Stakeholder Engagement to Inform National Weather Service Hydrologic Products and Services to Meet User Needs

NOAA National Weather Service
Water Resources Services Branch and Office of Water Prediction

February 15, 2019

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Background

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Water Resources Services Branch (WRSB) and the Office of Water Prediction (OWP) are actively applying social science to ensure that its existing and future services meet user needs. From early 2017 through summer 2018, WRSB sought input from stakeholders to gauge the value and utility of new products and services, including some of those in the early stages of development at the National Water Center (NWC). These stakeholders provided valuable input that will help inform future hydrologic products and services in support of water resources decision-making. As shown in Figure 1, stakeholders are concerned about the full gamut of water conditions. Stakeholders have expressed a need for additional and improved integrated water prediction information in the form of actionable water intelligence. Through stakeholder input, WRSB is gathering critical information about user needs and preferences. This input will shape improvements to existing products and services, as well as the development of new products and services to best meet core partners' decision-support needs.

The National Water Model (NWM) and the Hydrologic Ensemble Forecasting System (HEFS) are two of the most critical and immediate capabilities that are being developed to provide a range of hydrologic prediction services in response to stakeholder priorities.

Figure 1. Stakeholder Priorities

A strategic plan for the National Water Center outlines a step-wise schedule for building those and other NWC capabilities in the future, as shown in Figure 2. This project advances the strong foundation of social science that has informed the NWC strategic plan and further informs the development of hydrologic products and services to meet user needs for their routine water resources decisions as well as flooding event-driven decisions.

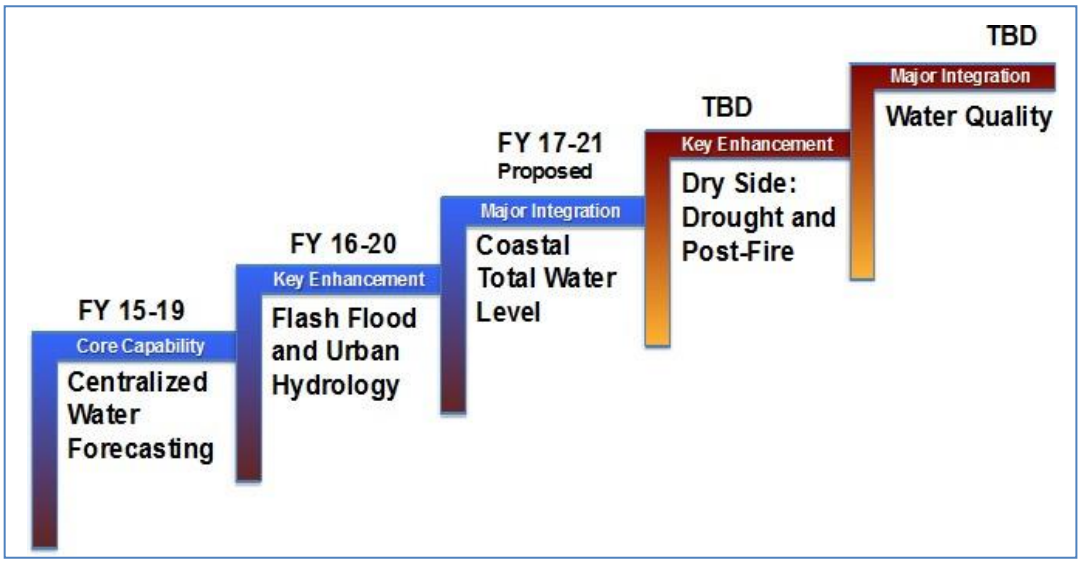


Figure 2. Step-wise process for building NWC capabilities

Summary Findings

To obtain information on core partner and stakeholder needs for NWM and HEFS capabilities, WRSB and OWP conducted internal focus groups with subject matter experts, four stakeholder engagement workshops, and three focus groups with emergency managers, reaching a total of **250 stakeholders.**

- Internal Focus Groups: 41 stakeholders (2017)
- Stakeholder Engagement Workshops: 151 stakeholders (2017)
- Emergency Manager Focus Groups: 58 stakeholders (2018)

These meetings brought together diverse core partner groups to best understand stakeholder/user decision points, information needed to make those decisions both currently and, in the future, and how NWC and OWP data services can help inform users decision-making. The table below lists each set of meetings and the resultant findings. More detailed descriptions of the engagements are provided in the next section. Full reports from each of the three sets of engagements can be found in Appendices A-C.

Table 1. 2017-2018 Stakeholder Engagements: Summary Findings – Identified Needs

Internal Focus Groups
Improvements to gaging networks
River flow predictions at every mile and hour (including velocity)
Water quality forecasting
Longer-term consistent quantitative precipitation forecasting
More robust inundation mapping
Full implementation of HEFS
Seasonal flows and longer-term forecasts

Data services to allow users to import data into local tools and set their own thresholds for local needs.
Stakeholder Focus Groups
Develop National, Regional and Local Flood Prediction Map Services, Low Flow Prediction Map Services, and Water Supply Forecast Data and Map Services;
Present data and information that reflects routine (baseline), high flow and low flow conditions with antecedent conditions including precipitation and soil moisture overlays;
Display data and information in a variety of formats including maps, tables, and hydrographs;
Provide forecasted information at various timescales including observed conditions, hourly, daily, weekly and seasonal; and
Illustrate flood inundation (extent and depth).
Emergency Managers Focus Groups
All products are useful, especially when used in combination.
More contextual data (antecedent conditions, precipitation, historic events) is needed.
Inundation: include uncertainty, depth, and change over time.
When depicting a flood event, magnitude was generally viewed as the most important, followed by time to peak flow, then probability of an event occurring.
Participants thought that the 1.5-year recurrence interval and “bank-full” description should be re-considered, as the 1.5-year recurrence interval may be too low and “bank-full” may not be a familiar term.
Considerations for delivery strategy should include clarity between roles (National Water Center vs. River Forecast Centers). Consider a single point of access to download data and training on how to download and use the data.
Gaps include coastal coupling, considerations for watershed with regulated flow and flashy canyon topography, inundation depth, and more neighborhood-scale products

Internal Focus Groups and Stakeholder Engagements

Conducting the internal focus groups and four stakeholder engagement workshops elicited user needs and key priorities for WRSB and OWP, moving forward. Summaries from those two sets of meetings and identified needs and priorities are described below. Needs and priorities identified during the Emergency Managers Focus Groups are described in the section that follows.

Internal Focus Groups (January-May 2017)

To inform products and services to be provided by the NWC, internal expert input was sought to begin the process of determining priority user needs. Subject matter experts were identified to represent the interests and concerns of eight core partner groups, with whom they interact regularly. The internal experts and their respective core partners groups were organized as follows: Emergency management and Media; Water supply management and Utilities; Transportation and Navigation; Watershed management (policy); Fisheries and Recreation; and Agriculture. Forty-one subject matter experts were selected from River Forecast Centers (RFCs) and Weather Forecast Offices (WFOs) across all NWS regions, as well as representatives from other NOAA offices. These experts were polled to rank and comment on the importance of existing and experimental hydrologic products/services to their assigned core partner groups.

Poll results were then tallied across all core partner groups to create a priority ranking of existing products and services.

Priority Ranking of Existing Products and Services – What's Important:

1. Deterministic Hydrologic Forecast (RVF)
2. 24-Hour Quantitative Precipitation Forecast (Day 1 - 3)
3. NWS Hydrologic Services Program Web Presence (AHPS)
4. Weather Prediction Center Quantitative Precipitation Forecasts (QPF)
5. Short Range River Forecast Uncertainty (HEFS)
6. Flood Warning for Forecast Points (FLW)
7. Ensemble Streamflow Prediction (ESP)
8. Long-range River Forecast Risk Web Page (AHPS)

The subject matter experts also participated in focus group webinars on new and improved hydrologic products and services. The discussions were framed around products and services needed to inform key decisions that core partners need to make. Several new and improved products and services, common to multiple focus groups, surfaced from these discussions. This input was binned according to new and improved products, and new/improved services (observation, forecasting, decision-support and data services) that could better serve core partner priorities/needs moving forward.

Priorities moving forward:

- Improvements to gaging networks
- River flow predictions at every mile and hour (including velocity)
- Water quality forecasting
- Longer-term consistent quantitative precipitation forecasting
- More robust inundation mapping
- Full implementation of HEFS
- Seasonal flows and longer-term forecasts
- Data services to allow users to import data into local tools and set their own thresholds for local needs.

The full summary report for the internal focus groups is available as Appendix A.

Stakeholder Workshops (February-August 2017)

Between February and August 2017, WRSB sought input from stakeholders to gauge the value and utility of new products and services, including some of those in the early stages of development at the NWC). WRSB and OWP conducted four stakeholder engagement workshops, attended by a total of 151 stakeholders. These stakeholders provided valuable input that will help inform future hydrologic products and services in support of interdisciplinary federal, state, and local water resources decision making. Workshops were held in Austin, Texas, Phoenix, Arizona, Greenville, North Carolina, and Waterloo, Iowa in collaboration with local NWS River Forecasting Centers (RFCs), Weather Forecast Offices (WFOs) and federal agencies such as the Federal Emergency Management Agency (FEMA), US Geological Survey (USGS), and the US Army Corps of Engineers (USACE).

The workshop locations were chosen to represent a range of geographic challenges related to hydrologic forecasting in general and flash flood prediction. To obtain the most constructive feedback on the enhanced products and data services, stakeholders represented a variety of core partner groups including flood managers, dam operators, water suppliers, agriculture, transportation, media, emergency managers, ecosystem planners, and public health officials. Participants were guided through three demonstration stations to obtain their feedback on the following prototype products and services:

- Understanding uncertainty (graphics and hydrographs)
- Inundation (maps showing water depth and lateral extent of flooding)
- Stream flow Anomaly (departure from normal maps)

At each station participants were asked:

- Is this product easy to understand/ does it convey information clearly?
- Is it useful? How would you use it to inform your decisions?
- How could it be improved and are there other products that could be used in combination with this product to increase its effectiveness?

At the end of the demonstration stations, participants voted on those products that they considered of greatest value to meet their needs. Results from the Iowa, Texas and Arizona workshops are summarized in Figure 3 below. Figure 4 illustrates decision support needs identified by stakeholders at the Greenville, NC engagement workshop.

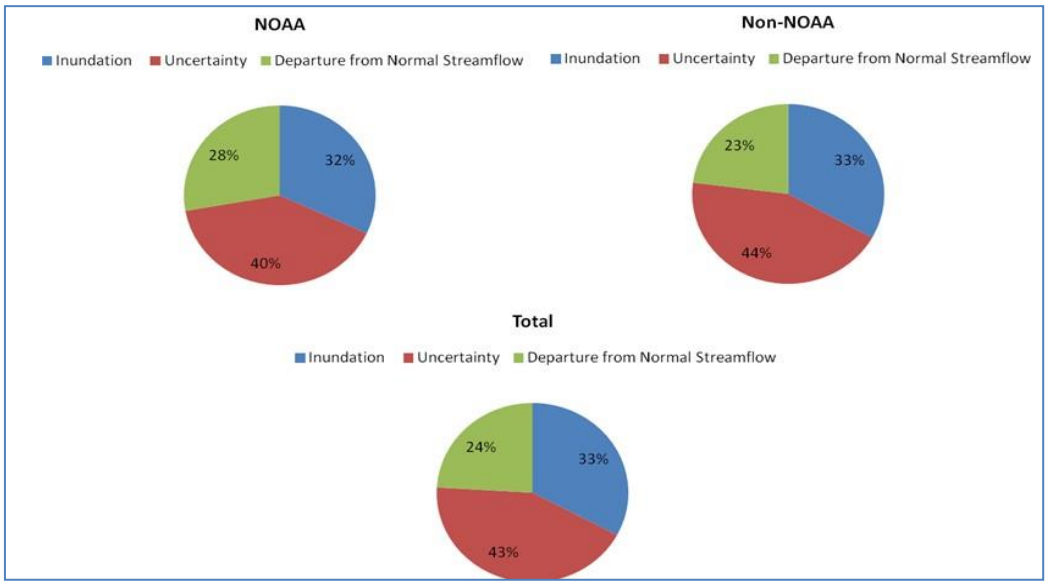


Figure 3. Rotation Station Voting: Compiled results from Waterloo, Phoenix, and Austin. Results are segmented by voter affiliation.

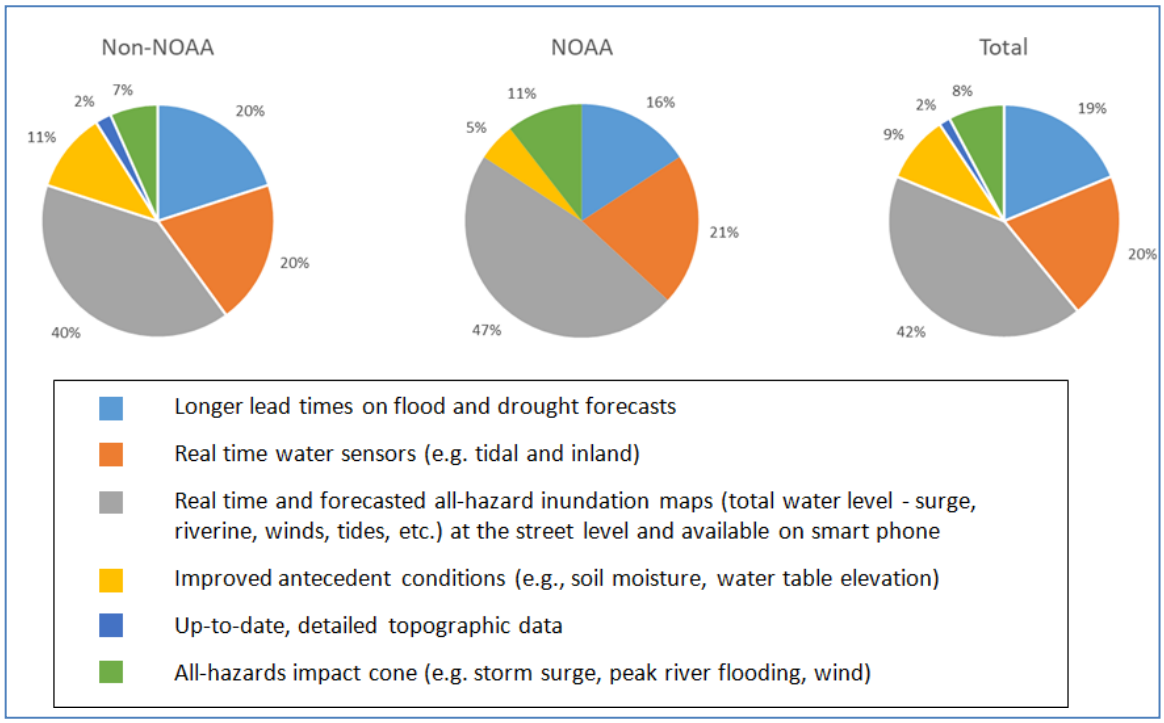


Figure 4. Top Decision support needs – Greenville, NC. Compiled results on top priority, segmented by voter affiliation for NOAA and Non-NOAA participants.

Common Themes

Across the stakeholder engagement workshops, common themes were identified.

- NWM products and services should clearly describe exactly what a user is viewing. This includes input information, accuracy of model predictions, and clear legends.
- WFO and RFC staff must be trained on the functionalities, capabilities, and applicability of the NWM services to effectively deliver these services
- Products that do not incorporate regulated flow (e.g., levees) provide planning-level information that could be used to alert water resource managers and responders in advance of a flash flood. This information requires local input to incorporate flow considerations not analyzed in the NWM products.
- Some local users expressed interest in incorporating the capability to ingest data from the NWM. This local data may include normal stream flow, soil moisture content, etc.
- Precipitation overlays were requested across all three types of products.
- Some of the NWM products, especially the inundation maps, could be helpful in un-gauged areas.

Recommendations

Based on input from the internal focus group findings and from the four stakeholder engagement workshops, the WRSB and OWP identified the top priorities and stakeholder needs moving forward:

- Develop National, Regional and Local Flood Prediction Map Services, Low Flow Prediction Map Services, and Water Supply Forecast Data and Map Services;

- Present data and information that reflects routine (baseline), high flow and low flow conditions with antecedent conditions including precipitation and soil moisture overlays;
- Display data and information in a variety of formats including maps, tables, and hydrographs;
- Provide forecasted information at various timescales including observed conditions, hourly, daily, weekly and seasonal; and
- Illustrate flood inundation (extent and depth).

