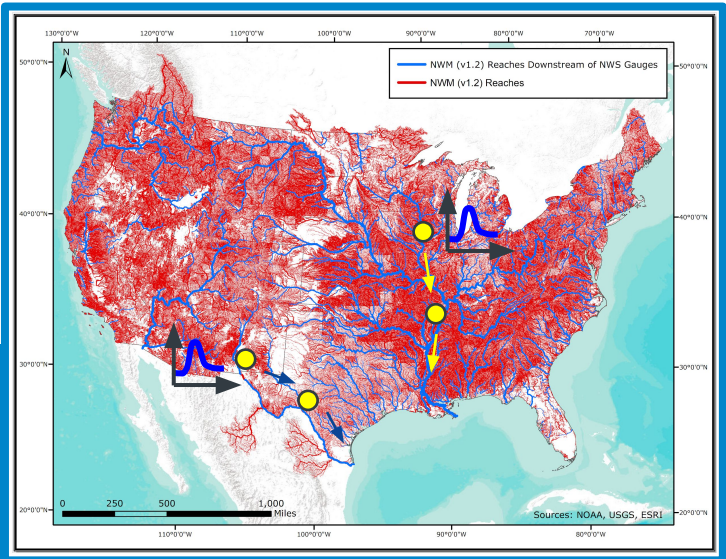


Evolving Water Prediction Capabilities



~3,600 NWS River Forecast Points
Traditional NWS River Model
~1 forecast point for every **1,000** river miles

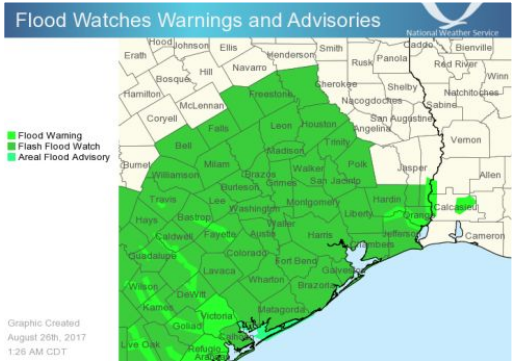


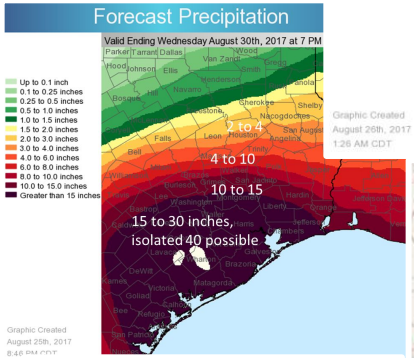
~2.7M NWM River Forecast Points
National Water Model (NWM)

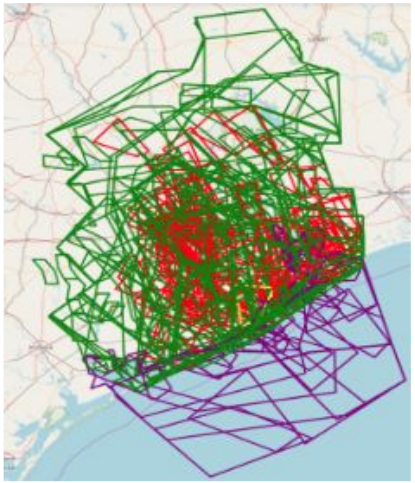
Note there are 3.4M river miles in the U.S.

Example: Hurricane Harvey--2017

- Flood warning polygons provide value but they don't give the whole picture
- Flood inundation mapping would have painted a better picture about potential impacts
- Better at answering questions…
  - Do we have to evacuate the assisted living facility?
  - How many houses are going to flood?
  - From where should we bring swift water rescue teams?
  - How bad is it going to be?
  - How much worse will it get?
  - What's your reasonable worst case scenario?
  - When can we get into the area that flooded?







Example: Asheville, NC / Helene--2024

Record Flooding Forecast in Asheville, NC

Friday, September 27, 2024
12:45 AM EDT

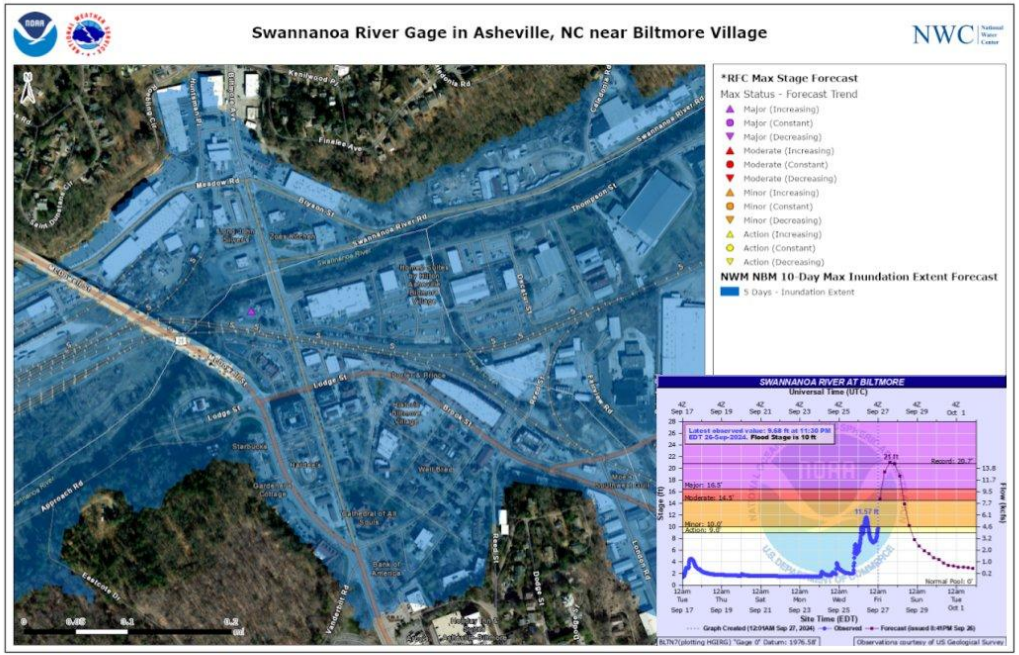
Life Threatening Flooding Possible

Key Messages

- Record flooding is forecast along the Swannanoa River
- Life threatening flooding may be possible
- Flood inundation mapping suggests widespread flooding in the Biltmore Village area of Asheville (shown in blue in the image on the right)
- To escape rising water, take the shortest path to higher ground.

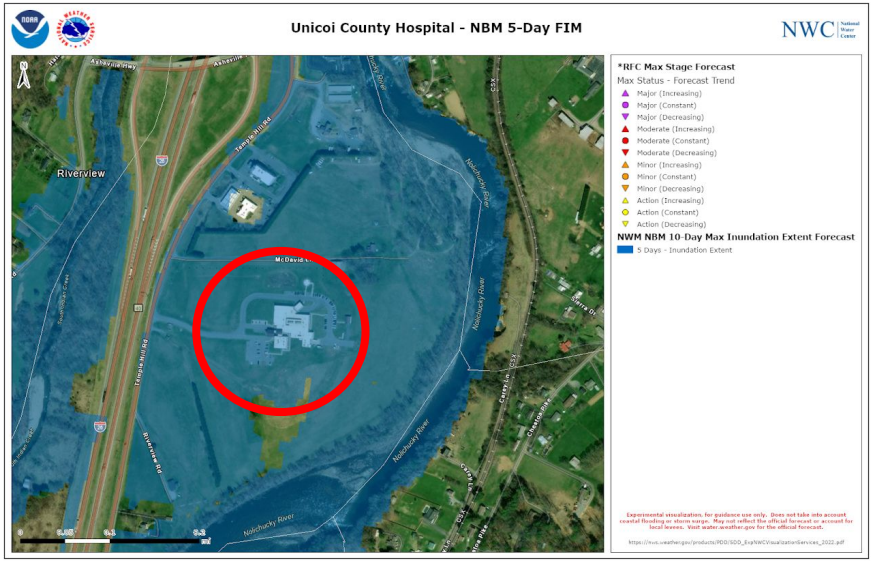
Timing

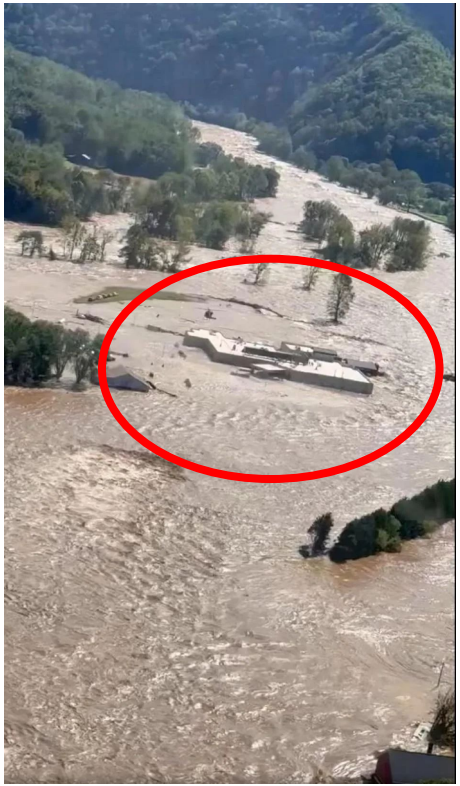
- Flooding is ongoing and expected to crest Friday evening at record stage



Example: Unicoi County Hospital (Erwin, TN / Helene--2024)

- Official NWS river forecast indicated record flooding on the Nolichucky River
- Stages far above those even seen before
- How high will the water get?
- What will be affected?

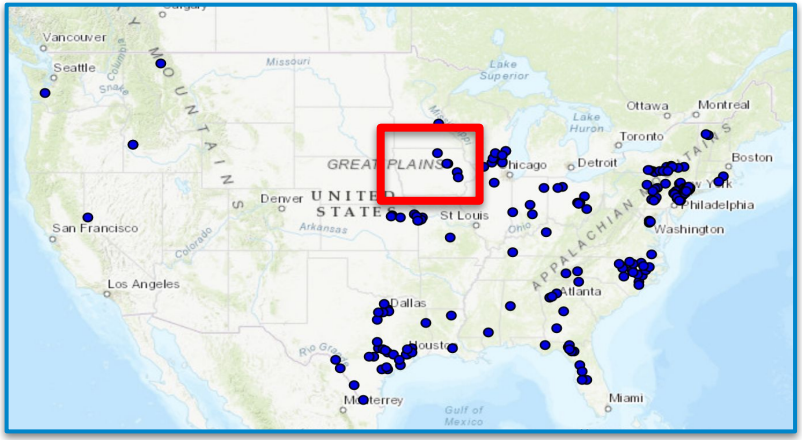




NWPS Partner Flood Inundation Mapping

NWPS Partner Flood Inundation Mapping Libraries (NWPS Partner FIM) - Static maps at ~200 NWS river forecast locations. Maps derived from engineering scale hydraulic models.

< 1,000 miles



Locations in Iowa

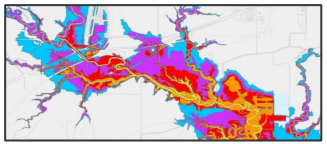
- **Winnebago River at Mason City**
- **Iowa River at Iowa City**
- **Cedar River at Cedar Falls**
- **Cedar River at Waterloo**
- **Cedar River at Cedar Rapids**

There are five Iowa Flood Center inundation libraries in Iowa as shown above

NWS FIM Capabilities

Static

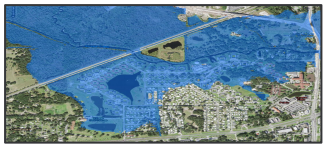
NWPS Partner FIM Libraries (NWPS Partner FIM) ~200 NWS river forecast locations. Shows the flood extent & depth based on a river crest of X feet. This is a hydraulic-based FIM which can be used with high confidence.



NWS Flood Categorical HAND FIM Libraries (CatFIM) ~3,000 NWS river forecast locations. Maps derived from 10 m Height Above Nearest Drainage (HAND) solution. *(Currently scheduled for public launch in Spring 2024)*

Dynamic

Forecast River Forecast Center Flood Maps (RFC 5-Day Max Forecast) downstream of ~3,600 NWS river forecast locations. Maps derived from traditional NWS river forecasts and 10-m Height Above Nearest Drainage (HAND) solution.