The full summary report for the stakeholder engagement workshops is available as Appendix B.

Emergency Manager Focus Groups (Spring 2018)

Following input from the internal focus groups and four stakeholder workshops in 2017, a logic model (Figure 5) was created to represent stakeholder needs at spatial scales (national, regional/watershed, local/neighborhood) and temporal scales (hourly, daily, weekly and seasonal) that reflected priority user needs. This logic model was driven in large part by the findings in the bulleted list above.

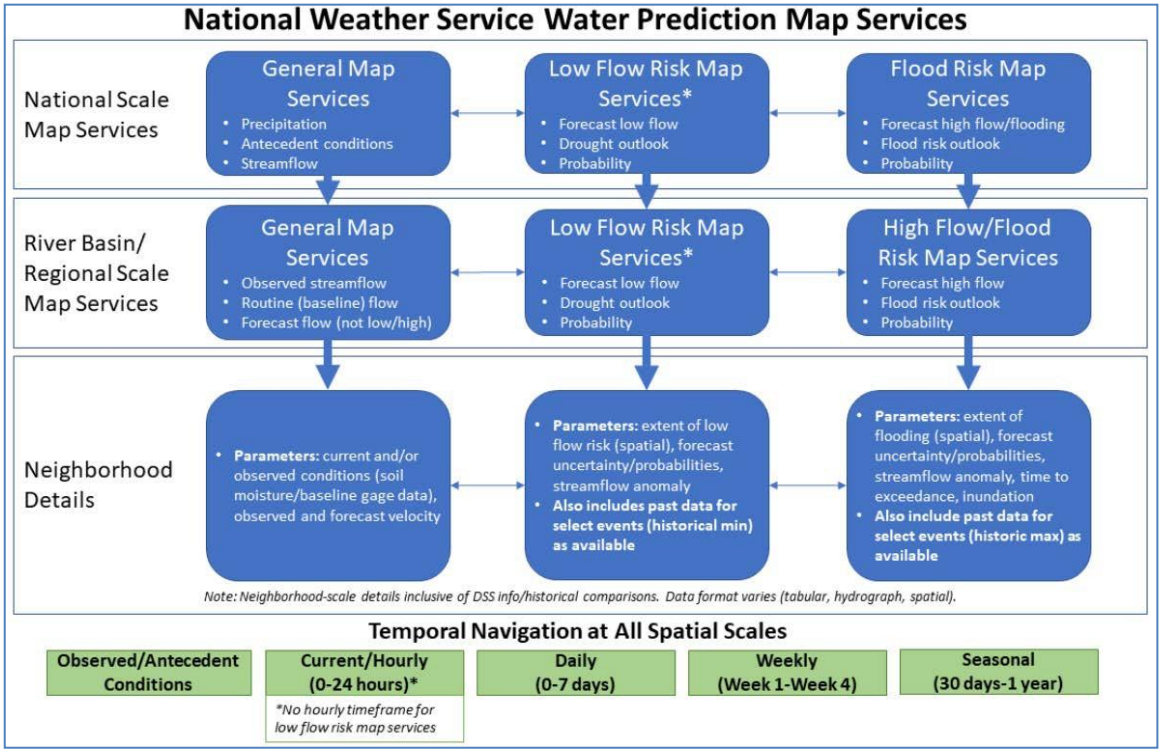


Figure 5. Logic Model depicting water prediction data services and potential prototypes.

Three focus group sessions were scheduled to ground-truth the logic model within one sector – Emergency Management (EM). At the EM focus group sessions, prototypes were tested with 58 emergency managers (EMs) that attended regional gatherings from three distinct geographic areas of the country: the southeastern regional meeting of emergency managers (Nashville, TN),

the front range of the Colorado Rocky Mountains (Denver CO), and the Mid-Atlantic coast (Atlantic City, NJ). During the focus group sessions, map services were defined for high flow and low flow scenarios and depicting how data could be displayed as map services at national and regional scales created prototypes. Due to time constraints at focus group events, not all user requirements could be shown. At the neighborhood scale, a list of parameters was developed in lieu of prototypes

Focus group scripts were developed and used to coincide with the images and questions that served as prompts for focus group input. An Esri StoryMap was developed to mirror the logic model structure (Figure 5) and facilitate the presentation of several different map data services (e.g., high flow/flood risk maps). Figure 6 depicts the main page of the StoryMap for the Denver, CO focus group meeting.

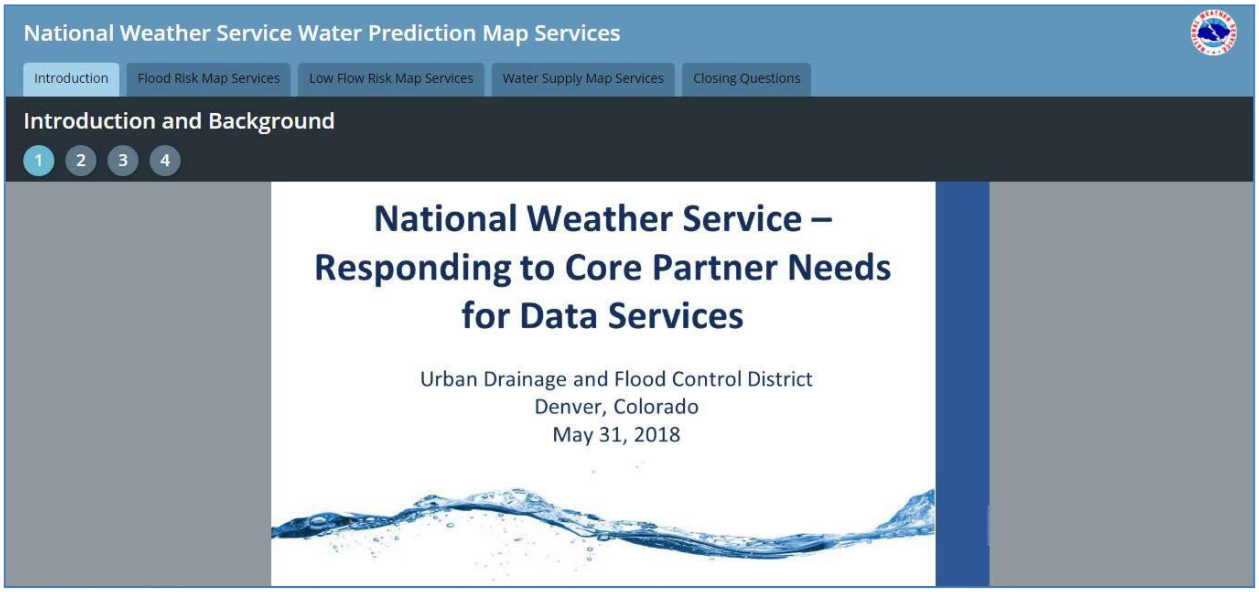


Figure 6. StoryMap depicting NWM prototypes and prediction services

Each focus group introduction included a short description of previous stakeholder engagement activities before presenting the logic model shown above. Participants were then asked a basic introductory question: "What best describes your area of responsibilities?" to gather information on the scale at which participants generally work (local, state, regional, national, tribal, and other).

Most of the content presented at the focus group meetings was in the Flood Risk Map Services tab (Figure 6). Participants were shown prototype products at the National scale and River Basin/Regional Scale. The timescale shown was dependent on participant responses to a Poll Question: "Which timescales do you consider most critical when making decisions regarding flooding?" with responses matching the timescale options – Observed Conditions, Hourly Forecast, Daily Forecast, Weekly Forecast. No interactive products were available to present at the Neighborhood Details scale, so users were shown three static examples of the types of data that could be available at that fine scale – inundation (extent of flooding), observed and forecasted river levels (hydrograph), and river level and flow uncertainty. To see those visualizations, see Appendix C: Emergency Manager Focus Group Summary.

Throughout the StoryMap presentation, embedded polls solicited participant feedback. The following questions were asked during each event:

- "What best describes your area of responsibilities?"
    - Local, State, Regional, National, Tribal, Other
- "Which timescales do you consider most critical when making decisions regarding flooding? Rank the following:"
    - Observed Conditions, Hourly Forecast, Daily Forecast, Weekly Forecast
- "Please rank the following forecast products based on how useful they would be when making decisions regarding flooding."
    - High flow magnitude, High flow probability (chance), Time to high flow
- "Please rank the neighborhood products based on how useful they would be when making decisions regarding flooding."
    - Inundation, Hydrograph, Streamflow Uncertainty
- "On a scale of 1-5, please rate how useful these types of services would be to your decision making."

EM-Identified Priorities Moving Forward and User Preferences:

- All products are useful, especially when used in combination.
- More contextual data (antecedent conditions, precipitation, historic events) is needed.
- Inundation: include uncertainty, depth, and change over time.
- When depicting a flood event, magnitude was generally viewed as the most important, followed by time to peak flow, then probability of an event occurring.
- Participants thought that the 1.5-year recurrence interval and "bank-full" description should be re-considered, as the 1.5-year recurrence interval may be too low and "bank- full" may not be a familiar term.
- Considerations for delivery strategy should include clarity between roles (National Water Center vs. River Forecast Centers). Consider a single point of access to download data and training on how to download and use the data.
- Gaps include coastal coupling, considerations for watershed with regulated flow and flashy canyon topography, inundation depth, and more neighborhood-scale products.

Figure 7. Nashville EM Stakeholder Engagement

The full summary report for the focus group sessions is available as Appendix C.

Next Steps

Watershed-Based Stakeholder Engagements

Following all three sets of stakeholder engagement activities, watershed-based mixed stakeholder engagements will be convened to understand cross-sector and potentially competing stakeholder needs and decision points across NWM data services.

The following locations were chosen for watershed-wide stakeholder engagement workshops planned for fall 2018 through Spring 2019.

- Delaware River Basin (PA-NY-NJ-DE) – October 30, 2018
- Penobscot River Basin (Maine) – May 2019

Building on the lessons learned and stakeholder-driven priorities, the NWC will create data services for specific scenarios (e.g., high flow). Stakeholders will walk through a hypothetical scenario/storm event and view NWM data services and currently available NWS briefing materials (e.g., AHPS information, hydrographs, etc.). Stakeholder feedback will inform improvements to existing products and services, as well as new products and services from NWS offices and the NWC to best meet core partners' decision-support needs.

Economic Benefit Assessment

An economic evaluation will be conducted as part of this project. Below we outline the approach for this work. In scoping this evaluation, the initial goal was to focus on a sector with large benefits associated with improved flood forecasting; select high value products affected by flooding in that sector; illustrate value of improved hydrologic forecasting products/services; and use this research as a case study to create a framework for NWC to assess benefits across other sectors.

Transportation of freight across multiple modes (rail, truck, and ship) was initially selected for assessment to capture impacts associated with 1) "spoilage"—value lost because of delays in shipping certain types of freight (e.g., agricultural products), and 2) operational losses associated with delays. Uncertainty in the outputs of the NWM to develop concrete benefits that could be linked to improved decision making necessitated a foundational approach as a first step towards conducting an economic assessment of improved forecasting once the net improvements in NWM forecasting can be estimated. Baseline impacts associated with delays and spoilage will be calculated and interviews will be conducted to explore how the freight moving industry could potentially make better decisions and use improved temporal and spatial forecasting when it is available. A methodology paper will also be developed to incorporate the improved decision making into the benefits assessment once more concrete information about how the NWM improves decision-making is available in the future.

Step 1: Use Freight Analysis Framework (FAF) data to determine the average value of all (44 categories) commodities moved by rail, ship, and truck from over 100 origins and destinations outlined in FAF. FAF provides a comprehensive data set of freight moved in the U.S.

Step 2: Estimate losses associated with delays. For example, what is the spoilage and operational losses with a 12-hour delay, 1-day delay, 3-day delay, and 7-day delay? This will help us understand the potential for loss in association with FAF data.

Step 3: Calculate baselines and case study values. Using hypothetical events in areas, we will be able to estimate how certain event types (and associated delays) would impact each region. Additionally, we can look at the probability of events in all regions to roll up the potential impact at the national level.

ERG will be interviewing freight moving industry groups to better understand how improvements in spatial and temporal forecasting would improve decision making to help inform our methodology paper for how to go beyond baseline calculations (and calculate actual benefits of the NWM) in the future.

Appendices

- Appendix A: Internal Focus Group Summary
- Appendix B: Stakeholder Engagement Summary
- Appendix C: Emergency Manager Focus Group Summary

Appendix A: Internal Focus Group Summary

Social Science Evaluation of National Water Center Hydrologic Ensemble Forecast Service, National Water Model and Technical Support Services: Internal Focus Groups
NOAA National Weather Service
Water Resources Services Branch and Office of Water Prediction

January 28, 2018

Executive Summary

To inform products and services to be provided by the Water Resources Services Program of the National Weather Service, internal expert input was sought to begin the process of determining priority user needs. Subject matter experts were identified to represent the interests and concerns of eight core partner groups, with whom they interact regularly. The internal experts and their respective core partners groups were organized as follows:

- Emergency management and Media
- Water supply management and Utilities
- Transportation and Navigation
- Watershed management (policy), Fisheries and Recreation
- Agriculture

Forty-one subject matter experts were selected from River Forecast Centers (RFCs) and Weather Forecast Offices (WFOs) across all NWS regions, as well as representatives from other NOAA line offices. They were polled to rank and comment on the importance of existing and experimental hydrologic products/services to their assigned core partner groups. Poll results were then tallied across all core partner groups. The following products and services (listed in descending order) were ranked as the most important across all core partner groups:

	Table 1. Highest Priority Ranking of Existing Products and Services to Meet Core Partner Needs.
1	Deterministic Hydrologic Forecast (RVF)
2	24-Hour Quantitative Precipitation Forecast (Day 1 - 3)
3	NWS Hydrologic Services Program Web Presence (AHPS)
4	Weather Prediction Center Quantitative Precipitation Forecasts (QPF)
5	Short Range River Forecast Uncertainty (HEFS)
6	Flood Warning for Forecast Points (FLW)
7	Ensemble Streamflow Prediction (ESP)
8	Long-range River Forecast Risk Web Page (AHPS)

The subject matter experts also participated in focus group webinars on new and improved hydrologic products and services. The discussions were framed around products and services needed to inform key decisions that core partners need to make. Several new and improved products and services, common to multiple focus groups, surfaced from these discussions. This input was binned according to new and improved products, and new/improved services (observation, forecasting, decision-support and data services) that could better serve core partner needs.

Findings within these categories suggested, among other things, a need for:

- Improvements to gaging networks
- River flow predictions at every mile and hour (including velocity)
- Water quality forecasting

- Longer-term consistent quantitative precipitation forecasting
- More robust inundation mapping
- Full implementation of HEFS
- Seasonal flows and longer-term forecasts
- Data services to allow users to import data into local tools and set their own thresholds for local needs.

Results are summarized in Tables 3 and 4 in the main body of the report.

Based this input, as well as the input from four stakeholder engagement workshops, the WRSB and OWP have identified the top priorities moving forward:

- Develop National, Regional and Local Flood Prediction Map Services, Low Flow Prediction Map Services, and Water Supply Forecast Data and Map Services;
- Present data and information that reflects routine (baseline), high flow and low flow conditions with antecedent conditions including precipitation and soil moisture overlays;
- Display data and information in a variety of formats including maps, tables, and hydrographs;
- Provide forecasted information at various timescales including observed conditions, hourly, daily, weekly and seasonal; and
- Illustrate flood inundation (extent and depth).

Introduction

This report documents the methodology, findings and recommendations from the first phase of a social science assessment, the purpose of which is to inform the future direction of the National Water Center (NWC), as set forth in NOAA Water Initiative Vision and Five -Year Plan (2016). NOAA has established the National Water Center to implement a national water modeling and information services framework to provide advanced hydrologic services to meet stakeholder needs. It is a cornerstone of the NOAA Water Initiative, which envisions "a Nation in which everyone from individual citizens to businesses and public officials has timely, actionable information about their vital water resources at their fingertips and can factor this information wisely into their decisions about water risks, use, management, planning, and security." The goal is "to transform water information service delivery to better meet and support evolving societal needs," specifically:

- Build strategic partnerships for water information services
- Strengthen water decision support tools and networks
- Revolutionize water modeling, forecasting and precipitation prediction
- Accelerate water information research and development
- Enhance and sustain water-related observations

This project builds on work conducted over the past several years, through stakeholder engagement, National Weather Service (NWS) Service Assessments and feedback from partners. This work indicates the need to better inform event driven, high impact (e.g., flash and river floods, drought) and routine, high value (e.g., municipal water supply, power generation, navigation, agriculture) decisions and manage risk in river basins across the nation by:

- Providing high spatial and temporal resolution analyses and forecasts of the full spectrum of water budget parameters (e.g., soil moisture, evapotranspiration, river flow, groundwater, water quality, snowpack) from the "summit to sea;"
- Expanding the temporal range, improving the accuracy, and quantifying the certainty of river stage and volume forecasts;
- Linking water resources forecasts to a representation of the areal extent and depth of forecasted flood

waters and associated potential socioeconomic impacts; and

- Integrating access to the geospatial water resource information from multiple federal agencies through a single portal.

The purpose of this evaluation is to advise NWS Water Resources Services Program on how to improve existing products and services and identify new products and services based on two primary technologies—Hydrologic Ensemble Forecast Service and the National Water Model -- to enhance national, regional, and local hydrologic forecast and warnings and decision support services.

To begin this study, Eastern Research Group (ERG) and its subcontractor Nurture Nature Center (NNC) worked closely with the NOAA project team to develop an evaluation strategy summarized in Figure 1 below:

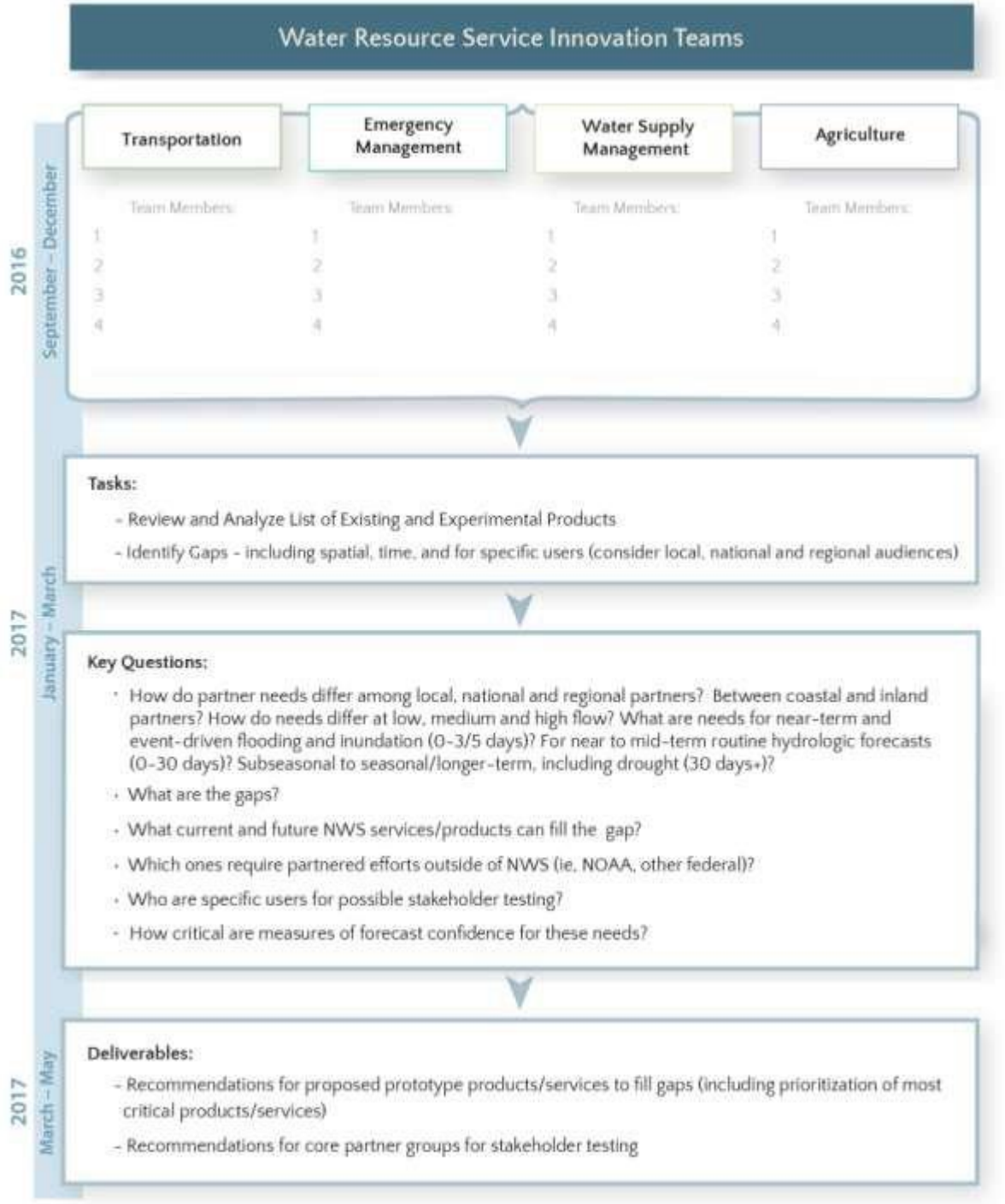


Figure 1. Overview of project process, tasks, evaluation strategy, key questions, and deliverables

As shown in Figure 1, the first phase of this study focused on obtaining insights about core partner needs from NWS key staff who interact with core partners on a day-to-day basis from their local and regionally based offices across the country. These internal core partner experts participated in one or more focus groups, each aimed at exploring one or more partner group needs.

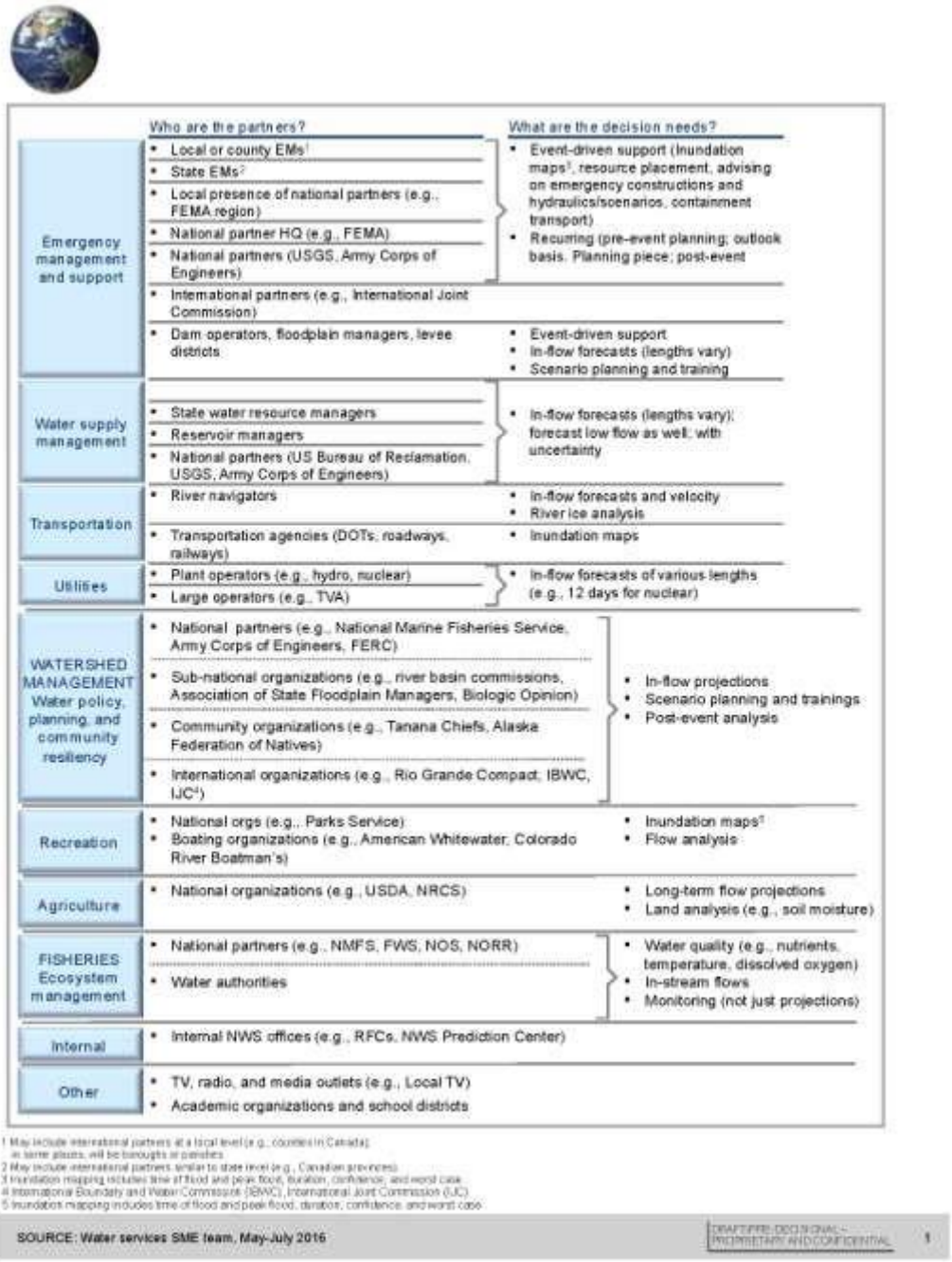


Figure 2. NWS Hydrologic Services Core Partner Groups

Core partners and their decision-making needs were previously defined by an internal working group and are shown in Figure 2 above. The results from this phase of the study, described below, identify priority improvements to existing products and services, and recommend priorities for development of new products and services, and operational improvements. To operationalize the recommendations, prototype products and services are also proposed.

Priority Ranking of Existing Products and Services

Experts from National Weather Service River Forecast Centers (RFCs) and Weather Forecast Offices (WFOs) who participated in the focus groups were asked to complete a short survey prior to the focus group sessions. Questions concerned the identification of primary users/customers, the common decisions those users need to make which require supporting forecasting products/services, currently used products, and outstanding partner needs. Specifically, participants were asked to assess the importance of *existing (including experimental)* products and services to their respective core partner group. They ranked products from an inventory of existing and experimental products and services (53 in all), which were binned according to: Weather Forecast Offices; River Forecast Centers; National; National Web Products; Experimental and "Other/local" (write in option). Participants were asked to select five in each category except for "National Web" and "Experimental," for which they were asked to select three. These selections were compiled across all focus group surveys, aggregated, and then ranked by percentage. Percentages were calculated by dividing the number/selection count for each product by the total number of selections for its category. The top scoring products and services across all categories is reported in Table 1. This quantification identifies those existing products and services viewed by all focus group participants, as the most important ones used by the core partner groups whose interests, they represent.

See Appendix A.1 for an example of the survey instrument (note: the survey was tailored slightly for each topic). See Appendix A.2 for a complete ranking of all existing products and services. A summary of the top eight existing products and services (all that scored above 60%) is presented in Table 1.

	Table 1. Highest Priority Ranking of Existing Products and Services to Meet Core Partner Needs	
1	Deterministic Hydrologic Forecast (RVF)	93%
2	24-Hour Quantitative Precipitation Forecast (Day 1 - 3)	80%
3	NWS Hydrologic Services Program Web Presence (AHPS)	78%
4	Weather Prediction Center Quantitative Precipitation Forecasts	73%
5	Short Range River Forecast Uncertainty (HEFS)	71%
6	Flood Warning for Forecast Points (FLW)	71%
7	Ensemble Streamflow Prediction (ESP)	68%
8	Long-range River Forecast Risk Web Page (AHPS)	61%

Based on the existing product analysis, deterministic hydrologic forecasts are widely and frequently used, as are 24-hour precipitation forecasts (QPF). These products were mentioned frequently during the focus group sessions with improvements suggested. The precipitation products are commonly adapted locally and regionally to meet user defined needs. In addition to ranking existing products and services, several open-ended questions were posed in the pre-webinar survey.

The open-ended questions concerned primary users/customers and the decisions those customers make which require forecast products and services. Results are summarized in Table 2, below.

Table 2. Summation of responses to open-ended survey questions about primary users and the decisions they make requiring hydrologic forecast products and services		
	Primary Users/Customers	Decisions
Transportation/ Navigation	Navigation (60%) Transportation (40%)	- What structures may be vulnerable due to high flow velocities-Range of river forecast possibilities – ships from abroad need to avoid anchoring offshore waiting to get up river - Ships traveling to inland ports need to determine cargo load and fuel amount based on forecasted river levels - Rapidly changing river levels can damage docked barges - Local roadway closures due to flooding
Water Supply/Utilities	Water supply management (77%) Utilities (23%)	- Outflow management for dams (requires inflows based on past and forecasted rainfall) - General operations – when to move equipment out of river area, when to pump water for cooling - When not to pull water due to high biomass/toxicity for drinking water - Where/when to schedule crews (electrical utilities use ice forecasts)
Water Policy (WP), Fisheries (F), Recreation (R)	Water policy, planning and community resiliency (64%) Ecosystem/fisheries managers (91%) Recreation – National Park Service, National Forest Service, recreation groups (27%)	- High/low flow fluctuations for habitat needs of endangered species (F) - Operation changes (dams, water withdrawals) needed to maintain environmental flows (F) - Water temperatures affect reproduction and health of fish populations (F) - When should state and local floodplain managers issue emergency regulations/deploy staff for flooding (WP)? - Where are future vulnerabilities and how can we plan for them in terms of future development and infrastructure (WP) - When to plan or postpone rafting trips (R)
Agriculture	Federal/state/tribal governments Irrigation districts State agricultural departments Farmers/producers General public	- Frost protection - Winter/summer extremes - When/how much to fertilize - When to harvest
Emergency Managers and Media	State, county, and local/city emergency managers Other state departments (homeland security, natural resources) USACE districts USBR NWS Warning Coordination Meteorologists Public Officials	- Pre-event planning and preparation - When and where to deploy resources - Specific timing and location of highest points of impact

New and Improved Priority Products and Services and Operational Improvements

The input from the internal focus groups will inform the identification of priority prototypes for hydrologic forecast products and services. The findings outlined below are based on the information gathered during five focus groups, each of which addressed priority decision-making forecast needs for: (1) transportation and navigation; (2) water supply/utilities; (3) water policy, fisheries, and recreation; (4) agriculture; (5) emergency managers and media) conducted through the winter and spring of 2017. The focus groups were composed of National Weather Service staff representatives with in-depth experience in, and close interactions with, core partner groups from the sectors. Representatives were selected from River Forecast Centers and Weather Forecast Offices throughout the United States to ensure balanced and broad geographic coverage.

After each 2-hour focus group, recommendations for future services and products (or operational changes) were identified. To elicit discussion, participants were asked the following questions:

- What are the critical decisions being made, who is making them, and what products/services are being used to inform them?
- Are these users operating at local, regional or national scales?
- Are they dealing with coastal or inland issues?
- Do they need the hydrologic forecast products/services on a routine or event-driven basis?
- How could NWS address these needs with new or modified products/services and with whom should we be collaborating?

Notes were taken for all focus group sessions by multiple staff and compiled. The user needs identified for each sector (transportation and navigation; water supply/utilities; water policy, fisheries, and recreation; agriculture; emergency managers and media) were summarized as bulleted lists in the following categories: 1) New products; 2) Improving/updating existing products/services, and 3) Operational improvements. These summary lists were shared with the full team and revised as necessary. To assess across sectors, all summary lists were compiled with redundancies noted as higher frequency issues (brought up multiple times). The compiled list was categorized as above (new products, existing products, and operational improvements). This list was then initially binned into the following areas: 1) Communication/Forecast Skill/Decision Support Services 2) Products and services (both new and existing) and 3) Operational improvements. The first area was further divided into: Communication skills 2) Overall technical forecast skill/capacity, and 3) Case specific/user specific needs.

To better consolidate and synthesize the findings and identify a handful of key needs and prototypes, the focus group information was assessed via the matrix format shown below. New products shown in Table 3 were described as forecasting, decision support tools or products, or communications/decision support and data services, and the temporal and spatial characteristics were noted. An item could have elements of multiple row categories (i.e. have both forecasting and decision support tool components). The temporal characteristics were short (on the order of days), medium (on the order of weeks), and long (on the order of months/seasonal) time frames; and the spatial characteristics were local, regional, and national. If the information was mentioned many times during the sessions it was listed as high frequency and those items deemed of high priority for prototypes were noted in the last column. This was repeated for improved products (Table 4) and operational improvements (Table 5). The matrix was revised based on staff group assessment to synthesize the findings and the results are described in the next section of this report.