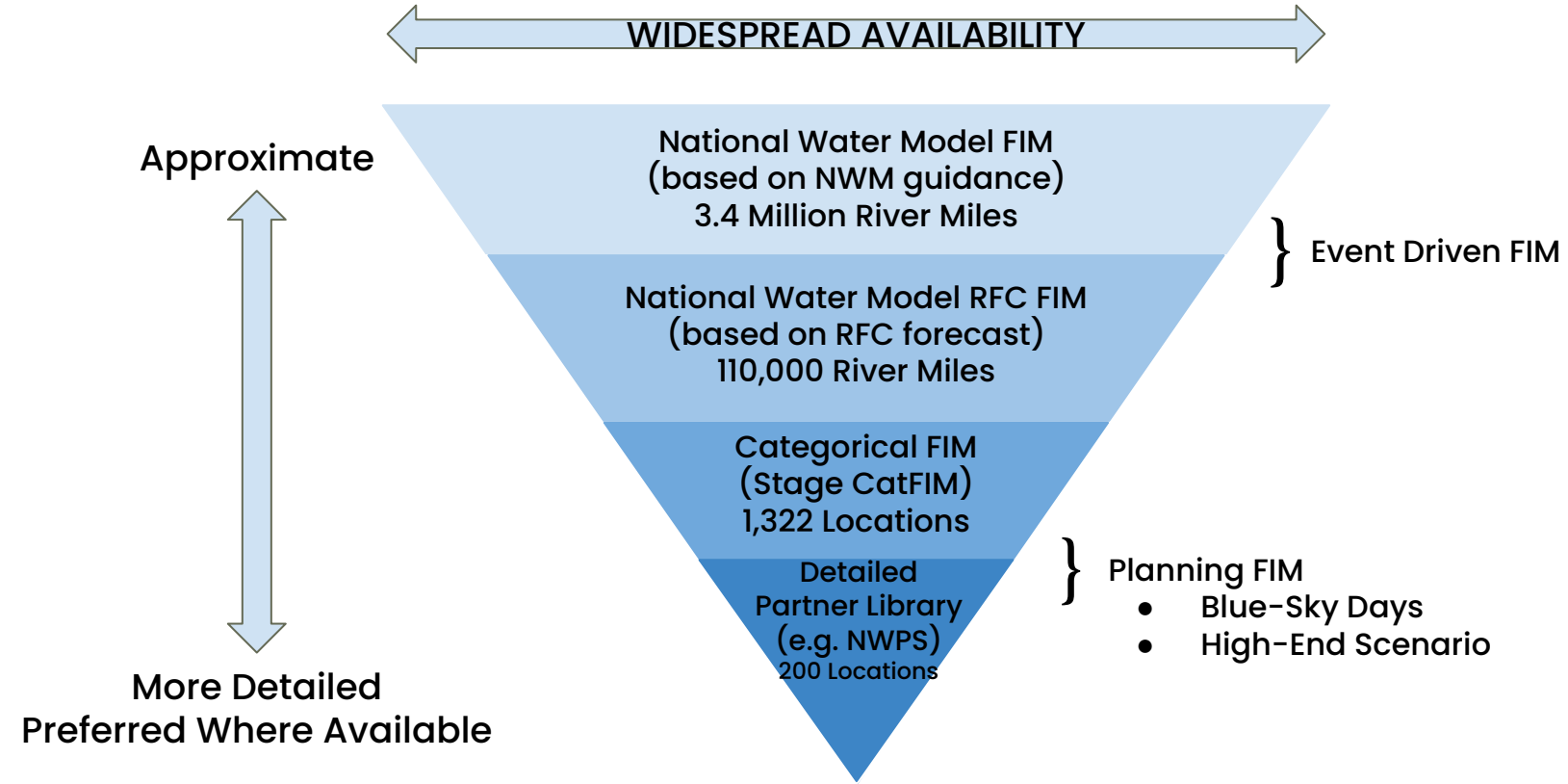


Forecast National Water Model Flood Maps (NWM 5-Day Max Forecast) along NHDPlus reach locations. Maps derived from NWM forecast and 10-m Height Above Nearest Drainage (HAND) solution.

National Water Model Latest Analysis (AnA) Flood Maps - utilizing observed rain and stream data to depict current flood extent. Maps derived from 10-m Height Above Nearest Drainage (HAND) solution.

Coverages
< 1,000 miles
~30,000 miles
~110k miles
~3.4M miles
~3.4M miles

Confidence and Flood Inundation Mapping



Interpreting NWS FIM

What is flooded?

~~*How deep will the water be?*~~

Flood Impacts & Photos — Collapse

If you notice any errors in the below information, please contact our Webmaster

18 Water reaches the bridge next to the gage house.

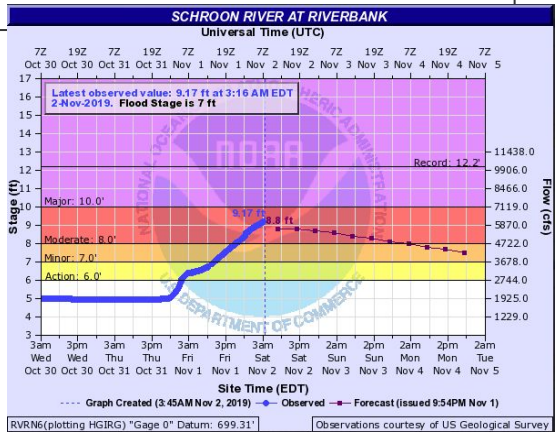
10 Water reaches major flood stage. There is 1 to 2 feet of water in homes and vacation properties near Warrensburg. Route 418 is under water in several locations. Sections of the highway are flooded along the right bank of river mostly upstream of gage.

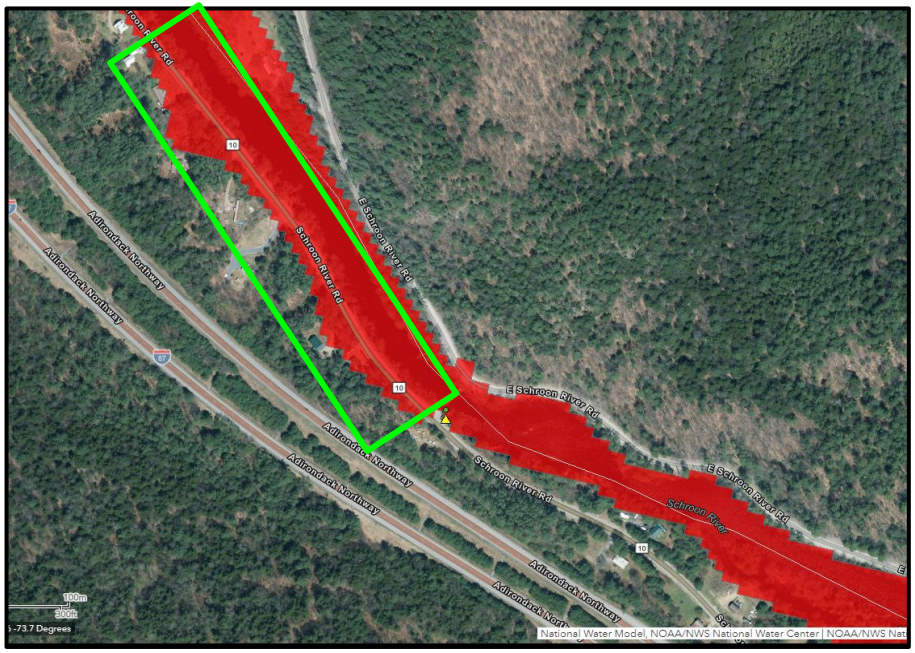
9 Water is over Tannery Road.

8 Water reaches moderate flood stage. Water surrounds several homes on Schroon River Road.

7 Water reaches minor flood stage with water in nearby lowlands and outbuildings.

6 Action stage. The river is near bankfull.



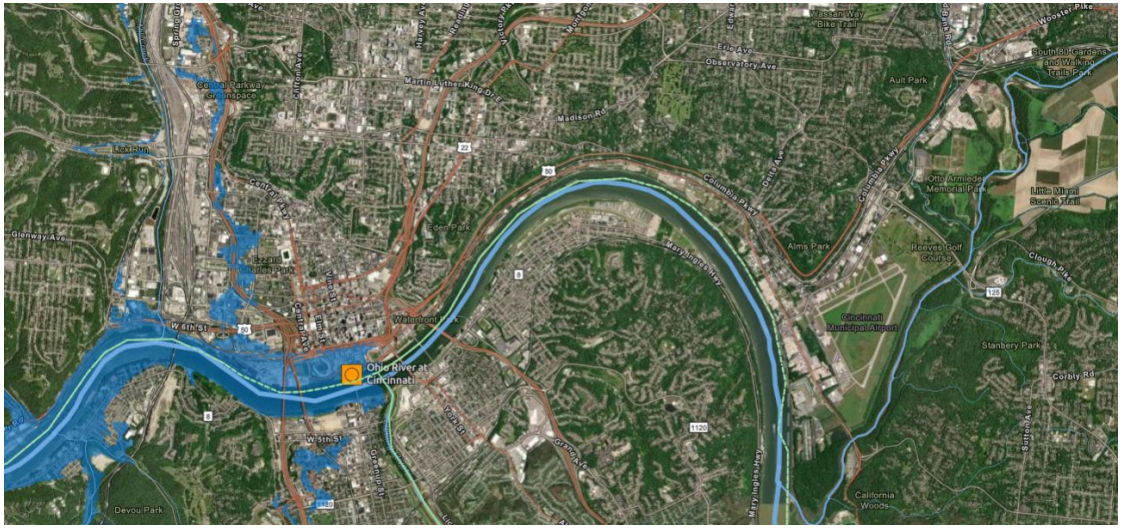


NWM Latest Analysis (AnA)

- Depicts closest reasonable inundation extent at the current time for locations exceeding the high water threshold
- High water threshold varies by region
- Latency (timing): ~80 minutes after top of every hour
- Limitation: reliability decreases in ungauged areas (or other data voids) where analysis cannot be tuned to observed information

RFC 5-Day Max Inundation Forecast FIM

- Depicts maximum inundation extent over the next 5 days derived from the official River Forecast Center (RFC) forecast
- Maximum streamflows are available downstream of NWS river forecast points whose forecast reaches Action Stage or higher flow threshold categories
- Latency (timing): ~45 minutes after forecast is issued
- Limitation: only available downstream of NWPS forecast points

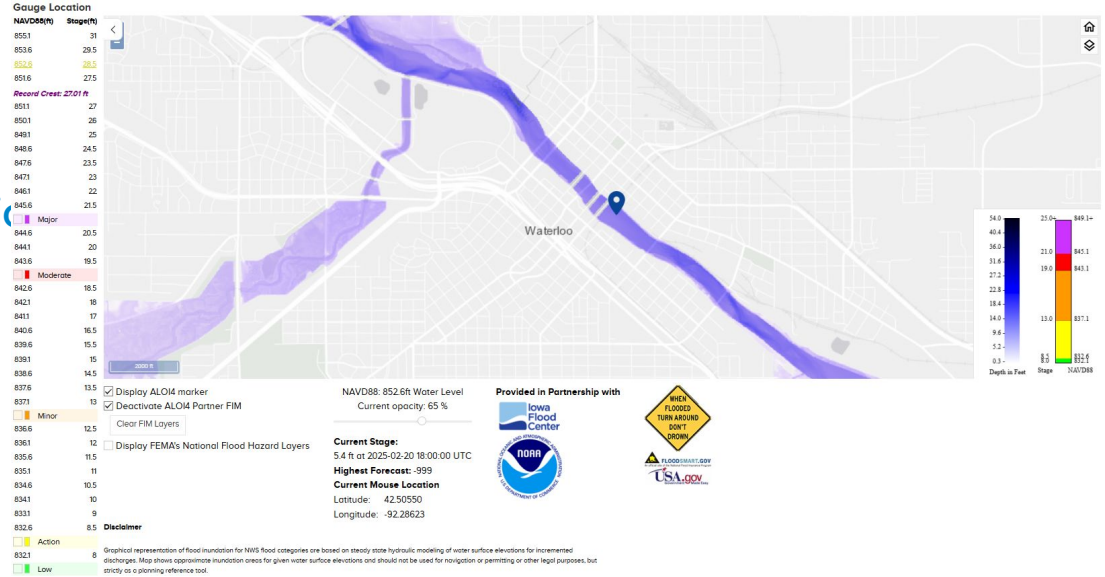


NWM 5-Day Max Forecast FIM

- Depicts inundation extent of peak National Water Model (NWM) streamflow forecast over the next 5 days where NWM is producing flows that meet or exceed high water threshold for a given river reach
- High water thresholds vary by region
- Latency (timing): ~30 minutes after 12Z, 18Z, 00Z and 06Z
- Limitation: Quality Control (QC) limitation exists because no forecaster is involved in decision-making process regarding forecast

NWPS Partner FIM

- Uses hydraulic modeling
- Not based on real-time river forecasts
- Availability: Nearly 200 sites natio
- 5 miles up / downstream
- High resolution (< 10 m)
- Extensively calibrated, verified
- Limited inundation of neighboring tributaries



IOWA FLOOD CENTER
Flood Inundation Mapping

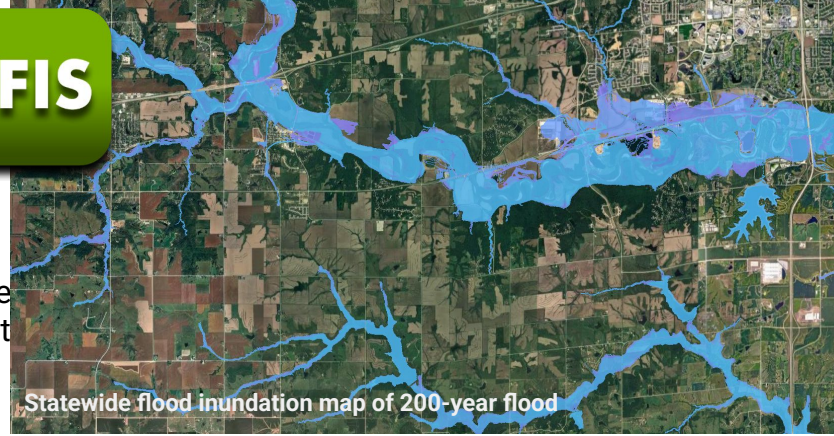
A critical resource to help citizens, emergency managers, community leaders and decision-makers identify and communicate Iowa's flood hazards and support informed floodplain management decisions.

Statewide Maps

- A collaboration with Iowa DNR, USACE and FEMA to update flood maps for every Iowa county. IFC researchers used laser radar (LiDAR) data provided by Iowa DNR to map all streams draining more than one square mile.

Community Maps

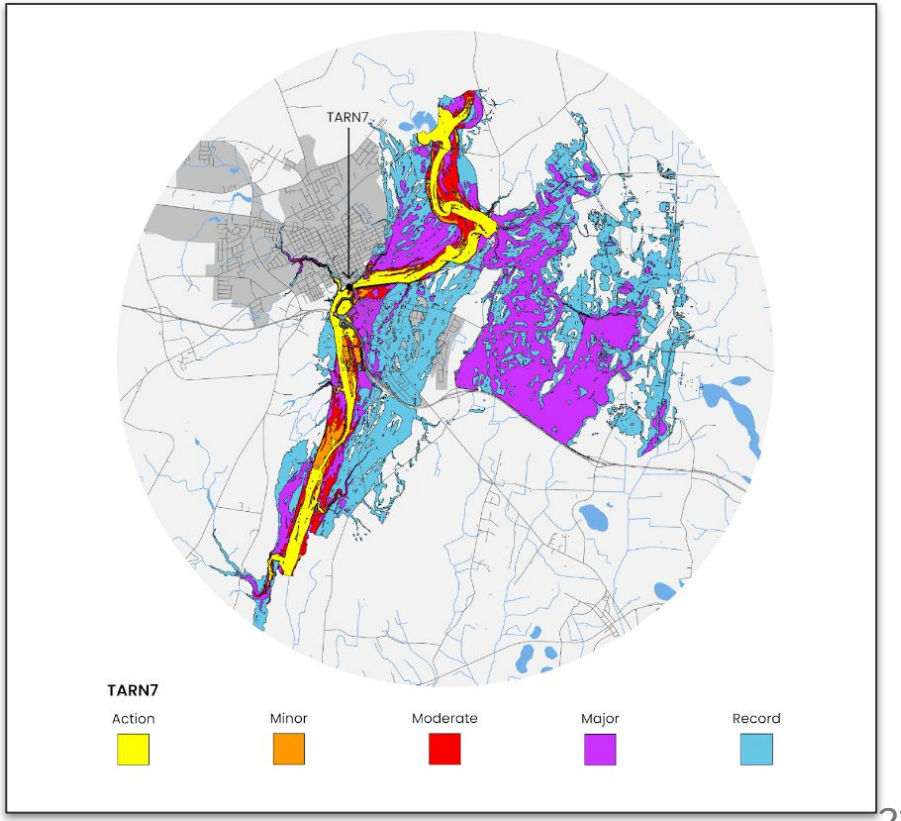
- IFC has developed flood inundation maps for dozens of Iowa communities that translate forecasted river stages into high-resolution, interactive, scenario-based maps.



Learn More → iowafloodcenter.uiowa.edu
View Flood Inundation Maps → ifis.iowafloodcenter.org

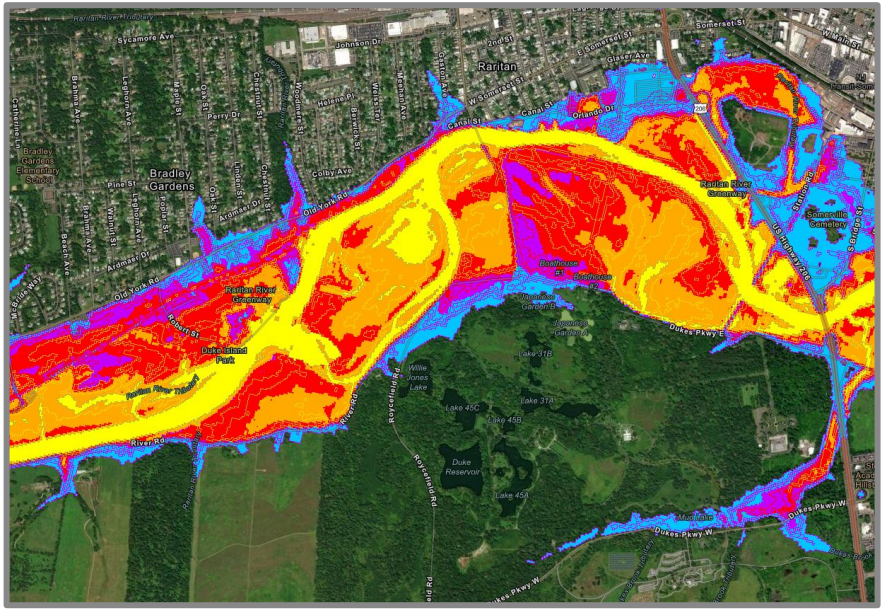
CatFIM

- Static inundation extent mapping library
- May be available at 1 ft increments or in the official NWS flood stage category thresholds (Action, Minor, Moderate, Major and Record)
- An invaluable tool for emergency planning and informing best practices for anticipation of potential future flood events
- Only available at select sites



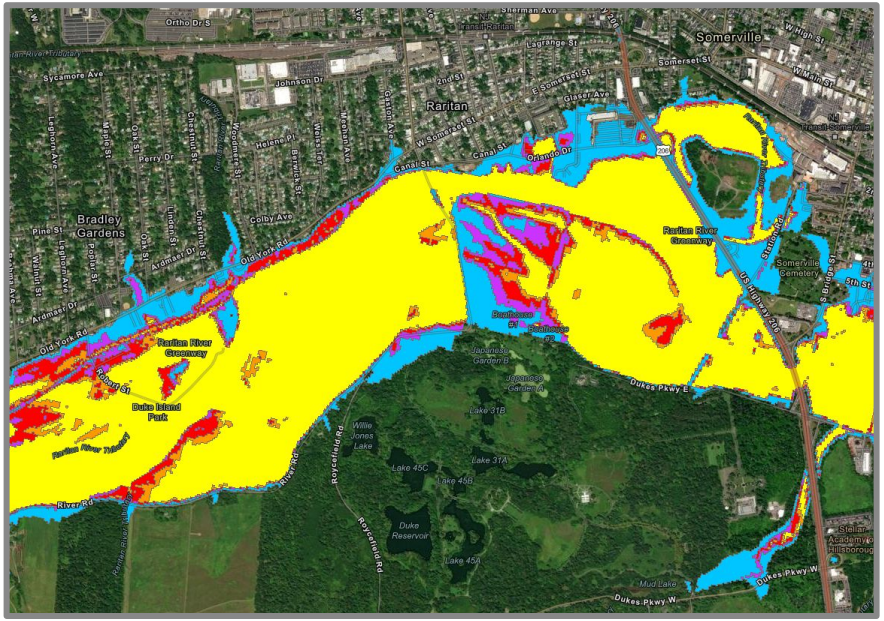
Stage-Based CatFIM

- Derived from NWM per HAND
- Not based on real-time river forecasts
- Limited availability (official NWS forecast points only)
- Inundation extent at 1 ft intervals
- Includes local flood categories
- 5 miles up / downstream
- 10 m resolution
- Uses USGS rating curves to establish the water surface elevation at the streamgage
- Planning / reference / what-if



Flow-Based CatFIM

- Derived from NWM per HAND
- Not based on real-time river forecasts
- Limited availability (official NWS forecast points only)
- Inundation extents at NWPS thresholds
- 5 miles up / downstream
- 10 m resolution
- Uses SRCs to determine stage throughout the reach and thus is subject to SRC error
- Planning / reference / what-if