The tables below represent a synthesis of common recommendations across all the focus groups. The recommendations, which will form the basis of potential priority prototypes, are based on:

1. How frequently the product or service was mentioned during the focus group discussions (to attempt to identify cross-cutting needs); and
2. Existing and planned work by the National Water Center.

Recommendations were categorized as potential new products, improvements to existing products, or operational improvements. The full summary of recommendations is available in the attached Appendix.

Table 3. Overall Findings – Priority New Products and Services

Improved Observation Networks	Forecasting	Products	DSS and Data Services
• Improved gaging network	• Higher spatial/temporal resolution flow forecasts at every mile (rivers) • Coastal coupling	River flow prediction at every mile and hour (e.g., on-line info by river basin for velocity and flood level changes at hourly intervals)	Coastal inundation mapping (for storm surge and river flood coupling)
	• Forecasted inundation mapping • Higher resolution inundation mapping		Inundation mapping services for event-driven decision-making
• Gaging system for water quality (e.g., sensors at stream gages)	Water quality forecasting • Composition of water flowing into estuaries (e.g., flood, drought events) • Salinity forecast - short to season 3-6 month • Turbidity/sediment delivery (flow-driven sediment and debris) • Water temp (late summer/fall, days-weeks range), including modeling	• Seasonal Water Quality Outlooks • Forecast/event-specific forecast	Event-specific consultation with core users

Table 4. Overall Findings – Priority Improved Products and Services

Improved Observation Networks	Forecasting	Products	DSS and Data Services
	• HEFS Implementation (including seasonal flows)	Seasonal Flow Outlooks	
Improved precipitation observations	• Longer-term, consistent QPF • 60-day QPF	60-day forecast product	
	Water supply forecasting at all time scales, high and low flows	• Seasonal/multi-seasonal • More robust and consistent snow model • Volumetric probability of water supply for water year • WRMO implementation/inclusive of departures from normal • Snow vs. ice projections	
	Improved precipitation forecasting	AHPS (hydrograph) inclusive of uncertainty/ensemble info	
			Update to ESP with user-defined access
			Mobile-friendly enhancements
			Flexible data services/interrogation tools; service to format data for incorporation into local tools
			Invest in front-end web services

In addition to new and improved products, participants made suggestions for enhancements to operations that would meet user needs. These are summarized below.

TABLE 5. Overall Findings – Priority Operational Improvements (no decision support tools identified)

Forecasting (data)	Communications and decision support services (data service or product)
Improving warning accuracy (avoid warning fatigue)	
	Improved finer resolution tools for creating images/hydrographs for end users
	Improved clarity/consistency with forecast maps
	Consistency! QPFs, briefing timing, inundation maps, messaging
	Improving briefing process and efficiency
	Mobile-friendly enhancements
	Improved archival capacity
	Improve timeliness of communication with media during events

Recommendations for New and Improved Products and Services

Based on this input, as well as the input from four stakeholder engagement workshops, WRSB and OWP has identified the top priorities moving forward:

- Develop National, Regional and Local Flood Prediction Map Services, Low Flow Prediction Map Services, and Water Supply Forecast Data and Map Services;
- Present data and information that reflects routine (baseline), high flow and low flow conditions with antecedent conditions overlays including precipitation and soil moisture;
- Display data and information in a variety of formats including maps, tables, and hydrographs;
- Provide forecasted information at various timescales including current conditions, hourly, daily, weekly and seasonal; and
- Illustrate flood inundation (extent and depth).

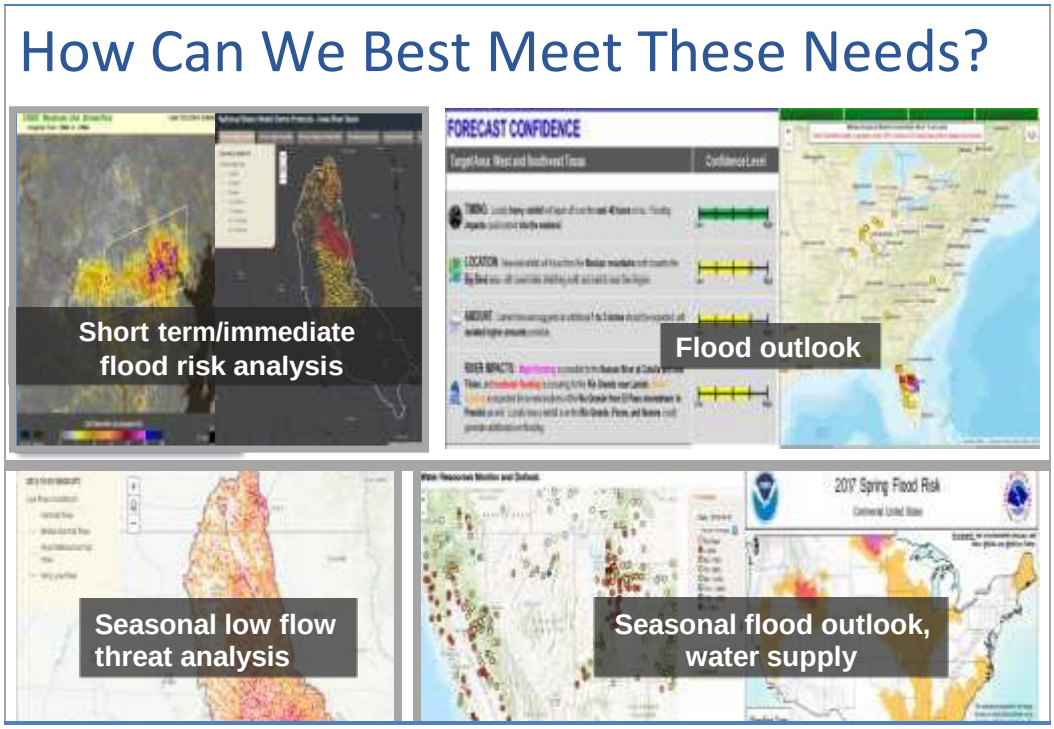


Figure 3. Crosscutting considerations: visualization, uncertainty, and confidence – serving the range of information needs from the public to a sophisticated user.

WRSB and OWP plan to develop conceptual prototype mockups to reflect these needs. The above products and data may reflect routine (baseline) and high flow, low flow conditions. The information can be derived from precipitation and hydrologic forecasts and may be displayed in a variety of formats including maps, tabular displays and hydrographs. In addition, stakeholders indicated that precipitation and soil moisture overlays would be helpful for decision-making. Another request was to make information available at various timescales including:

- Current conditions
- Hourly (0-24 hours; users select hour)
- Daily (0-7 days; users select day)
- Weekly (Week 1-Week 4; users select week)
- Seasonal (30 days-1 year; users select month).

Next Steps

Moving forward, these conceptual prototypes will be used to obtain additional feedback from NWS core partners in the emergency management and water resources management sectors. Those core partners will be asked to evaluate the conceptual prototypes for decision-making applicability, usefulness in various water risk scenarios, and compatibility with their current data and information resources. After further refinement regional watershed partners will evaluate the prototypes to assess broader applicability. All this input will then be used to recommend the development of priority products and services at the National Water Center based on user needs over the next several years.

In recommending development of new and improved products and services, priorities will be considered in the broader context of the full suite of products and services being planned for rollout at the NWC. In order to acknowledge the iterative and evolutionary nature of new product and services development, and the appropriate applications and users for these products at various stages of their development, we envision the following "hierarchy" for the product development process. As products and services are developed, they may move from one category into another.

- Type 1 Products and Services: National Scale Product for Wide Range of Users (for use by the general public)
    - Produced by NWC
    - Examples:
        - Water Resources Monitor and Outlook (WRMO)
        - National Flood Risk and National Low Flow Risk Maps
        - River segment or point-specific
        - Hydrographs
- Type 2: Data provided by NWC for use internally
    - NWC data used by others (RFCs, WFOs, sophisticated users) to tailor products or to be used in models
    - Examples:
        - Flash flood threat analysis– internal product to help guide flood watch/warning. May bring in other data (e.g., infrastructure)
        - Inundation maps in response to high-risk event
        - Low flow anomaly, low flow visualization in response to specific low-flow event
        - Data flows for sophisticated users, upon request via WFO, RFC
- Type 3: Data Services for sector specific, user-specific or 3rd party specialized applications
    - Examples:
        - Soil moisture data and forecasted moisture to predict runoff
        - Anomaly products – blend information from anomaly with HEFs output for more detailed (river segment) threat analysis

Appendix A.1. Example of the survey instrument for internal subject matter experts (note: the survey was tailored slightly for each topic)

Registration Poll Questions for water policy, planning, resiliency; ecosystems/fisheries; recreation

1. ***Who is your primary user/customer?*** *(Choose top 2)*
    - *a.* Water policy, planning, and community resiliency (e.g., federal partners, Assoc. of State Floodplain Managers, Coastal Zone Management officials, Tribes, RBCs)
    - *b.* Ecosystem/fisheries managers (e.g., federal partners, NGOs, watershed associations)
    - *c.* Recreation (e.g., National Park Service, National Forest Service, recreation groups)

2. ***What are common decisions your customers/users need to make which require supporting forecasting products/services?*** *(Please only answer for users you selected in Q1. Please select up to 3 answers in each user category.)*
    - *a. Policy, planning, and community resiliency*
        - ○ When should state and local floodplain/coastal managers issue emergency regulations/deploy staff in anticipation of a major flood?
        - ○ When/to what extent should projects occurring in the floodplain be secured before an event?
        - ○ Where/when will high water occur to document maximum flood levels for planning/mapping/regulatory purposes?
        - ○ Where are our future vulnerabilities and how we can plan for them (future flood levels, future droughts) in terms of future development and infrastructure?
        - ○ Other: _____

    - *b. Ecosystem/fisheries*
        - ○ What in-stream flow velocities are expected to anticipate erosion/sedimentation impacts?
        - ○ When should fish be stocked for best chance of survival?
        - ○ When might dams release water in anticipation of a flood and will there be enough time to allow for ramp down rates to mitigate impacts?
        - ○ What fluctuations in high and low flow are predicted in the future for determining habitat requirements/needs for endangered species?
        - ○ What future changes in operations (dams, water withdrawals, etc.) should be made to ensure environmental flows are maintained?
        - ○ Other: _____

    - *c. Recreation*
        - ○ When should boat/rafting trips be planned based on expected flow conditions?
        - ○ What types of precautions should be undertaken (for example, based on expected stream-flow velocity)?
        - ○ Should recreation areas/camping sites be closed or should access be limited due to expected flood conditions (inundation areas and expected water depth)?
        - ○ Should outings be postponed or ended early based on forecasted conditions?
        - ○ What are projected future conditions, so we can plan to optimize future investment (frequency/timing/duration of new trip itineraries)?
        - ○ Other: _____

3. Keeping in mind your primary customer and the decisions they need to make, please identify the 5 (or 3) most important products/services currently used for each category:

WFOs (select 5)
Areal Flood Warning (FLW)
Areal Flood Watch (FFA)
Flash Flood Statement (FFS)
Flash Flood Warning (FFW)
Flood Statement - Areal Advisories (FLS)
Flood Statement - Flood Advisory for Forecast Points (FLS)
Flood Statement - Follow-up to Flood Warning for Forecast Points (FLS)
Flood Warning for Forecast Points (FLW)
Flood Watch for Forecast Points (FFA)
Hydrologic Outlook (ESF)
Hydrologic Statement (RVS).
Hydrologic Summary (RVA).
Hydro meteorological Coordination Message (HCM)
Hydro meteorological Data Products (RRx)
Hydro meteorological Data Summary Products (HYx)

RFCs (select 5)
Contingency River Forecast (CRF)
Deterministic Hydrologic Forecast (RVF)
Extended-Range Streamflow Prediction (ESP)
Flash Flood Guidance (FFG)
Headwater Flash Flood Guidance (FFH)
Hydro meteorological Coordination Message (HCM)
Hydro meteorological Data Summary Products (HYx)
Hydro meteorological Discussion (HMD)
Significant River Flood Outlook Product
Streamflow Guidance (ESG)

National (select 5)
4-Hour Quantitative Precipitation Forecast (Day 1 - 3)
48-Hour Quantitative Precipitation Forecast (Day 4 - 5) (95E)
48-Hour Quantitative Precipitation Forecast (Day 6 - 7) (97E)
5-Day Quantitative Precipitation Forecast (p120i)
6-Hour Quantitative Precipitation Forecasts (Day 1- 3)
7-Day Quantitative Precipitation Forecast (p168i)
Airborne Survey Gamma Product (RRM)
Daily SNOTEL Report (RSD)
Excessive Rainfall Discussion (ERD)
Excessive Rainfall Potential Outlook (94E, 98E, 99E)
Hydro meteorological Automated Data System Report (RRS)

Mesoscale Precipitation Discussion (MPD)
Modeled Areal Extent of Snow Cover Product (SCV)
Modeled Snow Water Equivalent by Basin Product (SWE)
Monthly SNOTEL Report (RSM)
Quantitative Precipitation Forecast Discussion (PFD)

National Web Products (select 3)
National Hydrologic Assessment.
National Significant River Flood Outlook
National Snow Analysis
NWS Hydrologic Services Program Web Presence (AHPS)
Precipitation Frequency Estimates and Probable Maximum Precipitation Documents
Weather Prediction Center Quantitative Precipitation Forecasts

Experimental (select 3)
NSSL's FLASH
Post Wildfire Debris Flow and Flash Flood Web Pages
Long Range River Flood Risk National Webpage (AHPS)
Short Range River Forecast Uncertainty (AHPS)
Water Information Interface Webpage
Expansion of NOAA/NWS Support for Multi-agency Runoff Risk Forecasts
Other and local products (open-ended answer)

4. Please list the top 3 outstanding core partner group needs, in order of importance (1 = most important):

Water policy, planning, and community resiliency

1
2
3

Ecosystem/fisheries

1
2
3

Recreation

1
2
3

Appendix A.2: Complete ranking of all existing products and services

a. WFOs (select 5)	Count	Percentage
1. Areal Flood Warning (FLW)	20	53%
2. Areal Flood Watch (FFA)	17	45%
3. Flash Flood Statement (FFS)	8	21%
4. Flash Flood Warning (FFW)	21	55%
5. Flood Statement - Areal Advisories (FLS)	6	16%
6. Flood Statement - Flood Advisory for Forecast Points (FLS)	3	8%
7. Flood Statement - Follow-up to Flood Warning for Forecast Points (FLS)	13	34%
8. Flood Warning for Forecast Points (FLW)	27	71%
9. Flood Watch for Forecast Points (FFA)	7	18%
10. Hydrologic Outlook (ESF)	21	55%
11. Hydrologic Statement (RVS).	10	26%
12. Hydrologic Summary (RVA).	6	16%
13. Hydro meteorological Coordination Message (HCM)	3	8%
14. Hydro meteorological Data Products (RRx)	7	18%
15. Hydro meteorological Data Summary Products (HYx)	4	11%
TOTAL	38	

b. RFCs (select 5)	Count	Percentage
1. Contingency River Forecast (CRF)	22	50%
2. Deterministic Hydrologic Forecast (RVF)	41	93%
3. Extended-Range Streamflow Prediction (ESP)	30	68%
4. Flash Flood Guidance (FFG)	15	34%
5. Headwater Flash Flood Guidance (FFH)	7	16%
6. Hydro meteorological Coordination Message (HCM)	1	2%
7. Hydro meteorological Data Summary Products (HYx)	6	14%
8. Hydro meteorological Discussion (HMD)	10	23%
9. Significant River Flood Outlook Product	23	52%
10. Streamflow Guidance (ESG)	16	36%
TOTAL	44	

c. National (select 5)	Count	Percentage
1. 24-Hour Quantitative Precipitation Forecast (Day 1 - 3)	32	80%
2. 48-Hour Quantitative Precipitation Forecast (Day 4 - 5) (95E)	19	48%
3. 48-Hour Quantitative Precipitation Forecast (Day 6 - 7) (97E)	12	30%
4. 5-Day Quantitative Precipitation Forecast (p120i)	14	35%
5. 6-Hour Quantitative Precipitation Forecasts (Day 1- 3)	10	25%
6. 7-Day Quantitative Precipitation Forecast (p168i)	16	40%
7. Airborne Survey Gamma Product (RRM)	4	10%
8. Daily SNOTEL Report (RSD)	2	5%
9. Excessive Rainfall Discussion (ERD)	8	20%
10. Excessive Rainfall Potential Outlook (94E, 98E, 99E)	11	28%
11. Hydro meteorological Automated Data System Report (RRS)	6	15%

12. Mesoscale Precipitation Discussion (MPD)	7	18%
13. Modeled Areal Extent of Snow Cover Product (SCV)	0	0%
14. Modeled Snow Water Equivalent by Basin Product (SWE)	12	30%
15. Monthly SNOTEL Report (RSM)	6	15%
16. Quantitative Precipitation Forecast Discussion (PFD)	8	20%
TOTAL	40	

d. National Web Products (select 3)	**Count**	**Percentage**
1. National Hydrologic Assessment.	7	16%
2. National Significant River Flood Outlook	11	24%
3. National Snow Analysis	14	31%
4. NWS Hydrologic Services Program Web Presence (AHPS)	35	78%
5. Precipitation Frequency Estimates and Probable Maximum Precipitation	18	40%
6. Weather Prediction Center Quantitative Precipitation Forecasts	33	73%
TOTAL	45	

e. Experimental (select 3)	**Count**	**Percentage**
1. NSSL's FLASH	9	24%
2. Post Wildfire Debris Flow and Flash Flood Web Pages	6	16%
3. Long Range River Flood Risk National Webpage (AHPS)	25	66%
4. Short Range River Forecast Uncertainty (AHPS)	27	71%
5. Water Information Interface Webpage	10	26%
6. Expansion of NOAA/NWS Support for Multi-agency Runoff Risk Forecasts	16	42%
TOTAL	38	

f. Other and local products (open-ended answer)
For the services we provide, we don't really rely on conventional text products. The most widely used product is the graphical RVF that the CNRFC has been producing for many years. We also send out emails that go to both the regulating agencies (such as NOAA Fisheries, US Fish and Wildlife, USACE, California Fish and Wildlife) and the agencies and private companies that are regulated. These emails get all parties on the same page regarding the likelihood of an extension or curtailment of watershed activities (gravel mining, timber harvest, restoration work, etc.) based on the forecast weather. For particularly challenging transition seasons (where the trend in weather patterns is uncertain), we conduct weather-briefing webinars for the same mixed audience. This approach of providing the same information to both the regulating and the regulated entities has improved the communication and collaboration between the regulating and regulated entities. The result is increased economic output from watershed activities while also achieving improved natural resource protection.
In eastern region - we have been providing short range meteorological model based probabilistic streamflow guidance (MMEFS) for 4 years - this product suite has been a huge success. It provides precipitation, temperature forcings from 3 NWP ensemble systems and the resulting streamflow and stage simulations as well as projected snowmelt contribution. Check it out at https://www.weather.gov/erh/MMEFS if not familiar with it. This effort has helped to frame a portion of the graphical output which will be delivered in HEFS (Hydrologic Ensemble Forecast System) forecasts which will be expanded over the next several years to many AHPS ESP locations.
10 day forecast precipitation/temperature graphics Water supply products Peak Flow products Minimum Flow products
Spring Breakup Outlook Spring Breakup Map Special Weather Statements

Situation-specific IDSS notification products, email and webinar briefings, landslide threat information (webpage, alerts).
QPE from RFCs.
IDSS products sent directly to them. Users need something pushed to them to alert them, vs going out and finding things themselves. Also, they like a confidence level assigned to the prediction. IE Low/Moderate/High
RVA Product from LMRFC (NEWRVAORN) 28 Day Forecasts
Flow and Velocity Products are a real need by navigation along the Ohio River and our navigation users with waterways and USCG etc. have asked for expansion to every river mile.
Flow forecast hydrographs Hourly QPE graphics Probabilistic forecasts
Customers are interested in soil temperature and soil moisture forecasts as well
Most CPC products (home page), ENSO discussions and outlooks, NCEI state of the climate information, soil moisture & temp, SNOTEL SWE maps, NOHRSC snow data, USGS streamflow info.
Water supply outlooks coordinated between NWS, NRCS
Water Resources Dashboard on the Climate Resilience Toolkit
Outlooks and historical data and information. See Water Resources Dashboard (https://toolkit.climate.gov/topics/water-resources/water-resources-dashboard)
Use of a daily graphical HMD that is a daily hydrologic/hydrometeorology/meteorological discussion/briefing tool. The use of Water Resource briefings on a monthly basis and every 2 weeks as a "Spring Outlook" tool during the snow melt season.
Great Lakes meteorological forecasts
CPC's suite of outlooks from 6-10 to seasonal, full year out.
Hourly gridded QPE products produced by RFC (should by listed as a part of 3b)!
Other national product not listed - PPQPF for our PQPF ensembles (used as contingency forecasts)
Reservoir inflow forecasts (should be listed as part of 3b).
Why are we having to choose only a select number of products for each type? Our customers have varied needs and are in varied climates... Therefore, they use different NWS products in order to meet their needs!
Why are we differentiating different types of flood products when there is already an ongoing effort to simplify these?
Briefings -which express confidence and details on timing, as well as more detailed impacts
Water Supply forecasts
A vast majority of the decision support information provided by WFOs has nothing to do with "products" - they are done via briefings, emails, graphics created locally, social media, and phone discussions. The choices above don't reflect what really matters to our partners.

Appendix B: Stakeholder Engagement Summary

Stakeholder Engagement to Inform National Water Center Hydrologic Products and Services to Meet User Needs
NOAA National Weather Service
Water Resources Services Branch and Office of Water Prediction

January 28, 2018

Executive Summary

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Water Resources Services Branch (WRSB) and the Office of Water Prediction (OWP) are actively applying social science to ensure that its existing and future services meet user needs. Between February and August 2017, WRSB sought input from stakeholders to gauge the value and utility of new products and services, including some of those in the early stages of development at the National Water Center (NWC). WRSB and OWP conducted four stakeholder engagement workshops, attended by a total of 151 stakeholders. These stakeholders provided valuable input that will help inform future hydrologic products and services in support of interdisciplinary federal, state, and local water resources decision making. Workshops were held in Austin, Texas, Phoenix, Arizona, Greenville, North Carolina, and Waterloo, Iowa in collaboration with local NWS River Forecasting Centers (RFCs), Weather Forecast Offices (WFOs) and federal agencies such as the Federal Emergency Management Agency (FEMA), US Geological Survey (USGS), and the US Army Corps of Engineers (USACE).

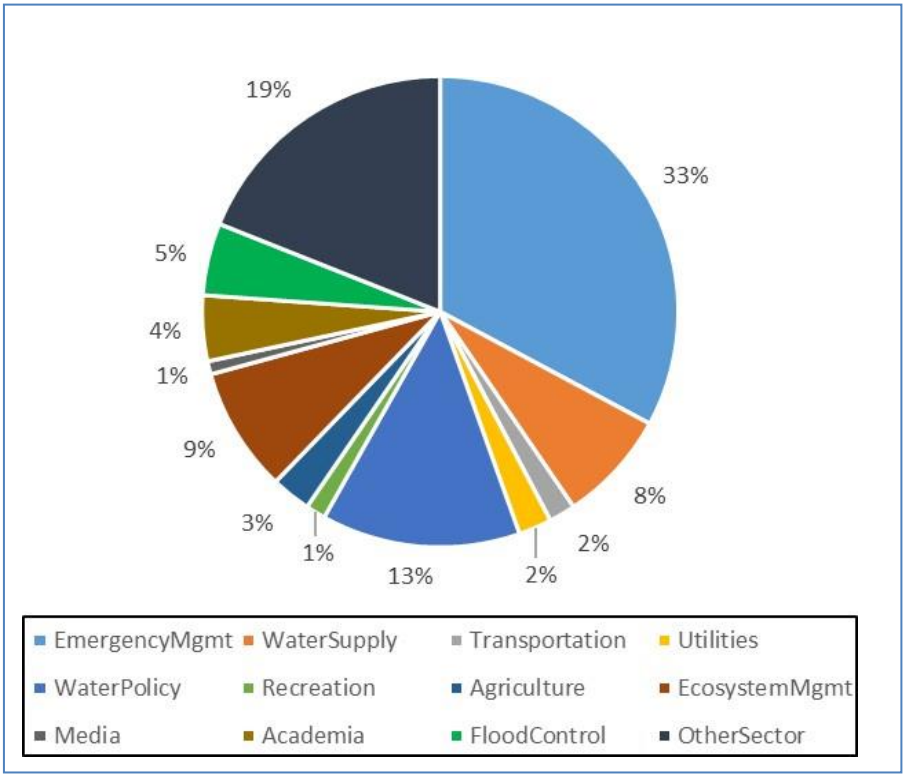


Figure 1. Stakeholder representation: Match chart to legend by reading chart clockwise and legend from top left to right, starting with Emergency Management (33%). Other sectors include consulting, research, operational weather forecasting, natural hazards coordination, data collection, and floodplain management.

Water Resources Stakeholder Engagement Workshops	
Location	**Date**
Austin, TX	February 8, 2017
Phoenix, AZ	April 19, 2017
Greenville, NC	June 21, 2017
Waterloo, IA	August 10, 2017

The workshop locations were chosen to represent a range of geographic challenges related to hydrologic forecasting in general and flash flood prediction. Other selection criteria included active local networks, sophisticated and diverse users, and advanced local services. To obtain the most constructive feedback on the enhanced products and data services, stakeholders represented a variety of core partner groups including flood managers, dam operators, water suppliers, agriculture, transportation, media, emergency managers, ecosystem planners, and public health officials.

Participants were guided through three demonstration stations to obtain their feedback on the following prototype products and services:

- Understanding uncertainty (graphics and hydrographs)
- Inundation (maps showing water depth and lateral extent of flooding)
- Stream flow Anomaly (departure from normal maps)

At each station participants were asked:

- Is this product easy to understand/ does it convey information clearly?
- Is it useful? How would you use it to inform your decisions?
- How could it be improved and are there other products that could be used in combination with this product to increase its effectiveness?

At the end of the demonstration stations, participants voted on those products that they considered of greatest value to meet their needs. Results from the Iowa, Texas and Arizona workshops are summarized in Figure 2 below.

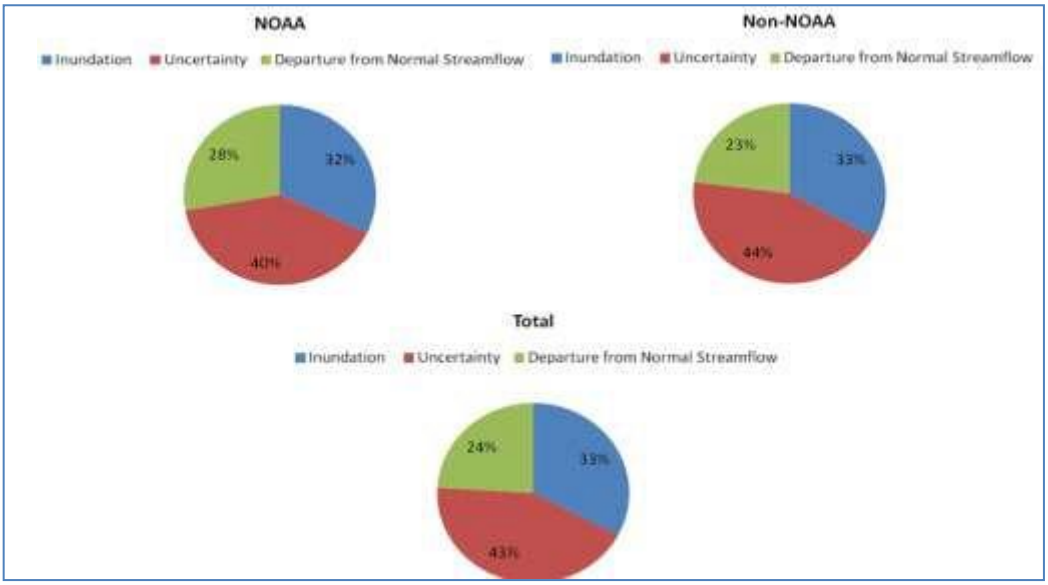


Figure 2. Rotation Station Voting: Compiled results from Waterloo, Phoenix, and Austin. Results are segmented by voter affiliation.

Results from the North Carolina workshop, where participants voted on their top priority user needs are summarized in Figure 3 below.

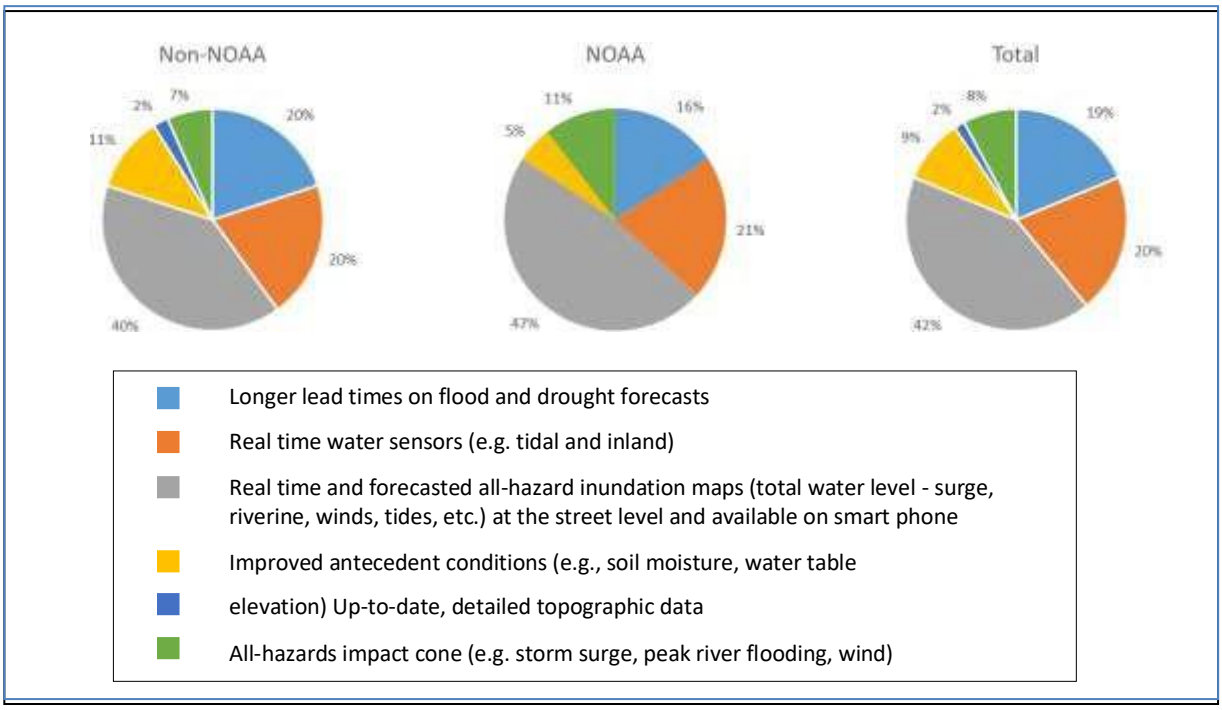


Figure 3. Top Decision support Needs – Greenville, NC. Compiled results segmented by voter affiliation for NOAA and Non-NOAA participants.

Based on this feedback, WRSB and OWP have identified top priorities moving forward:

- Develop National, Regional and Local Flood Risk, Low Flow Risk, and Water Supply Forecast Data and Map Services, depicted spatially as maps;

- Present data and information that reflects routine (baseline) and high flow, low flow conditions with antecedent conditions overlays including precipitation and soil moisture, as available;
- Display data and information in a variety of formats depending on user needs and applications, including spatial maps, tables, and hydrographs
- Provide forecasted information at various timescales from short term to seasonal; and
- Illustrate flood inundation (extent and depth)

Introduction

The Water Resources Services Branch (WRSB) and Office of Water Prediction (OWP) are engaging stakeholders to inform improvements to existing products and services, as well as new products and services to best meet core partners' decision-support needs. This project validates and builds upon findings from past stakeholder engagements conducted in the northeast, central, and western United States, which concluded that users need *actionable and integrated water intelligence from summit-to-sea, treetop-to-bedrock, and floods-to-drought at the time and space scales relevant to their decisions.*

WRSB and OWP have integrated stakeholder user needs information into its strategy for developing new hydrologic forecasting capabilities at the National Water Center (NWC). The NWC was created in 2014 with the goal of revolutionizing operational water resources analysis and forecasting. Objectives of the NWC include providing a central hub to efficiently manage the flow of water information, operating state-of-the-art water models in a high-performance computing environment, and producing, in partnership with NWS River Forecast Centers, a unique, comprehensive suite of new water resources information products and services.