Somerville
Raritan
Bradley Gardens
Duke Island Park
Lake 31B
Lake 31A
Lake 45C
Lake 45B
Lake 45A
Duke Reservoir
Mud Lake
Willie Jones Lake
Raritan River Trail
Dukes Pkwy E
Dukes Pkwy W
Old York Rd
River Rd
Somerset St
Johnson Dr
Canal St
Colby Ave
Ortho Dr S
Sycamore Ave
Perry Dr
Ardmore Dr
Pine St
Oak St
Maple St
Chestnut St
Walnut St
Poplar St
Linden St
Helena Pl
Weyman Ave
Mercer Ave
Garden Ave
Glaser Ave
Orlando Dr
Lagrange St
Sherman Ave
W High St
Somerville Cemetery
Stellar Academy Hillsborough
Raritan River Greenway
Raritan River Trail
Roycefield Rd
Bonsall Ct
Japanese Garden A
Japanese Garden B
Japanese Garden C
Duke Island Park
Duke Island Pl
Johnson Pl
Somerset Pl
Glaser Pl
Lagrange Pl
Sherman Pl
Somerset St
W Somerset St
E Somerset St
W High St
2nd St
5th St
Sycamore Ave
Legion Ave
Maple St
Oak St
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Chestnut St
Walnut St
Poplar St
Linden St
Helena Pl
Weyman Ave
Mercer Ave
Garden Ave
Glaser Ave
Orlando Dr
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Colby Ave
Ardmore Dr
Pine St
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Bonsall Ct
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River Rd
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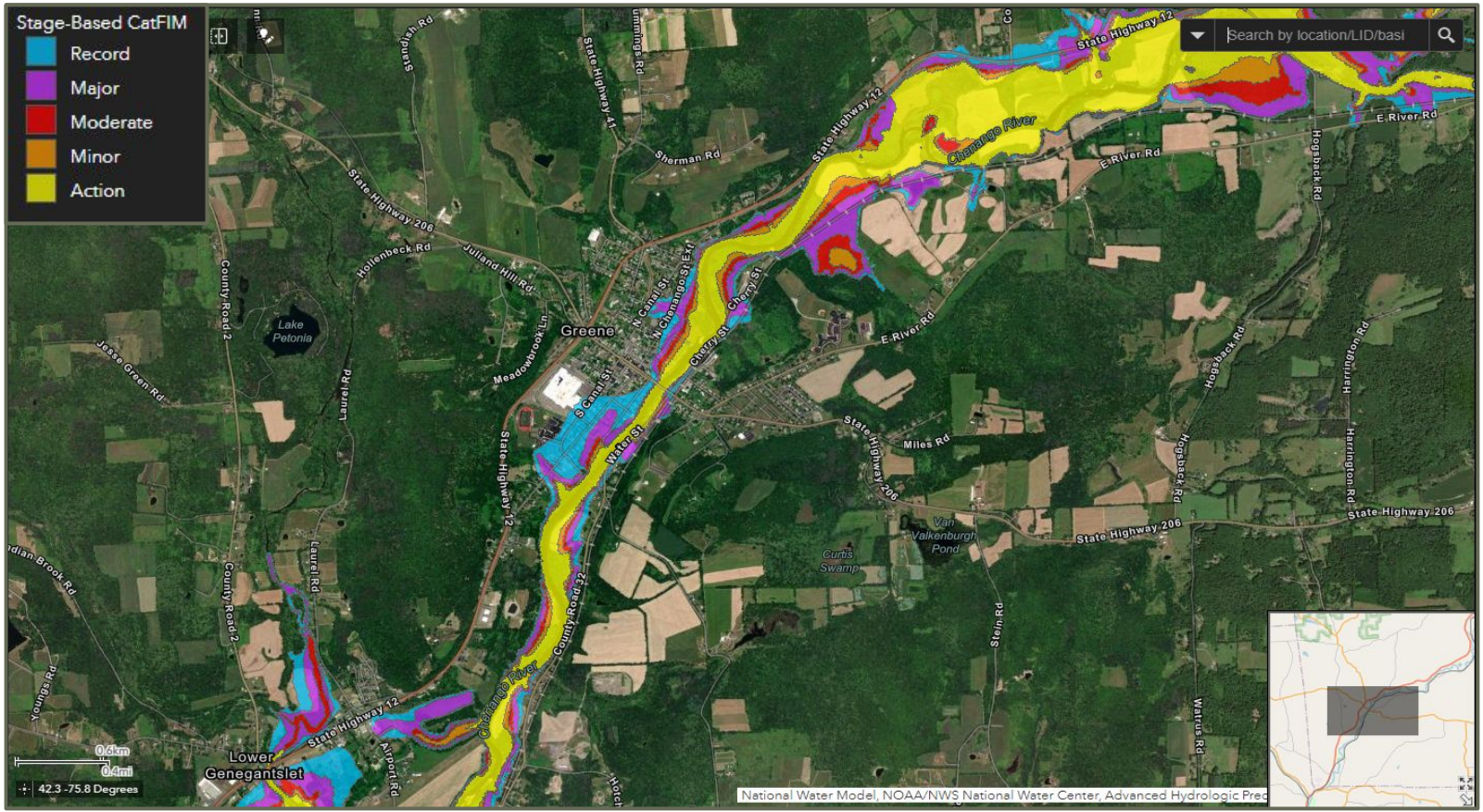
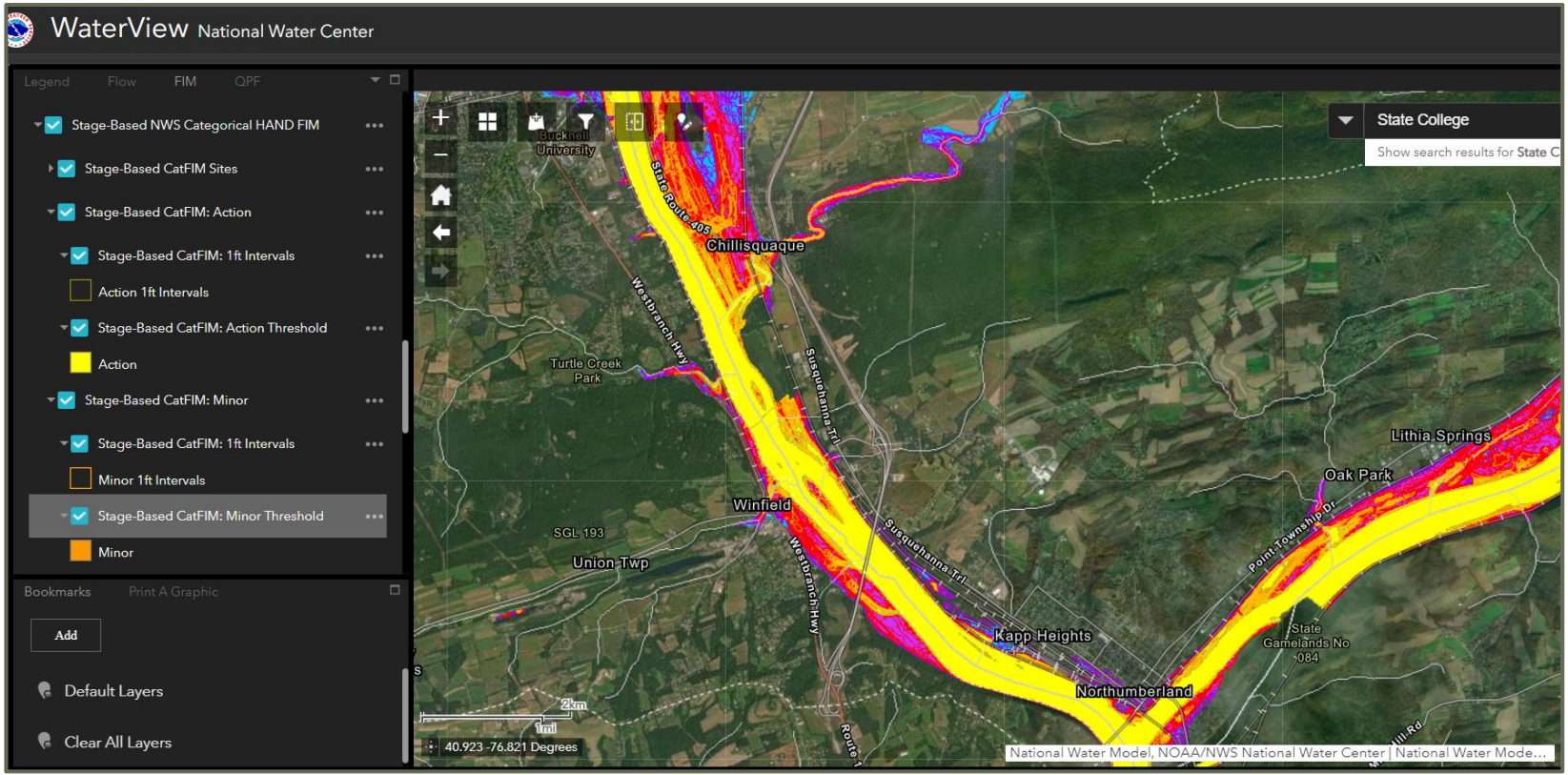
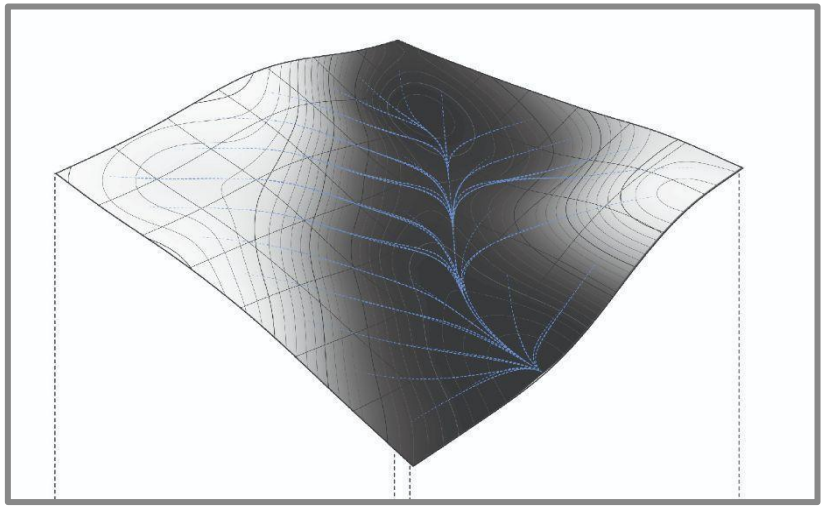
Stage-Based CatFIM



Stage-Based CatFIM



HAND (Height Above Nearest Drainage)

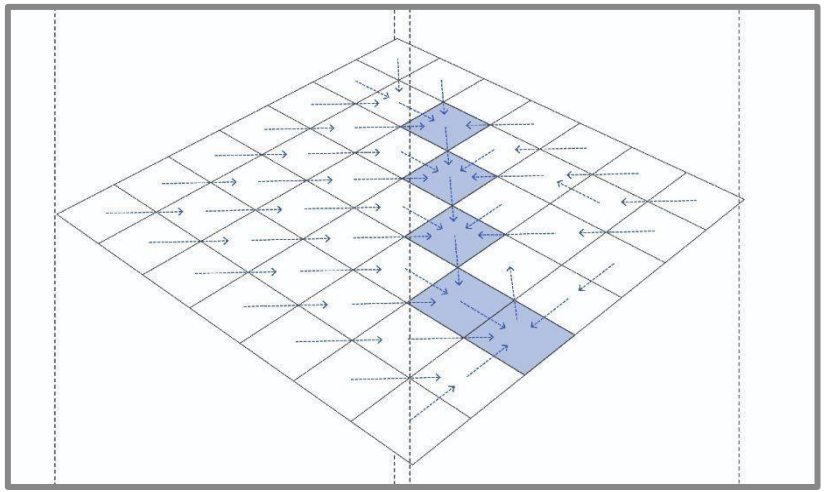


1 — 2 — 3 — 4 — 5 — 6

Identify Stream Reaches

Segment into 1.5 km flow lines from the Digital Elevation Model (DEM)

HAND (Height Above Nearest Drainage)

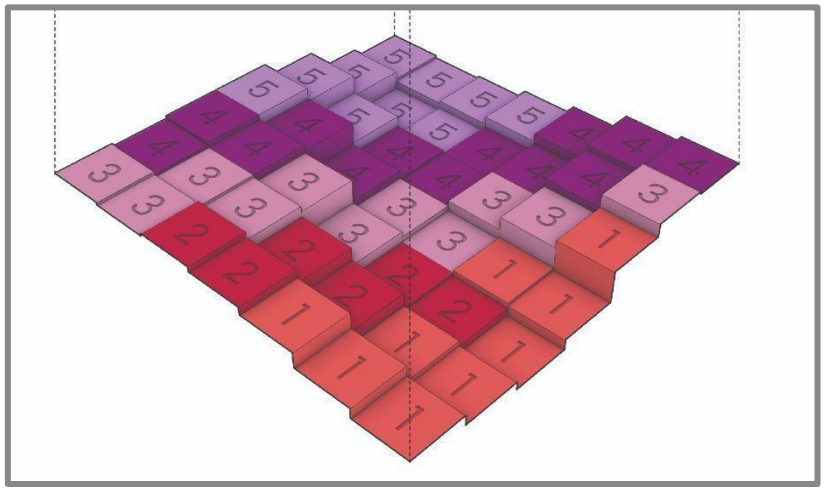


1 — 2 — 3 — 4 — 5 — 6

Generate Slope & Flow

Using the DEM, begin the process of hydro conditioning

HAND (Height Above Nearest Drainage)

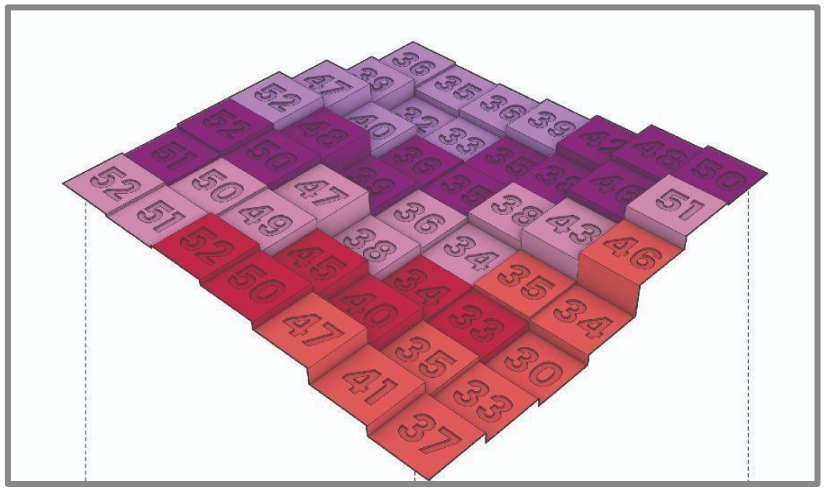


1 — 2 — 3 — 4 — 5 — 6

Delineate a Drainage Network

Creating the drainage network delineating the discrete catchments draining into each channel thalweg cell

HAND (Height Above Nearest Drainage)

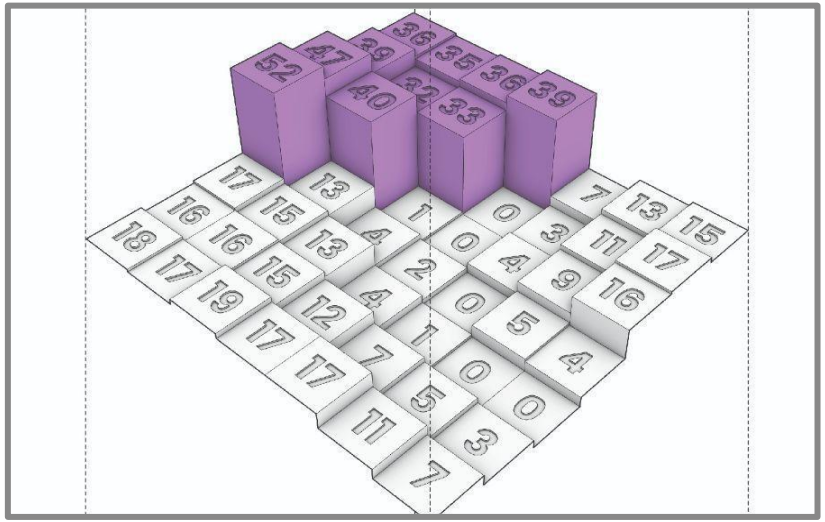


1 — 2 — 3 — 4 — 5 — 6

Convert Channel Elevation to Zero

Relating the elevation of the terrain to the elevation of the zero reference point (the channel thalweg)