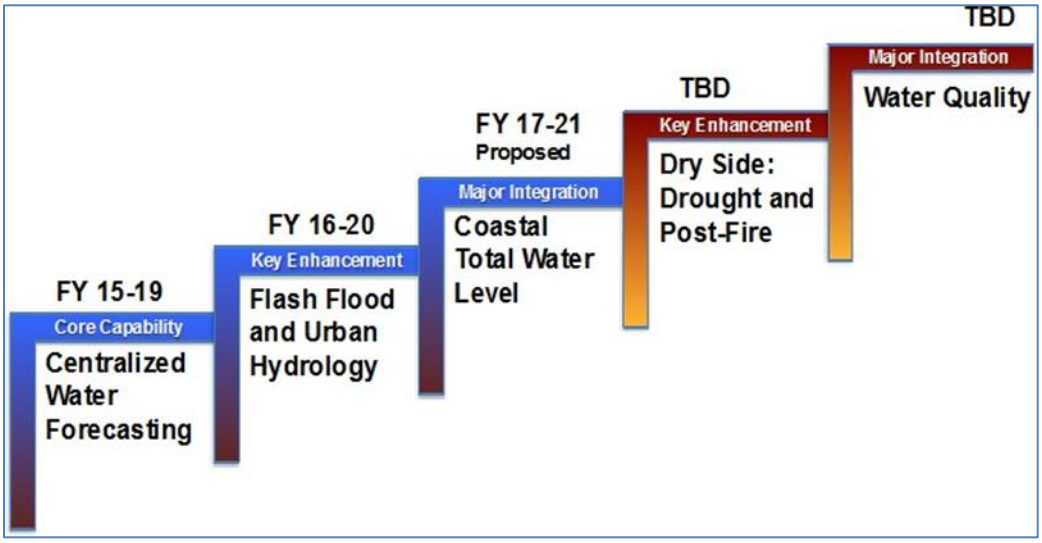


Figure 4. Step-wise process for building NWC capabilities

This project advances the strong foundation of social science that has informed the NWC strategic plan and further informs the development of hydrologic products and services to meet user needs for their routine water resources decisions as well as flooding event-driven decisions.

Summary of Stakeholder Workshops

Each workshop began with an overview of stakeholder engagement to date, the overall vision for improved water resources services within NOAA, and the plan for improved water resources products and services at the NWC. This overview provided participants with a common starting point to understand what led up to this effort, the plan for future hydrologic forecasting services, and how their input will be used to develop new products and services.

The workshop objectives were to:

- Validate past stakeholder input
- Better understand local user needs and priorities
- Demonstrate enhanced products, and
- Use input to assess, develop and refine new products and services

WRSB and OWP staff presented data and information services intended to augment local efforts related to monitoring, forecasting, modeling, and mapping, providing a preview of the prototype products, which participants would be assessing during the demonstrations.

The opening presentation emphasized the critical roles of the respective RFCs and WFOs, who participated in the workshop and contributed to the discussion.

Following the overview and workshop objectives, participants heard from a panel of local, regional and state representatives who addressed the area's most critical issues and needs. The purpose of the panel and following group discussion was to validate commonalities between past stakeholder input and current local user needs and "ground" everyone with an understanding of the realities and challenges faced in each of the workshop locations and to inform subsequent discussions based on that local perspective.

Synthesis of Common Themes and Key Differences

While many comments on the NWC products were similar across each of the four meetings, there were a few key differences. Below is a list of common themes heard at all four meetings, as well as general comments on each of the specific demonstration products and services: inundation mapping, stream flow anomaly mapping, and uncertainty forecasting.
To access more detailed meeting notes from all four of the stakeholder meetings visit: http://www.nws.noaa.gov/os/water/.

Common Themes

- NWM products and services should clearly describe exactly what a user is viewing.
    - This includes input information, accuracy of model predictions, and clear legends.
- WFO and RFC staff must be trained on the functionalities, capabilities, and applicability of the NWM services to effectively deliver these services
- Products that do not incorporate regulated flow (e.g., levees) provide planning-level information that could be used to alert water resource managers and responders in advance of a flash flood. This information requires local input to incorporate flow considerations not analyzed in the NWM products.
- Some local users expressed interest in incorporating the capability to ingest data from the NWM. This local data may include normal stream flow, soil moisture content, etc.
- Precipitation overlays were requested across all three types of products.
- Some of the NWM products, especially the inundation maps, could be helpful in un-gaged areas.

Differences

- Data needs depend on staff capacity and time to understand and interpret results. For example, some emergency managers expressed interest in more detailed data and information, but others preferred to receive information directly from the local RFCs and WFOs.
- Some emergency managers thought that the inundation mapping would be a useful tool for emergency planning, while others saw it as more of a mitigation tool.

Similarities

- **Inundation Mapping**
    - When viewing the inundation maps, stakeholders want to know the depth in addition to the extent of inundation.
    - For coastal users, river and coastal flooding need to be coupled into one product to make the inundation mapping useful.
    - Some localities have the capacity to produce inundation maps, but most stakeholders agreed that in un-gaged areas, the NWM inundation information would be helpful, especially if local input is included on issues related to regulated flows (e.g., levees, dams).
    - The legend should be more descriptive.
    - It would be useful to incorporate alerts or indicate potential roadway flooding (e.g., collaborate with Department of Transportation).
    - An archiving capability would be useful for state and federal disaster declarations, and in general to keep a record of what was predicted.

- A feedback mechanism would allow users to provide comments on the model
- The model resolution needs to be improved – i.e., greater than 10-meter Digital Elevation Model (DEM).

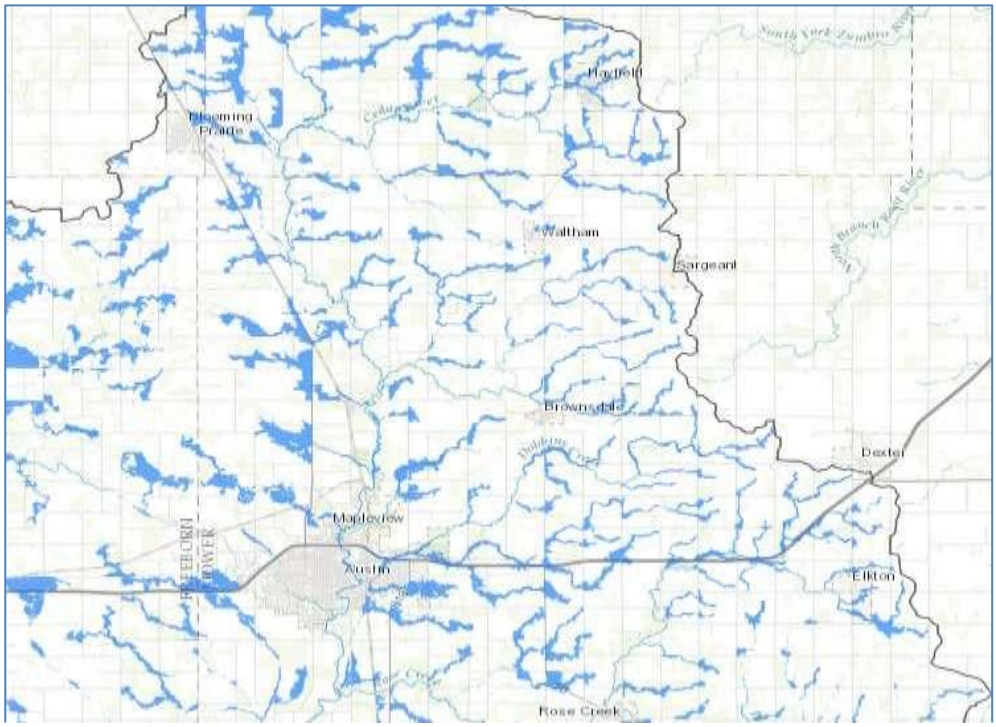


Figure 5. NWM inundation map example from the Waterloo, Iowa stakeholder engagement workshop.

- **Stream Flow Anomaly**
  - Monthly average threshold (2x) for stream flow anomaly is not an applicable comparison point
    - In dry areas where normal flow is low, the mapping may not be representative of "real" high flow conditions. For example, normal monthly average flow is 10 cubic feet per second (cfs), and the model presents conditions based on 2 times that monthly average.
    - Stakeholders suggested adding return intervals (e.g., 10 year), flood stages or an alternate threshold of flood level (e.g., major, moderate, minor).
  - Colors should be as consistent as possible with other NWS mapping colors to avoid confusion. Use-specific maps would benefit some industry partners. For example, the agriculture industry would benefit from the low flow anomaly forecast to understand soil moisture and stream flow predictions.
  - Sliding bar timescale features would be helpful in providing a temporal context for water resource managers and emergency responders.

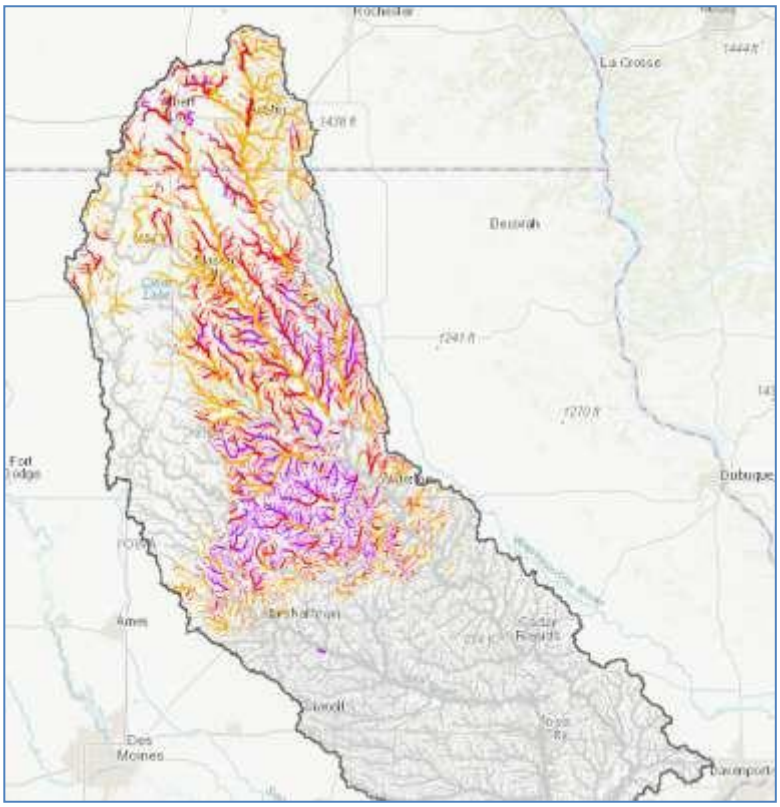


Figure 6. Example of NWM streamflow anomaly map from the Waterloo, Iowa stakeholder engagement workshop.

- **Understanding Uncertainty**
  - A wide audience of water resource managers and responders acknowledge that communicating uncertainty through probabilistic ensemble forecasts would be helpful for decision-making. However, it was noted that the NWM currently only uses deterministic modeling capabilities.
  - Long-range flood risk probability could be used for drought situations to assess when normal flow or higher than current flow could occur. This information could potentially drive water conservation or power generation policies.
  - Long-term uncertainty products (e.g., Long Range Experimental Flood Risk) would not be useful to emergency managers, but emergency managers could use the shorter-term products like probabilistic precipitation forecasts.
  - User-selected timescales are preferred.
  - More accuracy is needed before explaining the uncertainty hydrographs to responders and managers.
  - 1-5 days is a helpful range for forecasted information.
  - Long Range River Flood Risk may be helpful for large rivers, e.g., the Mississippi, but it is not helpful for small rivers.

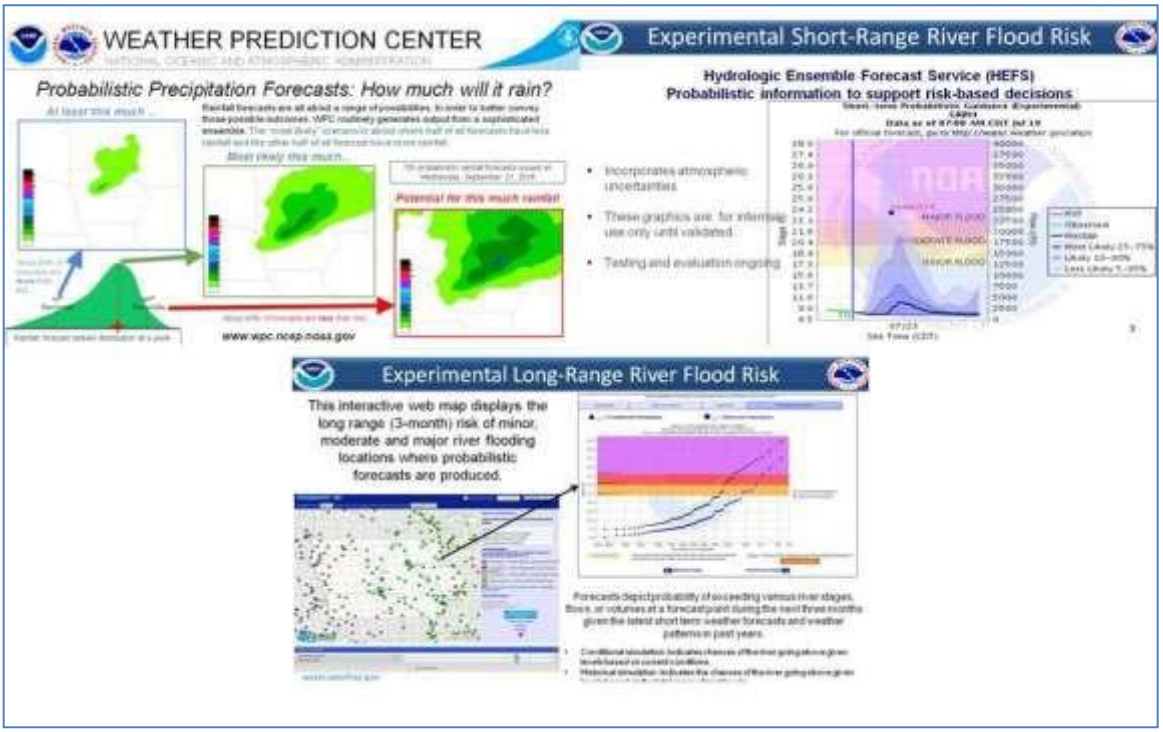


Figure 7. Example of uncertainty data forecast services and information from the Waterloo, Iowa stakeholder engagement workshop.

Consensus on Most Valued Prototype Products /Services

Following the rotation station conversations, participants at three of the four workshops were asked – "If you could invest in any of the 3 categories of data services/products that you viewed today, which would you choose?" Voting stations were set up in the plenary room and participants voted for products that they considered the highest priority to meet their decision support needs; NOAA and non-NOAA participants voted separately. Results are illustrated in the table below and above in Figure 2. Most of both NOAA and non-NOAA participants ranked uncertainty products #1, followed by inundation products #2, and departure from normal stream flow priority #3.

Rotation Station Voting	Inundation	Departure from Normal Stream flow	Uncertainty
Waterloo			
Non-NOAA Partners	25	11	46
NOAA/NWS	7	4	12
Phoenix			
Non-NOAA Partners	22	32	28
NOAA/NWS	5	6	13
Austin			
Non-NOAA Partners	35	14	35
NOAA/NWS	11	10	4
Total Compiled Results			
Non-NOAA Partners	82 (#2)	57 (#3)	109 (#1)

NOAA/NWS	23 (#2)	20 (#3)	29 (#1)
GRAND TOTAL	105 (#2)	77 (#3)	138 (#1)

At the Greenville, NC workshop, participants were asked to vote on top decision support needs, rather than on the specific NWM products and services. Rotation stations included inundation, departure from normal stream flow and, in place of the uncertainty station, a "blue sky" rotation station was added. Because this area is so heavily influenced by coastal hydrology, which was not represented in the prototype products, a broader view of user priorities was appropriate. At this station, entitled "Integrated Coastal Water Information Gaps – Needs and Gaps," participants were asked:

- What information do you need to inform critical decisions?
- Thinking both spatially and temporally, how can NWS most effectively deliver total water products and services to inform these decisions?