HAND (Height Above Nearest Drainage)

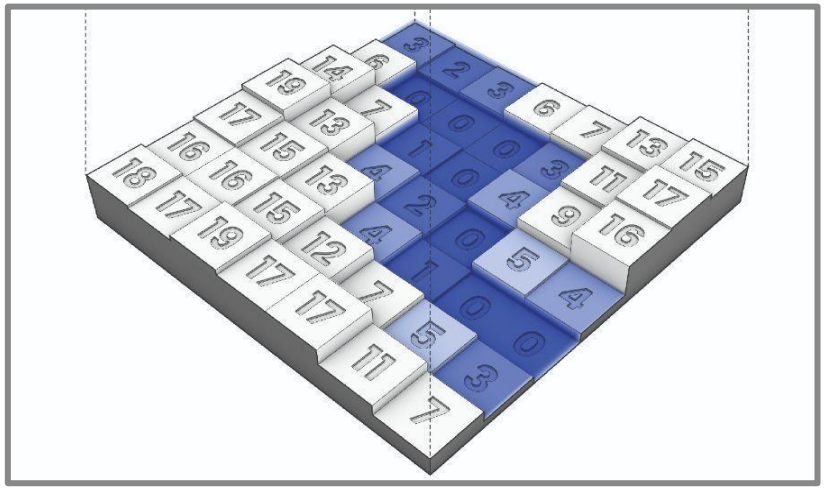


1 — 2 — 3 — 4 — 5 — 6

Calculate HAND for each catchment

Depict the elevation of the surrounding terrain above the river to which it drains

HAND (Height Above Nearest Drainage)



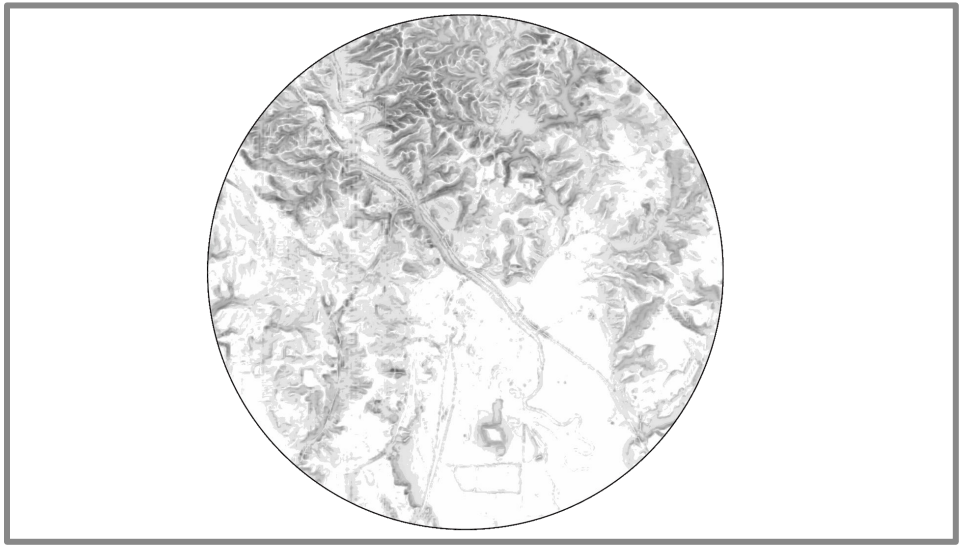
1 — 2 — 3 — 4 — 5 — 6

Compute the Relative Elevation Model

Each cell indicates the water depth needed to inundate that cell

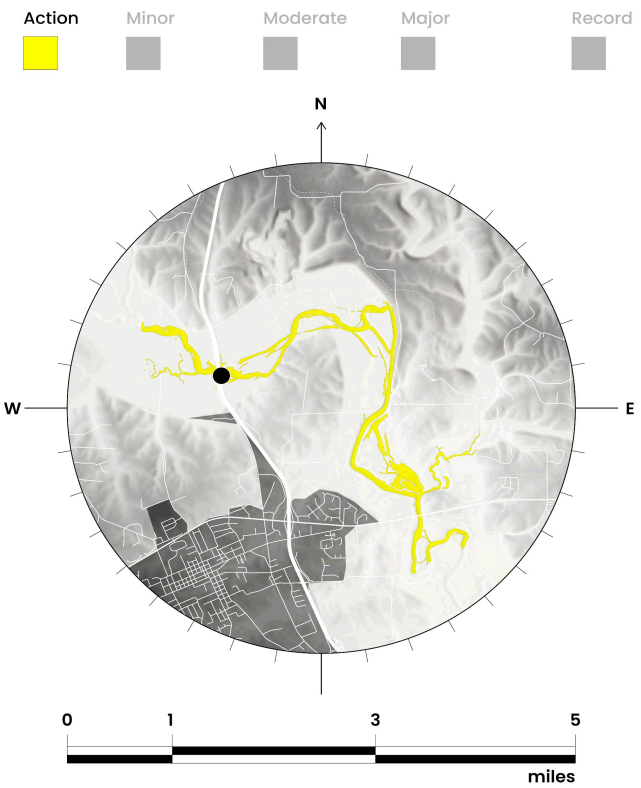
HAND Method: Process

- Strengths
  - Used for many FIM services
  - Fundamental and reliable method
- Limitations
  - Not a hydraulic model (zero physics)
  - Lack of bathymetry
  - FIM inaccuracies exist at / near levee areas
  - HAND does not account for backwater effects
  - HAND does not produce accurate waterbody inundation
  - Catchment boundaries can cause underestimation of inundation extents
  - Catchment boundaries can cause overestimation of inundation depths

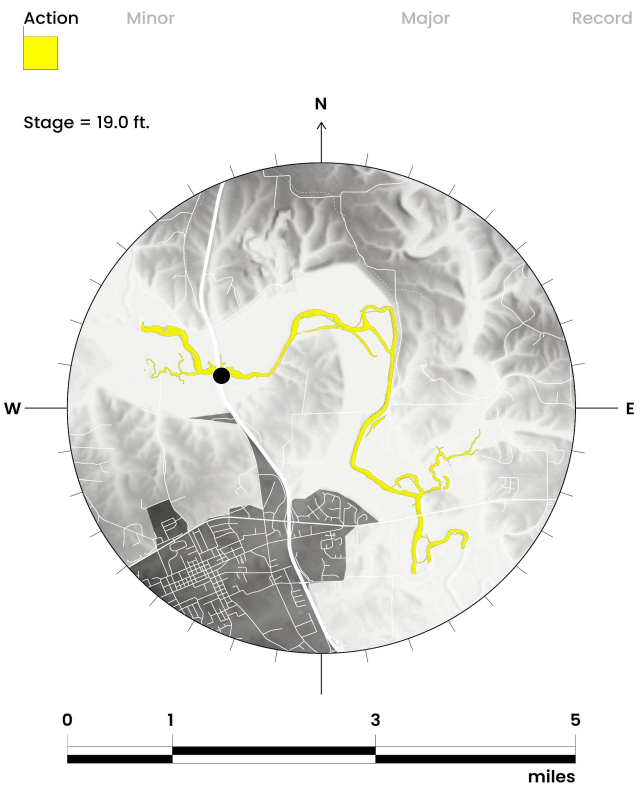


Flow-Based vs Stage-Based CatFIM (animation)

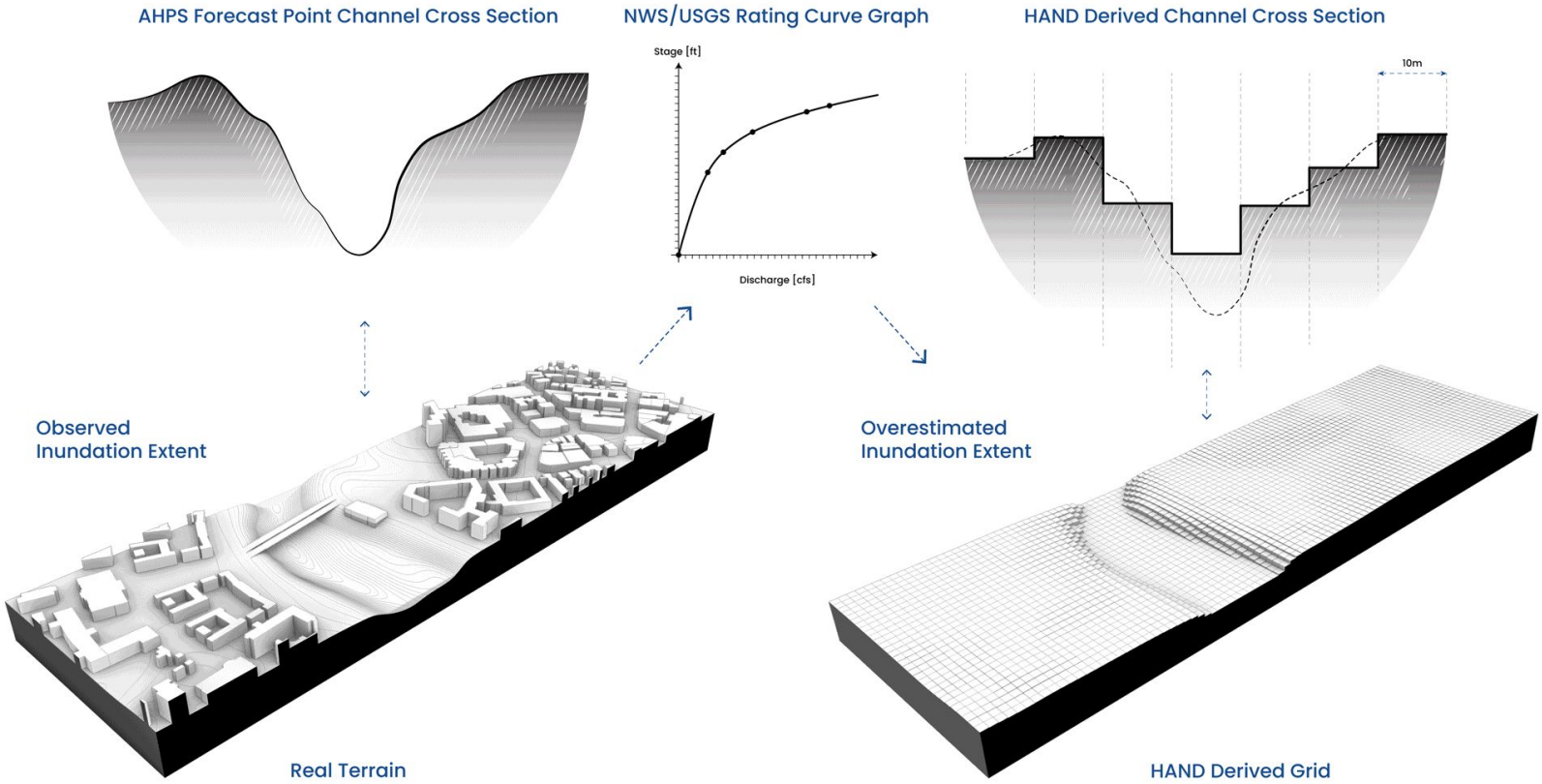
Flow-Based CatFIM



Stage-Based CatFIM



NWPS vs HAND Inundation Comparison (animation)



General FIM Limitations

- FIM is not perfect even though the maps can look neat
  - FIM may suffer from inaccuracies arising from issues with the modeling, elevation/landscape data and building/road placement
  - FIM may also suffer from inaccuracies in the input stream forecasts
  - Please coordinate with us leading up to and during flood events so that you can make the best-informed decisions

- FIM is based on landscape conditions at the time it was developed
  - FIM accuracy may be reduced if natural or man-made changes (permanent or temporary) occur to the river channel or flood plain afterwards
  - Examples: development, modification, failure or removal of flood protection systems such as levees, floodwalls or the development, modification, failure or removal of bridges and dams

General FIM Limitations (cont'd)

- NWS FIM is designed to address flooding from waterways such as rivers and streams (i.e., fluvial flooding)–not from flash flooding due to rapid runoff from rainfall such as in urban areas or in fields (i.e., pluvial flooding)

- NWS FIM is not designed for inundation resulting from ice jam flooding
  - With ice jams there can be local fluctuations in stage caused by the ice itself, not by the river flow

- NWS FIM--when compared to the regulatory FEMA Digital Flood Insurance Rate Maps (DFIRMs)--will depict different flooding scenarios
  - The differences occur because FIM and FEMA maps have been designed for different purposes and were developed based on different assumptions

Strengths of RFC and NWM FIM

- Visualizes flood forecasts and impacts for every river across the nation (including Alaska, Hawaii, Puerto Rico and the Virgin Islands)
- Creates a common picture of the river/stream flood threat in a given area
- Improves ability to target areas and preposition resources (regional, not local)
- Large scale regional response and reaction
- National, regional and county partners

"Had I have had this tool in 2011, we would have had a larger evacuation area established earlier, would have moved emergency assets out of the flood zone, pre-positioned support resources and been able to provide better information to the residents of the affected area."

- County Emergency Manager

Limitations of RFC and NWM FIM (cont'd)

- Extent only
  - Number 1 question about flooding after "where?" is "how deep?" Depth is not currently part of NWS FIM but is planned for the future
- Limited to 10 m digital elevation model
  - Can't see small physical features and their impact on FIM extent such as small ridges, bridges or unofficial levees
- Simplified physics
  - Equations describing the physics are simpler with more assumptions as compared to hydraulic models like HEC-RAS
  - Height Above Nearest Drainage (HAND) technique limitations

Limitations of RFC and NWM FIM (cont'd)

- NWM versions limited by quantitative precipitation forecast (QPF) input
  - The rainfall creating the flow is currently only Global Forecast System
  - Can't adjust or manipulate the forecast rainfall going into the model
- NWM Versions flow has no human influence for the forecast
  - Similar to being unable to adjust the rainfall, NWM version has no ability to adjust the flow generating the map
- Coastal use is limited
  - Current FIM capabilities are only able to address freshwater flooding
  - *Total Water Level FIM derived from a coastal coupled NWM approach is under development*

National Weather Service
Flood Inundation Map (FIM)
Resources and Services

Reference Maps ("Blue Sky")

(These maps are always available; not forecast dependent depend on forecasts)

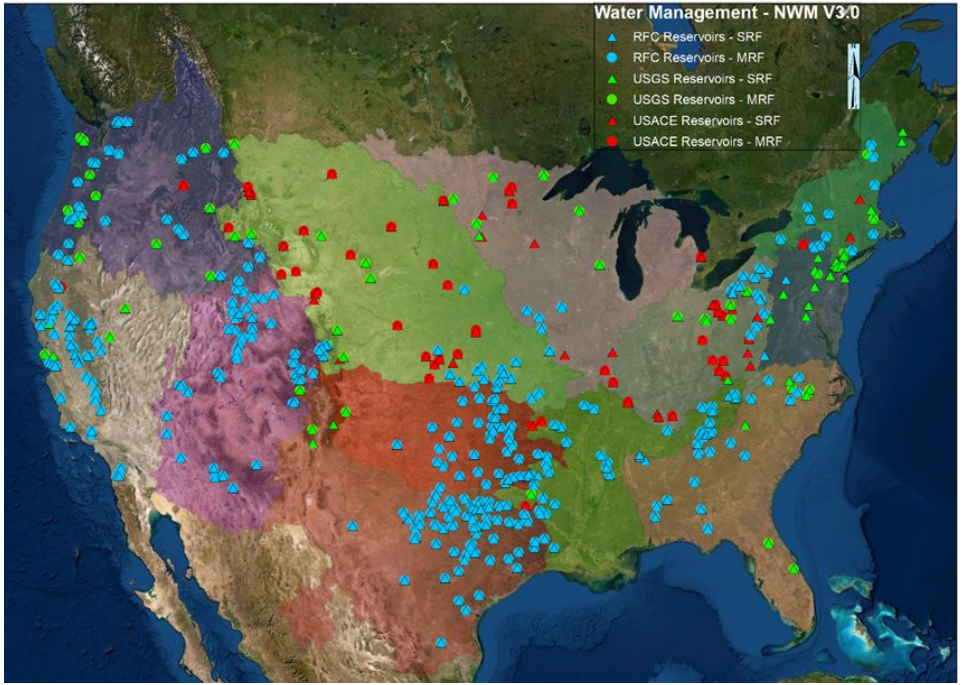
Forecast Maps ("Dark Sky")

(These maps are only available when flood/near-flood is forecast)

	NWPS Partner FIM	CatFIM	RFC FIM	NWM AnA FIM AnA = "Analysis"	NWM 5-Day FIM
How often is it updated?	**Always available** (static maps)	**Always available** (static maps)	**Event-by-event;** **Up to 1.5 hours after latest forecast is issued** (Forecast must exceed Action Stage)	**Event-by-event;** **Every 1.5 hours** (Forecast must be near flood)	**Event-by-event;** **Every 6.5 hours** (Forecast must be near flood)
Where is it available?	At some NWPS streamgage locations • **View maps online**	At most NWPS streamgage locations with defined NWS flood categories • **View maps online** • **Add to your GIS Dashboard**	At most NWPS streamgage locations with official NWS river forecasts • **View maps online** • **Add to your GIS Dashboard**	At any Stream in the NWM • **View maps online** • **Add to your GIS Dashboard**	At any Stream in the NWM • **View maps online** • **Add to your GIS Dashboard**
How should I use it?	• Best available NWS-sourced FIM • Provides high confidence of inundation extent and depth (but no FIM is perfect!) • Provides guidance for inundation around most levees, flood control structures and bridges	• View inundation extent near an NWPS river stream gage at 1-foot intervals, including at each of the NWS flood categories (Action, Minor, Moderate, Major, Record) • Best used for streamgaged streams - limited inundation availability for smaller tributaries	• View inundation extent based on the max value from the latest official NWS river forecast (up to 3-5 days) • RFC FIM may change with each forecast update	• View current, "right now" inundation extent for any stream or river • View max inundation extent for a recent flood • Inundation along smaller and unstreamgaged streams may be less accurate due to limited verification	• View max inundation extent over the next 5 days for any stream or river, based on NWM model guidance • NWM 5-Day FIM may change with each forecast update • Completely model-driven
When should I use it?	• Ongoing flooding • 1-3+ days prior to flood, for "what-if" planning • "Blue sky" reference	• Ongoing flooding, where NWPS Partner FIM is unavailable • 1-3+ days prior to flood, for "what-if" planning • "Blue sky" reference	• Ongoing flooding, where NWPS Partner FIM is unavailable • 1-2 days prior to flood, if NWS river forecast confidence is high	• Ongoing flooding, where no other FIM is available • Post-flood analysis, up to 14 days after flood	• Ongoing flooding, where no other FIM is available • 1-2 days prior to flood, for streams where no other FIM is available

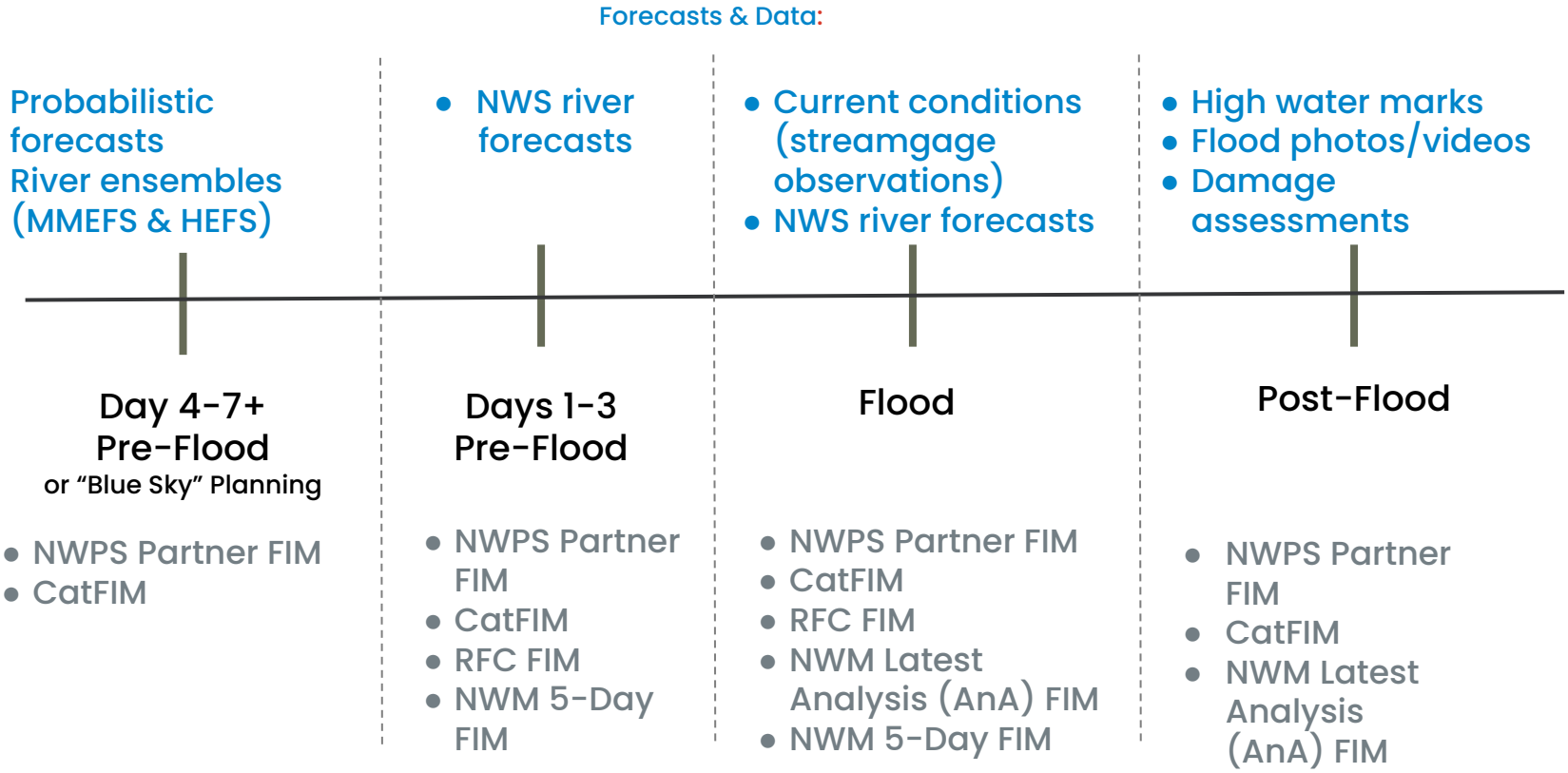
Reservoir Impacts on FIM

- Reservoir operations and outflows impact NWM streamflow accuracy and as a result the resulting FIM – flows could change if there has been significant impact
- Several thousand reservoirs represented in NWM but in basic fashion
  - "Fill and spill"
- NWM uses two other data ingest approaches (direct insertion assimilation) to improve modeled outflows