Each group brainstormed a list of high priority needs. Six top priority needs emerged when comparing results across all three rotations. A voting station was set up during the break (NOAA and non-NOAA participants voted separately), and participants voted as a group to identify the top three priorities. Results are illustrated in the table below and in Figure 3.

Voting – Top Needs	**Non-NOAA**	**NOAA**	**Total**
Longer lead times on flood and drought forecasts	9	3	12
Real time water sensors (e.g. tidal and inland)	9	4	13
Real time and forecasted all-hazard inundation maps (total water level: surge, riverine, winds, tides, etc.) at the street level and available on smart phone	18	9	27
Improved antecedent conditions (e.g., soil moisture, water table elevation)	5	1	6
Up-to-date, detailed topographic data	1	0	1
All-hazards impact cone (e.g. storm surge, peak river flooding, wind)	3	2	5

Preliminary Findings

The information collected from stakeholders on the initial set of prototype products introduced at these meetings will be considered in the broader suite of NWC products and services (drought, water quality, flooding, coastal coupling). Based on input from the four stakeholder engagement workshops, WRSB has identified the top priorities moving forward:

- Develop National, Regional and Local Flood Risk, Low Flow Risk, and Water Supply Forecast Data and Map Services, depicted spatially as maps;
- Present data and information that reflects routine (baseline) and high flow, low flow conditions with precipitation and soil moisture overlays, as available;
- Display data and information in a variety of formats depending on the best application, including maps, tables, and hydrographs;
- Provide forecasted information at various timescales from short term to seasonal; and
- Illustrate flood inundation (extent and depth).

Figure 7. Crosscutting considerations: visualization, uncertainty, and confidence – serving the range of information needs from the public to a sophisticated user.

WRSB and OWP plan to develop conceptual prototype mockups to reflect stakeholder needs, considering feedback and comments from the stakeholder engagement workshops. The above products and data may reflect routine (baseline) and high flow, low flow conditions. The information can be derived from precipitation and hydrologic forecasts and may be displayed in a variety of formats including maps, tabular displays and hydrographs. In addition, stakeholders indicated that precipitation and soil moisture overlays would be helpful for decision-making and that information should be available at various timescales including:

- Current conditions
- Hourly (0-24 hours; users select hour)
- Daily (0-7 days; users select day
- Weekly (Week 1-Week 4; users select week)
- Seasonal (30 days-1 year; users select month).

Low flow risk information would not be displayed at the short-term timescale. In addition, static inundation maps, from the NWC and the NWS inundation map library, at various locations, would be helpful to stakeholders.

Coastal Coupling

Stakeholders in North Carolina indicated that a total water level map showing timing of flood levels with combined impact of storm surge, tides and river elevations at regional and local scales and at short- and near-term timeframes would be useful decision-support information. It was noted however, that coastal coupling data services will require a significant effort between

NWS and the National Hurricane Center to integrate inland and offshore flood impacts. Thus, it will be a longer-term effort. These user priorities have been documented and will be explored as the NWM is further developed.

Next Steps

Moving forward, these conceptual prototypes will be used to obtain additional feedback from NWS core partners in the emergency management and water resources management sectors. Those core partners will be asked to evaluate the conceptual prototypes for decision-making applicability, usefulness in various water risk scenarios, and compatibility with their current data and information resources. After further refinement, we will convene watershed-based, mixed sector stakeholder meetings. At these meetings, core partner groups--who share water resources but have different needs—will meet to evaluate the prototypes for watershed-based decision-making. All this input will then be used to recommend the development of priority products and services at the National Water Center based on user needs over the next several years.

In recommending development of new and improved products and services, priorities will be considered in the broader context of the full suite of products and services being planned for rollout at the NWC. In order to acknowledge the iterative and evolutionary nature of new product and services development, and the appropriate applications and users for these products at various stages of their development, we envision the following preliminary "hierarchy" that represents the thought process for product development. As products and services are developed, they may move from one category to another.

- Type 1 Products and Services: National Scale Product for Wide Range of Users (for use by the general public)
    - Produced by NWC
    - Examples:
        - Water Resources Monitor and Outlook (WRMO)
        - National Flood Risk and National Low Flow Risk Maps
        - River segment or point-specific
        - Hydrographs
- Type 2: Data provided by NWC for use internally
    - NWC data used by others (RFCs, WFOs, sophisticated users) to tailor products or to be used in models
    - Examples:
        - Flash flood threat analysis– internal product to help guide flood watch/warning. May bring in other data (e.g., infrastructure)
        - Inundation maps in response to high-risk event
        - Low flow anomaly, low flow visualization in response to specific low-flow event
        - Data flows for sophisticated users, upon request via WFO, RFC

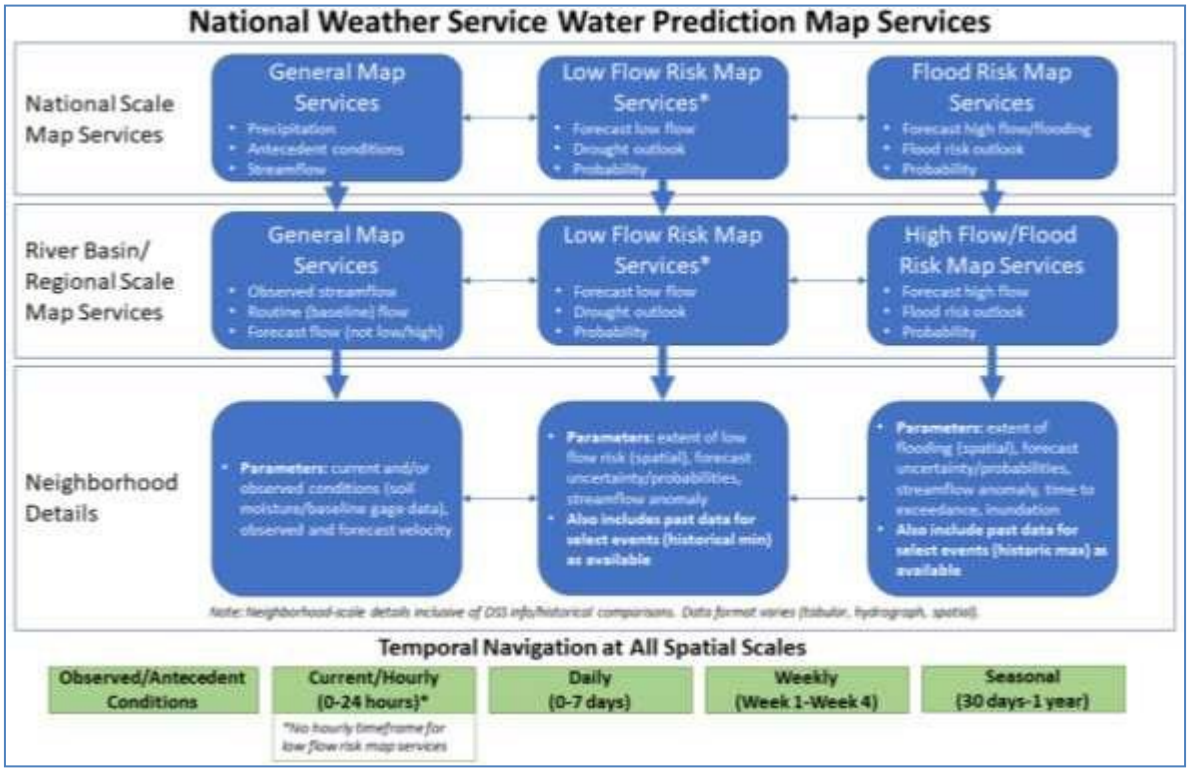
- Type 3: Data Services for sector specific, user-specific or 3rd party specialized applications
    - Examples:

- Soil moisture data and forecasted moisture to predict runoff
- Anomaly products – blend information from anomaly with HEFs output for more detailed (river segment) threat analysis

Appendix C: Emergency Manager Focus Group Summary
Stakeholder Engagement to Inform National Water Center Hydrologic Products and Services to Meet User Needs
NOAA National Weather Service
Water Resources Services Branch and Office of Water Prediction

Emergency Manager Focus Groups: Summary of Content and Input
Revised: November 28, 2018

Following input from the internal focus groups and four stakeholder workshops in 2017, a logic model was created to represent stakeholder needs at spatial scales (national, regional/watershed, local/neighborhood) and temporal scales (current conditions, hourly, daily, weekly and seasonal) that reflected priority user needs.

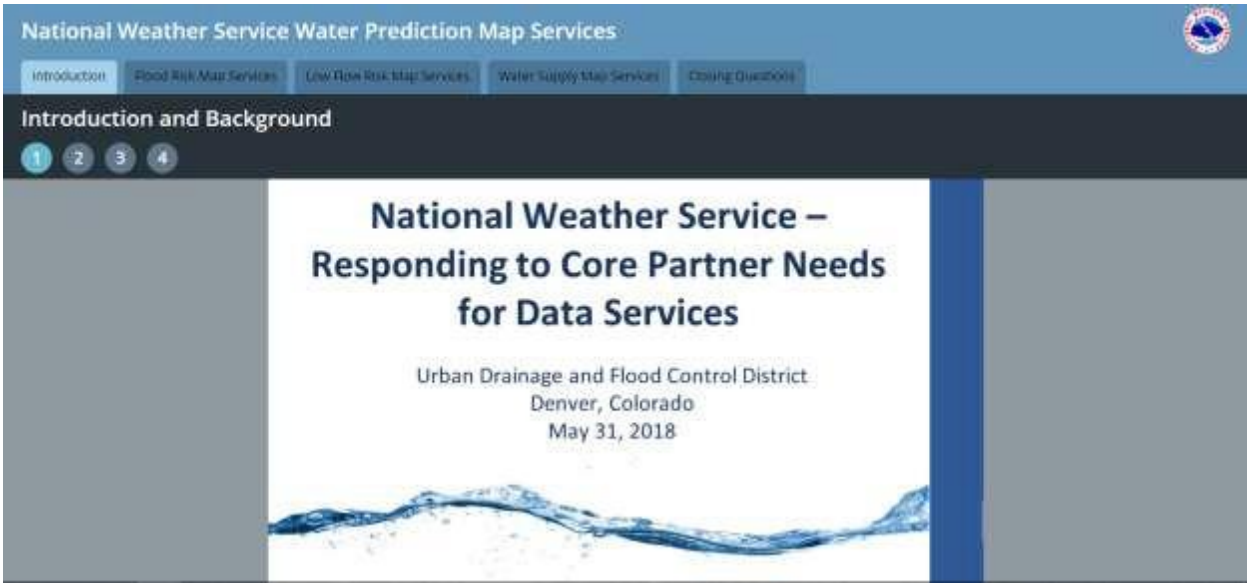


Map services were then defined for high flow and low flow scenarios and prototypes were created by depicting how data could be displayed as map services at national and regional scales. Due to time constraints at focus group events, not all user requirements could be shown. At the neighborhood scale, a list of parameters was developed in lieu of prototypes. ERG created the first set of conceptual prototypes and, after discussion and refinement, the National Water Center (NWC) created prototypes using data from the Lower Ohio River Basin.

Prototypes were tested with 58 emergency managers that attended regional gatherings from three distinct geographic areas of the country: the southeastern regional meeting of emergency managers (Nashville, TN), the front range of the Colorado Rocky Mountains (Denver CO), and the Mid-Atlantic coast (Atlantic City, NJ).

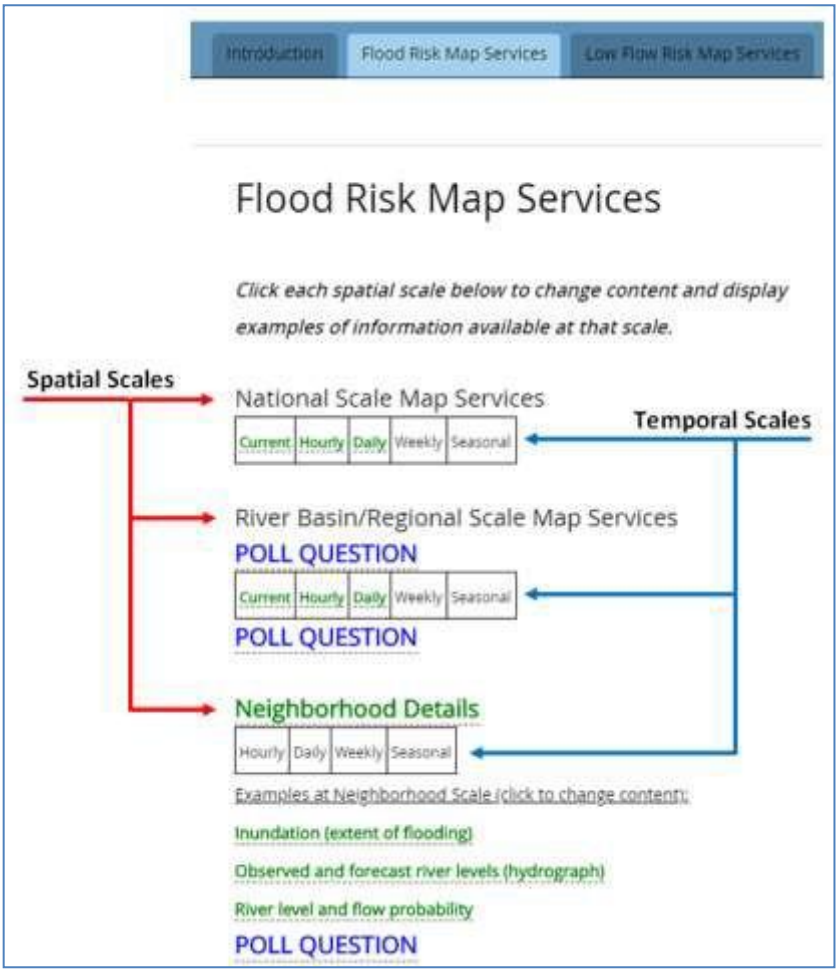
To facilitate navigation of the prototypes among different scales and time-steps, and to elicit feedback from relatively large focus groups, ERG integrated data visualization and real-time polling using Esri StoryMap and linked to PollEverywhere software. Focus group scripts were developed and used to coincide with the images and questions that served as prompts for focus group input.

The StoryMap was designed to mirror the logic model structure and facilitate the presentation of several different map data services (e.g. high flow/flood risk maps). The screenshot below shows the main page of the StoryMap for the Denver, CO focus group meeting.