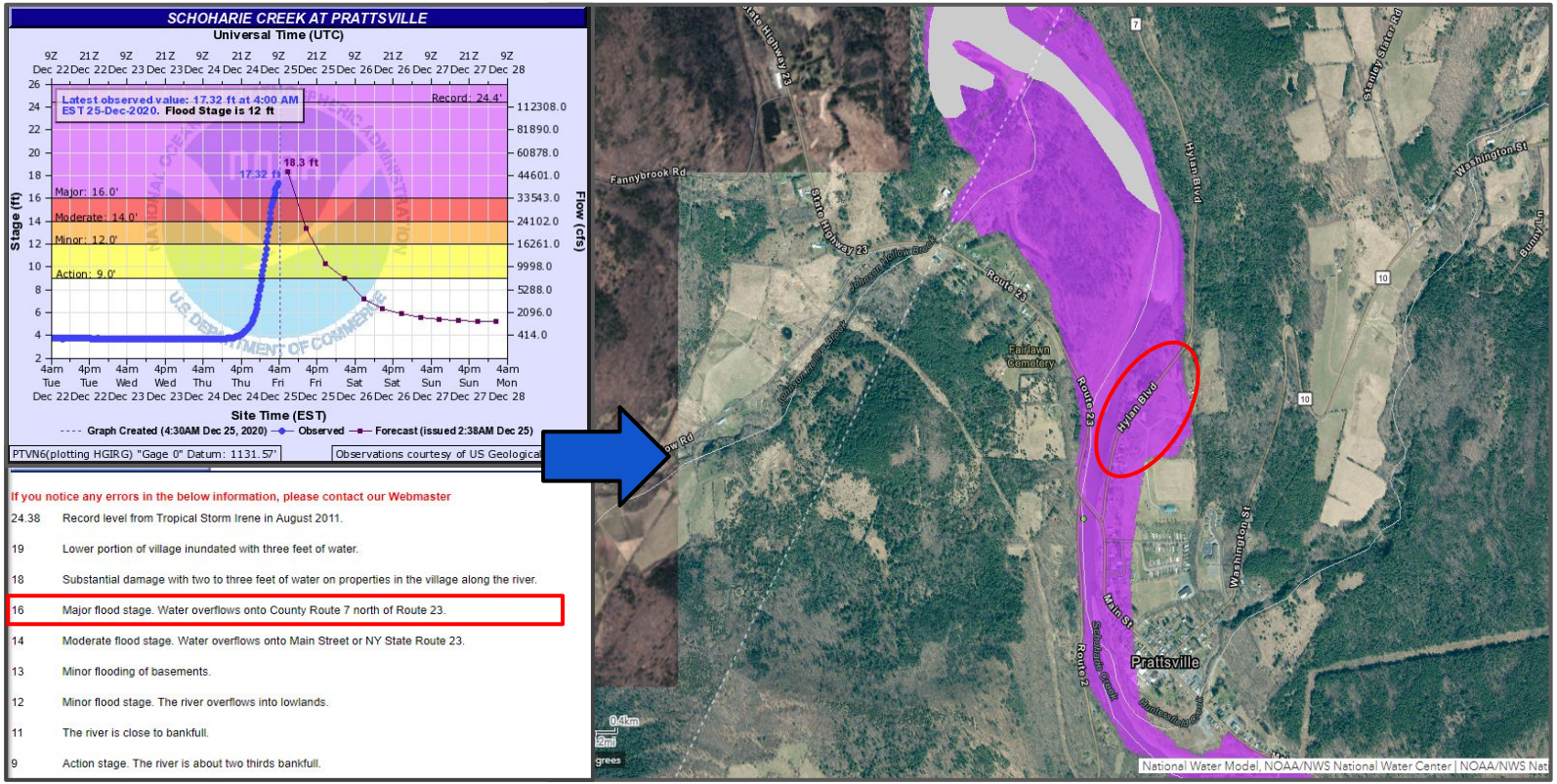


Flood Inundation Mapping and Impact-Based Decision Support Services

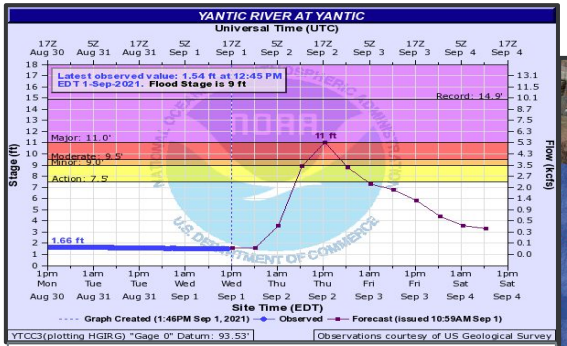
FIM Use Before, During and After a Flood Event



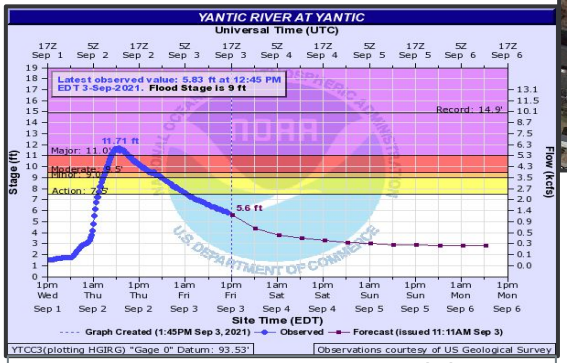
Putting Water On a Map



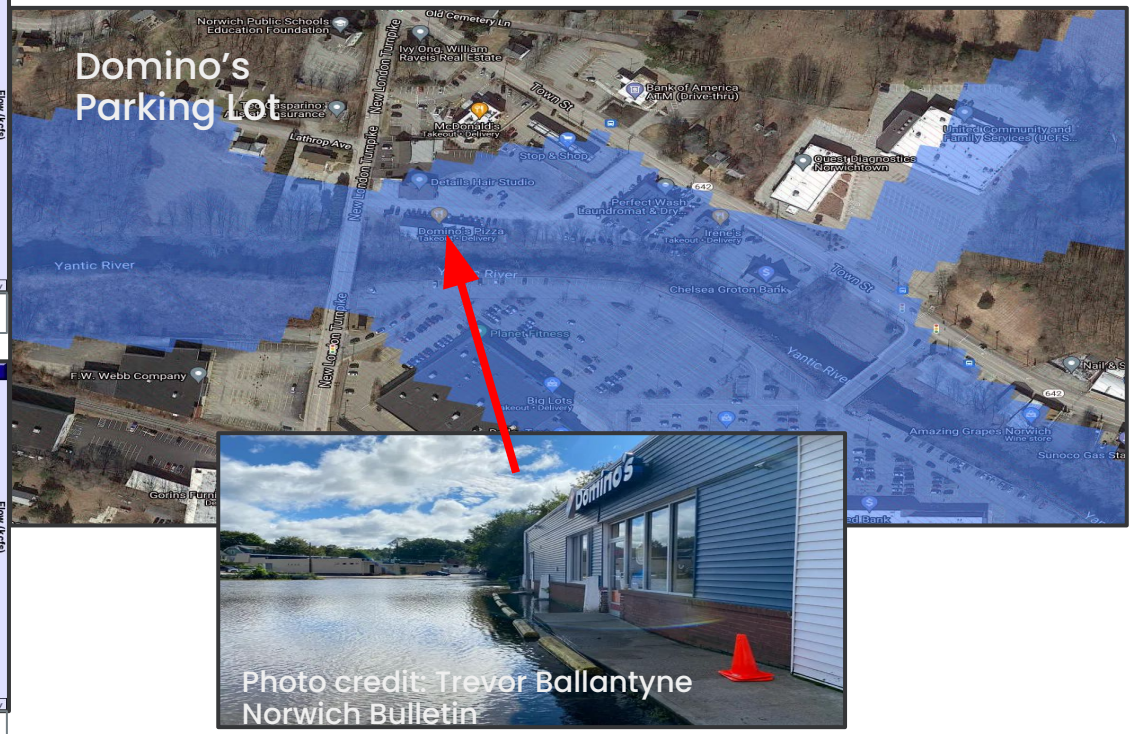
Visualizing FIM: Remnants of Ida in Connecticut



Official NWS river forecast issued on 9/1/2021



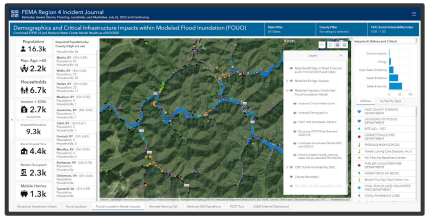
Observed crest above Major on 9/2/2021



FIM Impact-Based Decision Support Services (IDSS)

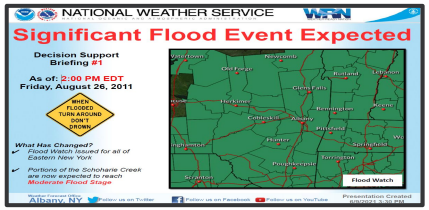
Increasing direct interaction with core partners based on various scenarios and needs

Public Services



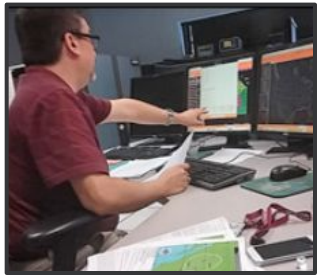
Providing the source of recommended FIM for the partner to ingest into their system (i.e. REST services via HydroVis).

Baseline IDSS



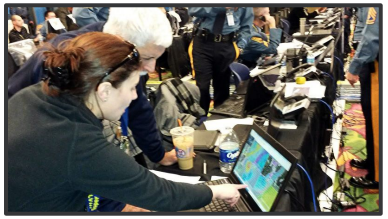
Providing graphics, email packages, webinars, NWSChat, etc. to convey general impacts.

Targeted IDSS



Providing targeted graphics, email packages, webinars, etc. to convey specific impacts based on specific needs and thresholds.

Integrated IDSS



Providing onsite, integrated support within partner's operations with detailed impact informations tailored needs and thresholds.

Most Common IDSS

Understanding Disclaimers

Official Disclaimer: *"These experimental maps represent the NWS' best approximation of inundation extent based upon modeled river discharge."*

"This map shows the flood extent based on a river crest of X feet. This is an approximate-based FIM which should be used more conservatively."

"This map shows the flood extent & depth based on a river crest of X feet. This is a hydraulic-based FIM which can be used with more certainty."

"This map does not have bridge inundation accurately represented. Reach out to NWS for any questions regarding bridge inundation."

"Local rainfall may also lead to flash flooding in this area that is not accounted for in this flood depiction."

During Tropical Events please see the National Hurricane Center Forecast

Wind speed and direction may enhance areas of flooding along the river.

Map shows flood extent. Depth is NOT provided.

Implementation Process

Phased Implementation of FIM Services

Percent of U.S. population served by Flood Inundation Mapping (FIM) services

- By September 30, 2023: 10% of U.S. population
- By September 30, 2024: 30% of U.S. population
- By September 30, 2025: 60% of U.S. population
- By September 30, 2026: 100% of U.S. population
  - Including coastal coupling

Enhancing the NWM: Development Trajectory

Foundation: 2016-2018

- First-ever NOAA water forecast model running on operational supercomputer
- 2.7 million reaches

Upgrades: 2019-2021

- Hawaii, medium range ens., physics upgrades, improved modularity, MPE ingest
- Expansion to PR and Great Lakes
- Reservoir modules, forcing upgrades, open-loop and improved Hawaii forcing

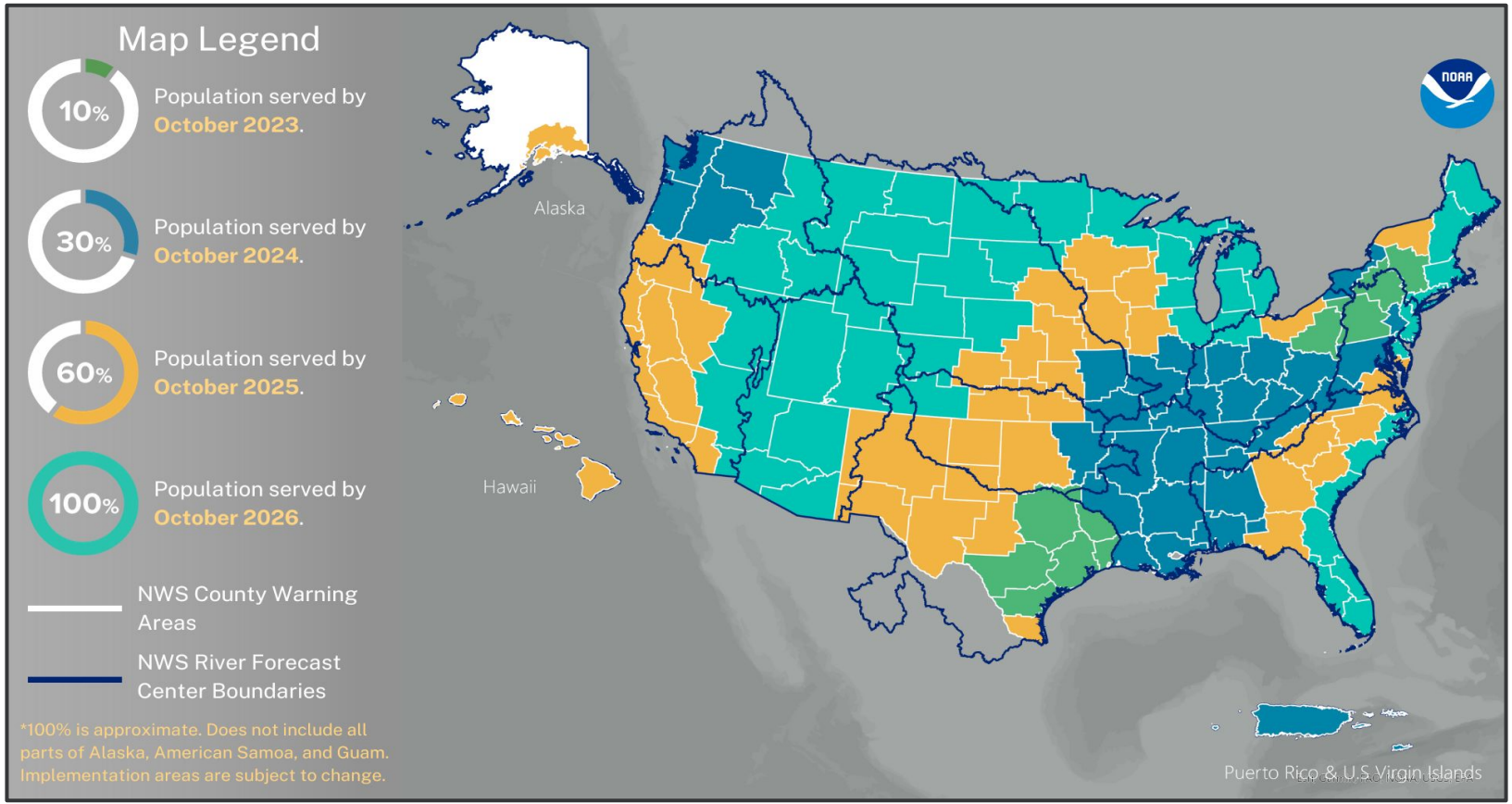
Future Upgrade: 2023

- Total water level
- Expansion to Alaska
- NBM forcing
- Improved runoff module, parameters, calibration and hydro fabric upgrades

Future Upgrade: 2025

- Use of NextGen Framework - heterogeneous modeling, improved modularity, expanded community development

NWS Flood Inundation Mapping Services Implementation

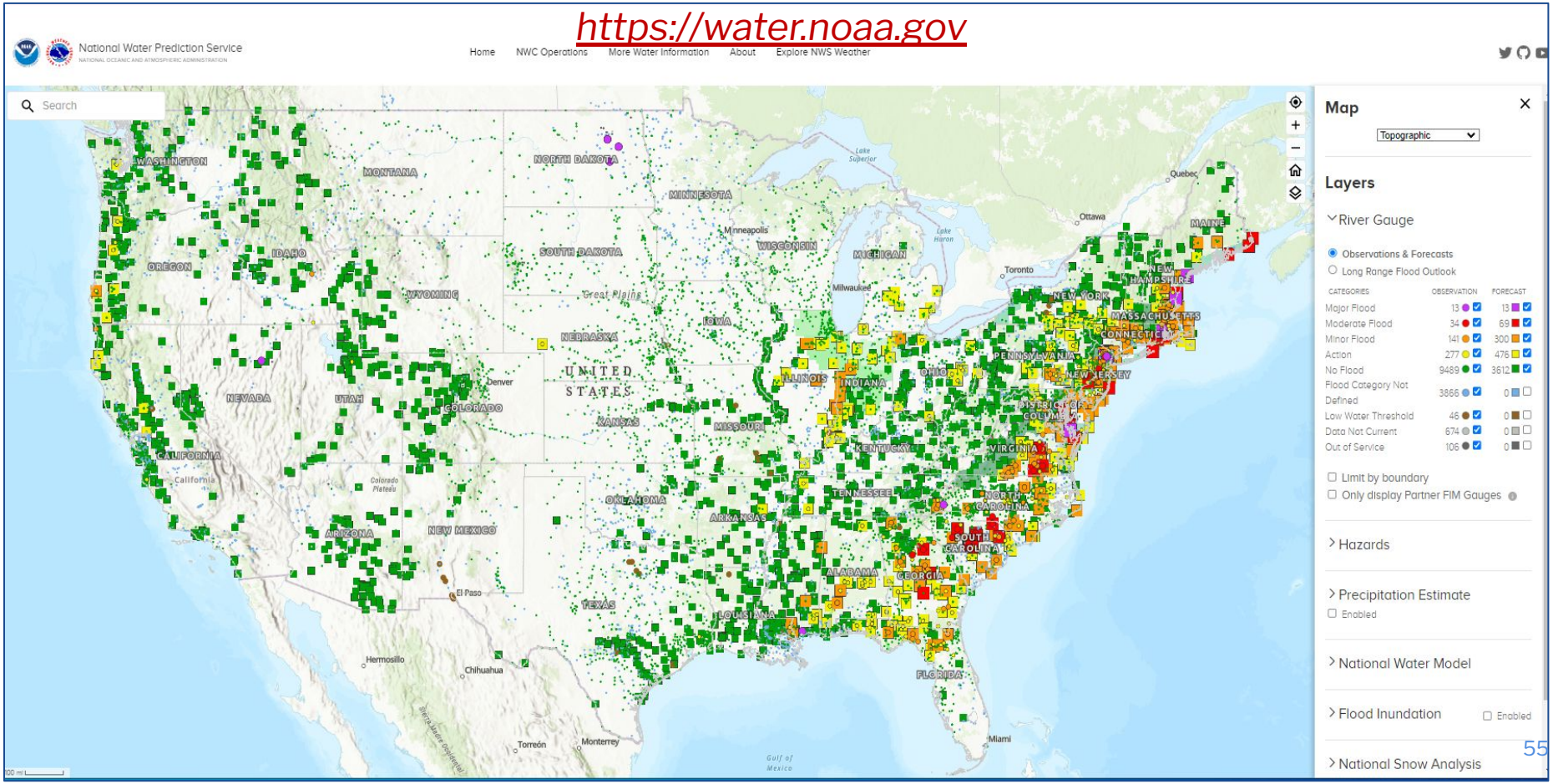


Viewing FIM

National Water Prediction Service (NWPS)

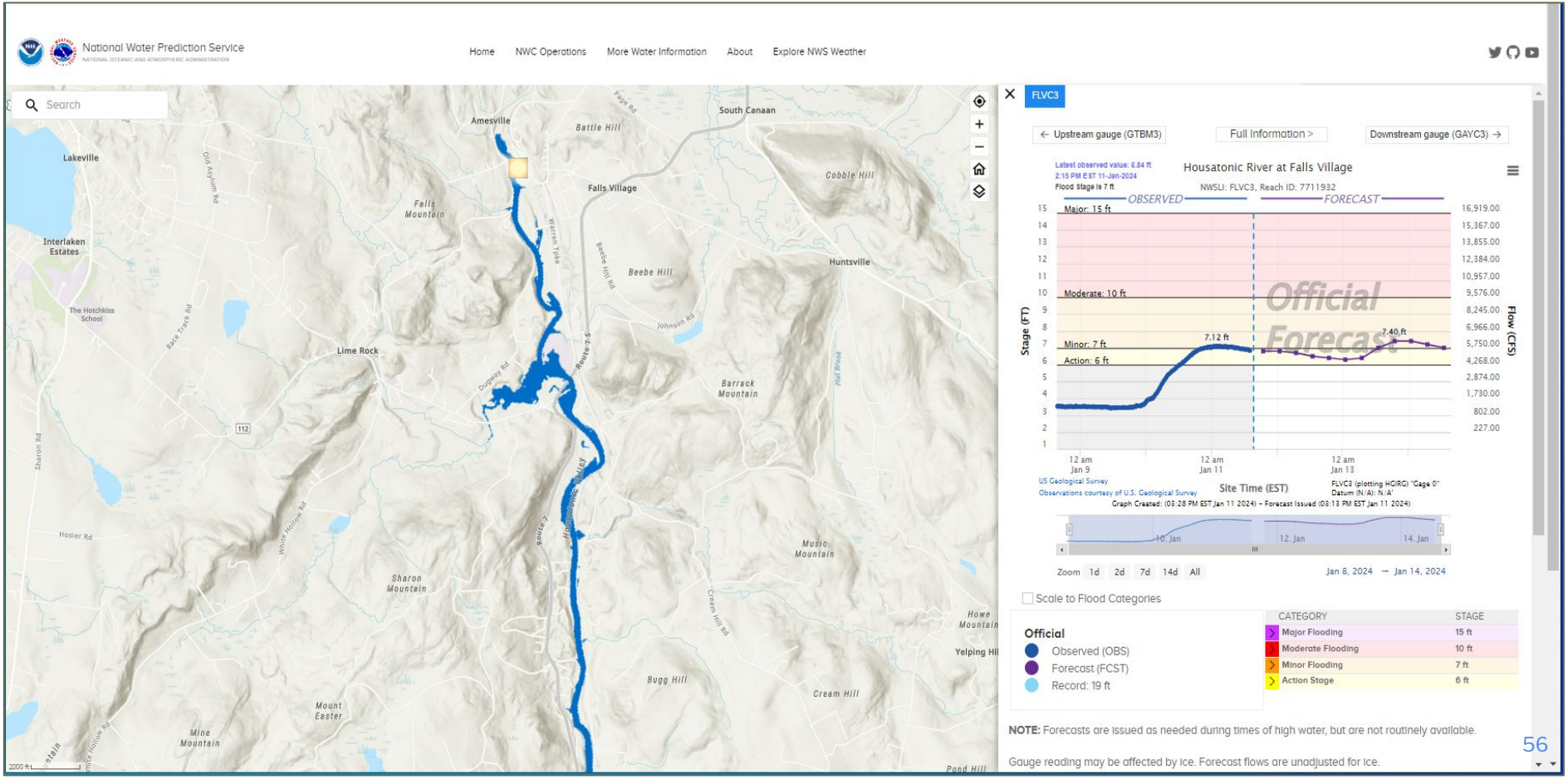
Implemented on 3/27/2024

https://water.noaa.gov



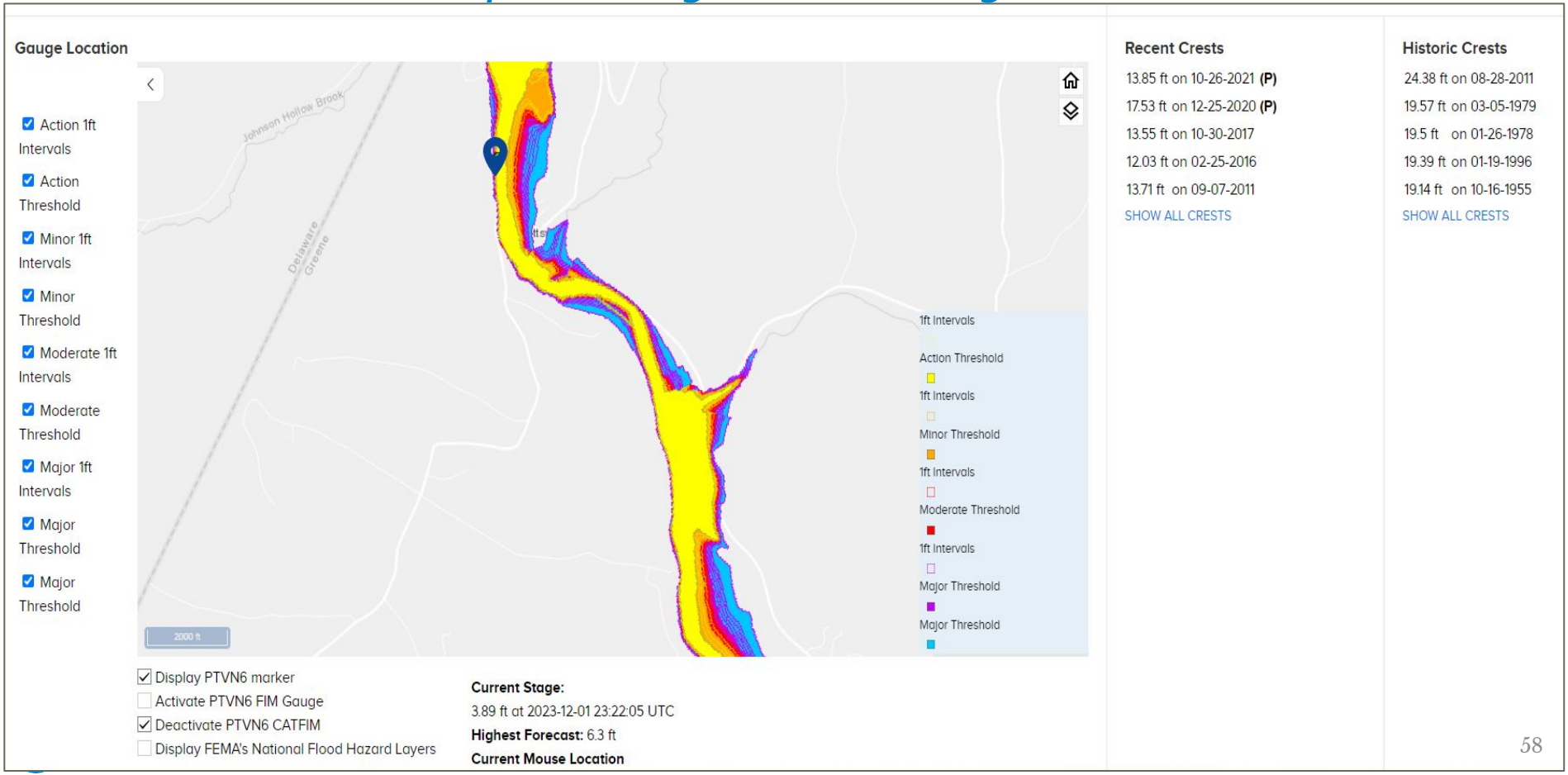
National Water Prediction Service (NWPS)

Linking Official NWS Forecasts and NWS FIM Services



National Water Prediction Service (NWPS)

Example of Stage-based Categorical FIM



Contact NWS Des Moines, IA
Jeff Zogg: jeff.zogg@noaa.gov

Thank You!