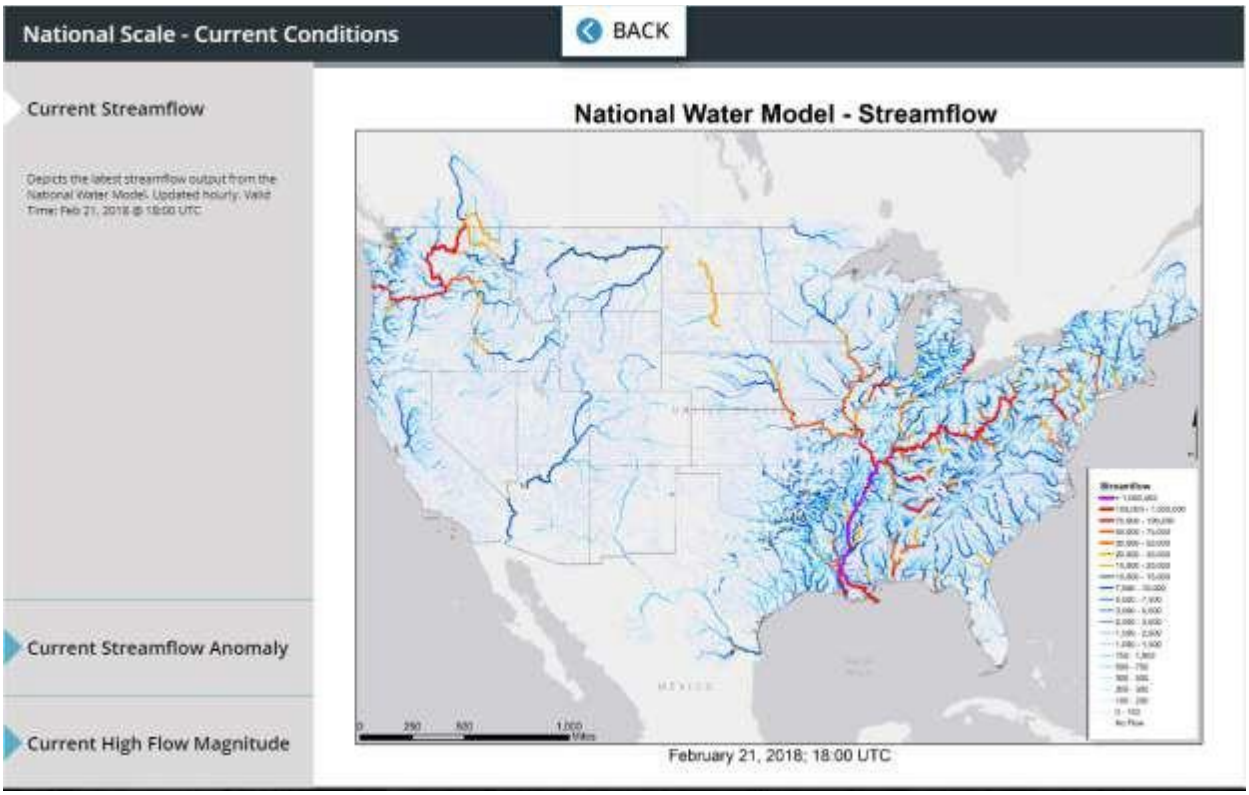


Each focus group introduction included a short description of previous stakeholder engagement activities before presenting the logic model shown above. Participants were then asked a basic introductory question: “What best describes your area of responsibilities?” to gather information on the scale at which participants generally work (local, state, regional, national, tribal, and other).

Most of the content presented at the focus group meetings was in the Flood Risk Map Services tab. The screenshot below shows the different navigation options for the presentation: green text indicates a spatial/temporal scale at which new information is presented in the Storymap. The presentation of information on this page matches the structure of the logic model, with different spatial and temporal scales shown in the panel on the left.



The first option shown at each focus group was the “Current Conditions” timescale for the National Scale Map Services as shown below. This display presented current streamflow, current streamflow anomaly, and current high flow magnitude from the National Water Model. All national maps were static images due to data file size restrictions.



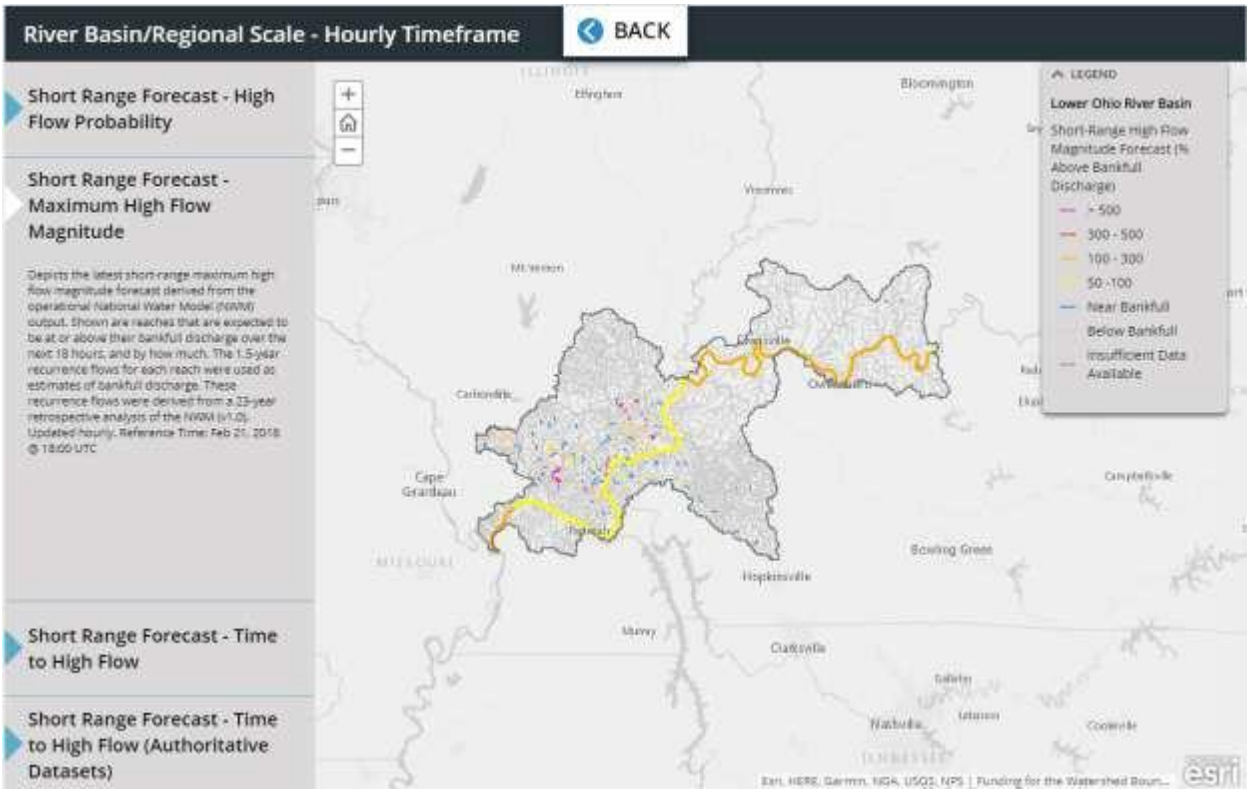
Participants were then shown prototype products at the River Basin/Regional Scale. The timescale shown was dependent on participant responses to a Poll Question: "Which timescales do you consider most critical when making decisions regarding flooding?" with responses matching the timescale options – Observed Conditions, Hourly Forecast, Daily Forecast, Weekly Forecast. The table below shows the different observational or forecast products for each spatial and temporal combination. The same products were viewable as static images at the national scale but were generally not shown during the focus group events due to time constraints and their lack of interactivity.

Spatial Scale	Current	Hourly	Daily
River Basin/Regional	• Current Streamflow • Current Streamflow Anomaly • Current High Flow Magnitude	• High Flow Probability • High Flow Magnitude • Time to High Flow • Time to High Flow (Authoritative Datasets) *	• Day 2 High Flow Probability • 3-Day High Flow Magnitude • Time to High Flow

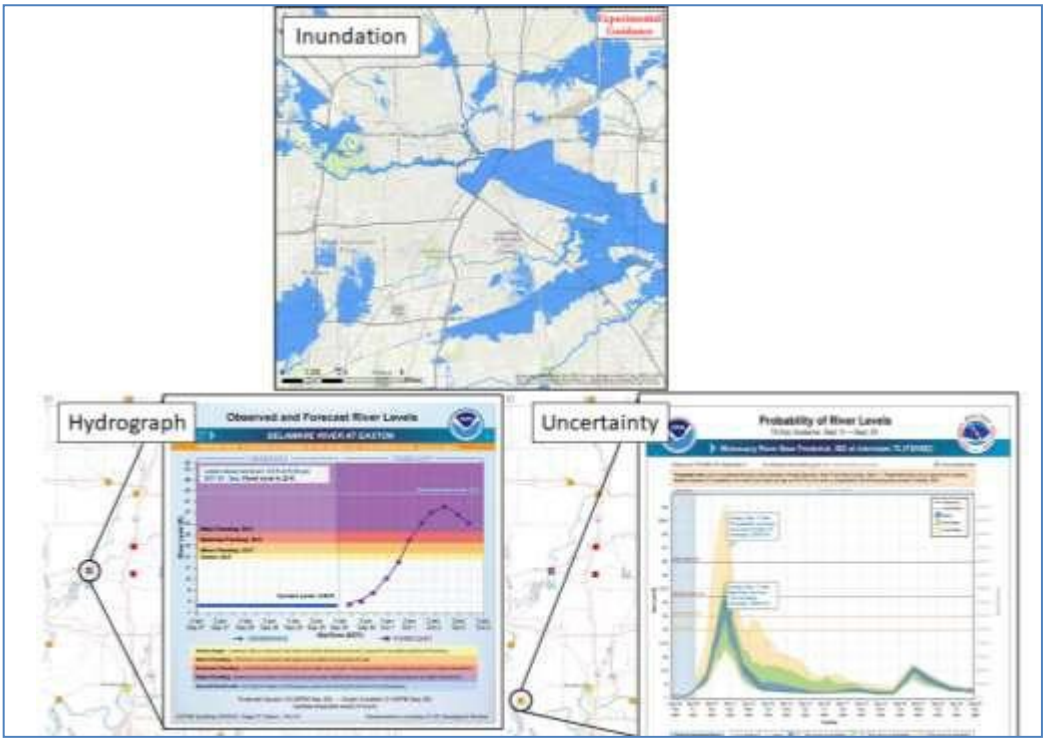
*The Time to High Flow (Authoritative Datasets) option was an interactive Esri WebApp designed to demonstrate to users how these services could be incorporated with their own GIS-based contextual information like roads, critical facilities, etc. This was only operational for the Denver focus group.

The screenshot below provides an example of what participants saw at the River Basin/Regional Scale for the Hourly timeframe. At this spatial scale the example products were interactive (zoom, pan, pop-ups on click) to demonstrate to users that these would not be static products but rather data services

that could be integrated into the users' GIS files and analyzed in comparison to other datasets (e.g., mapped critical infrastructure).



No interactive products were available to present at the Neighborhood Details scale, so users were shown three static examples of the types of data that could be available at that fine scale – inundation (extent of flooding), observed and forecasted river levels (hydrograph), and river level and flow uncertainty. The screenshots below show these static images.



Throughout the StoryMap presentation, embedded polls solicited participant feedback. The following questions were asked during each event:

- "What best describes your area of responsibilities?"
    - Local, State, Regional, National, Tribal, Other
- "Which timescales do you consider most critical when making decisions regarding flooding? Rank the following:"
    - Observed Conditions, Hourly Forecast, Daily Forecast, Weekly Forecast
- "Please rank the following forecast products based on how useful they would be when making decisions regarding flooding."
    - High flow magnitude, High flow probability (chance), Time to high flow
- "Please rank the neighborhood products based on how useful they would be when making decisions regarding flooding."
    - Inundation, Hydrograph, Streamflow Uncertainty
- "On a scale of 1-5, please rate how useful these types of services would be to your decision making."
    - 1 – Not at all useful, 2 – Slightly useful, 3- Moderately useful, 4 – Very useful, 5 – Extremely useful

Below is a summary of "key takeaways," from the emergency manager focus groups followed by polling data and major comments that emerged from the focus groups.

Key Takeaways

- All products are useful, especially when used in combination.
- More contextual data (antecedent conditions, precipitation, historic events) is needed.
- Inundation: include uncertainty, depth, and change over time.

- When depicting a flood event, magnitude was generally viewed as the most important, followed by time to peak flow, then probability of an event occurring.
- Participants thought that the 1.5-year recurrence interval and “bank-full” description should be re-considered, as the 1.5-year recurrence interval may be too low and “bank-full” may not be a familiar term.
- Considerations for delivery strategy should include clarity between roles (National Water Center vs. River Forecast Centers). Consider a single point of access to download data and training on how to download and use the data.
- Gaps include coastal coupling, considerations for watershed with regulated flow and flashy canyon topography, inundation depth, and more neighborhood-scale products.

The polling data and corresponding questions are summarized below, followed by a summary of comments that were focused on improvements to the data services to better meet emergency managers’ needs.

Questions	Responses	Nashville	New Jersey	Denver
What best describes your area of responsibility?	Local	78%	59%	55%
	State	11%	18%	18%
	Regional	0%	18%	9%
	National	11%	0%	0%
	Tribal		0%	0%
	Other	-	6%	18%
Which timescales do you consider? most critical when making decisions regarding flooding? Please rank the following:	Observed Conditions	1st	2nd	1st
	Hourly Forecast	2nd	1st	3rd
	Daily Forecast	3rd	3rd	2nd
	Weekly Forecast	4th	4th	4th
	Seasonal	5th	-	-
Which of the forecast products would you find most useful in your decision making? *	High flow potential**	16%	-	-
	High flow probability	26%	-	-
	Time to high flow	58%	-	-
Please rank the following forecast products based on how useful they would be when making decisions regarding flooding.	High flow magnitude	-	1st	1st
	High flow probability	-	3rd	2nd
	Time to high flow	-	2nd	3rd
Which of these neighborhood products are most useful? *	Inundation	69%	-	-
	Hydrograph	31%	-	-
	Uncertainty	0%	-	-
Please rank the neighborhood products based on how useful they would be when making decisions regarding flooding.	Inundation	-	1st	1st
	Hydrograph	-	2nd	3rd
	Uncertainty	-	2nd (tied)	2nd
On a scale of 1-5, please rate how useful these types of services would be to your decision making.	1 - Not at all useful	0%	0%	0%
	2 - Slightly useful	0%	0%	0%
	3 - Moderately useful	0%	0%	80%
	4 - Very useful	58%	75%	20%
	5 - Extremely useful	42%	25%	0%

*Questions asked at Nashville only – replaced for following focus group events by a ranked response.
**High flow potential was renamed High flow magnitude following the Nashville focus group event.
- Indicates a question and/or response not asked at a given focus group event.

General Feedback

- Most participants had not seen the national-scale products that are currently available on the web, and one commenter noted difficulty navigating the website to find information.

- All the products were viewed as useful, and there was much interest in accessing them from a single source and bringing the data into users' systems ("If it can't be integrated, we won't be using it").
- There was much interest in the delivery mechanism and assurance needed for consistency between services delivered via the National Water Center vs. the River Forecast Center and Weather Forecast Offices.
- Combining parameters would be more useful than displaying them separately. For example, color-coding inundation maps to show certainty of different flood elevations or relating inundation to amount of rainfall (inches per hour) would be informative.
- Greater lead-time is not highly valued if there's a great deal of uncertainty around the forecast.
- There was interest in more localized products – at a small watershed scale (< 50 square miles), assessment of accuracy, and pilot testing with a few sophisticated users. Several participants noted difficulty in commenting on services without testing them out in a real situation.
- Training as part of the roll-out strategy is important for users.

Flood Risk

- Showing where flooding occurred in a past time step, where it is occurring now, and where it is most likely to occur in the future would give emergency managers a better sense of how flood risk is changing throughout an event.
- Depth of inundation was viewed as important if not more important than lateral extent of flooding.
- 1.5-year recurrence interval is not something that emergency managers are typically concerned about. This stakeholder group uses more significant events (e.g., 5, 10, and 25-year storm event) as reference points. The 5-to-10-year storm events are more likely to be representative of when banks are overflowing. There was also some concern that 1.5-year recurrence interval is inconsistent with RFC information.
- Bank-full is not a term emergency managers typically use. Flood stage or "x" year flood event is more familiar terminology.

Uncertainty

- Quantitative precipitation forecasts (QPF) are relied upon heavily – longer-term forecasting is not valued if it is highly inaccurate.
- Provide access to forecast verification and uncertainty and parameters that are driving the forecast.
- It would be helpful to depict forecasts with associated confidence level (e.g., 50%, 90% confidence level), as in the hydrograph graphic. Another suggestion was using terminology consistent with winter storm products (least, most likely).

Context Issues

- Antecedent conditions are critical for understanding risk and should be reflected.
- Color scales should be consistent with other NWS products.
- For a better sense of impact, it would be helpful to show precipitation and infrastructure.
- Compare high flow, low flow, and inundation forecasts to past notable event of record (within recent memory).
- Translating high flow into level of impact is critical.
- In coastal areas, information about tides, storm surge, and sea level rise would be helpful.

- Post-event look-back it would be very instructive (show amount of precipitation/flooding predicted vs. what occurred).

Note: A water supplier attended the Denver focus group, and those views are noted below.

- Weekly forecast is preferred by reservoir operators so that they can more precisely plan for when reservoirs will fill.
- Weekly forecasts also become important for monsoonal flows.
- Products do not take into consideration dam operations. For dam operators, volume is more important than flow rate.