

# **Requirements for the National Flood Inundation Mapping Services**

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## List of Acronyms

<b>3DEP</b>	3D Elevation Program
<b>AHPS</b>	Advanced Hydrologic Prediction Service
<b>CWMS</b>	Corps Water Management System
<b>DFIRM</b>	Digital Flood Insurance Rate Map
<b>DHS</b>	Department of Homeland Security
<b>DSS</b>	Decision Support Services
<b>EAPs</b>	Emergency Action Plans
<b>FEMA</b>	Federal Emergency Management Agency
<b>FGDC</b>	Federal Geographic Data Committee
<b>FIM</b>	Flood Inundation Mapping
<b>FIM-DT</b>	Flood Inundation Mapping Design Team
<b>FIM-RT</b>	Flood Inundation Mapping Requirements Team
<b>FOUO</b>	For Official Use Only
<b>HEC</b>	Hydrologic Engineering Center
<b>HEC-FIA</b>	Hydrologic Engineering Center Flood Impact Analysis
<b>HEC-RAS</b>	Hydrologic Engineering Center River Analysis System
<b>H&amp;H</b>	Hydrology and Hydraulics
<b>IDS-DT</b>	System Interoperability and Data Synchronization Design Team
<b>IDS-RT</b>	System Interoperability and Data Synchronization Requirements Team
<b>ISF</b>	Information Services Framework
<b>IT</b>	Information Technology
<b>IWRSS</b>	Integrated Water Resources Science and Services
<b>MOU</b>	Memorandum of Understanding
<b>MMC</b>	Mapping Modeling and Consequences Production Center
<b>NAD83</b>	North American Datum of 1983
<b>NAVD88</b>	North American Vertical Datum of 1988
<b>NGVD29</b>	National Geodetic Vertical Datum of 1929
<b>NFIMS</b>	National Flood Inundation Mapping Services
<b>NLD</b>	National Levee Database
<b>NOAA</b>	National Oceanic Atmospheric Administration
<b>NSSDA</b>	National Standard for Spatial Data Accuracy
<b>NWIS</b>	National Water Information System
<b>NWS</b>	National Weather Service
<b>OGC</b>	Open Geospatial Consortium
<b>PDF</b>	Portable Document Format
<b>QA/QC</b>	Quality Assurance/Quality Control
<b>U.S.</b>	United States
<b>USACE</b>	United States Army Corps of Engineers
<b>USGS</b>	United States Geological Survey
<b>USNG</b>	United States National Grid
<b>UTM</b>	Universal Transverse Mercator
<b>WGS</b>	World Geodetic System
<b>WSC</b>	Water Science Center

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## **Executive Summary**

This Integrated Water Resources Sciences and Services (IWRSS) Flood Inundation Mapping (FIM) requirements report was prepared by representatives from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS), the U.S. Army Corps of Engineers (USACE) and the U.S. Geological Survey (USGS) to make recommendations and provide requirements for producing, sharing and disseminating flood inundation maps. In addition, these recommendations and requirements were coordinated with the IWRSS System Interoperability and Data Synchronization Requirements Team at key points in the report development process.

The IWRSS member agencies share a common goal of providing flood inundation map products to support stakeholders for all phases of the flood risk management lifecycle. Particular emphasis has been placed on enhancing existing flood forecast and warning systems vital to the protection of life and property during flood events. These requirements were developed to meet stakeholder needs. In order to maintain product relevance, the stakeholders should be consulted for input at key evaluation periods throughout the process of developing the proposed IWRSS National Flood Inundation Mapping Services.

### **Key Findings**

The collaborative effort by the FIM Requirements Team produced the following key findings:

- All three IWRSS agencies are actively developing valuable flood inundation maps for various purposes including project planning, emergency planning, emergency response and flood risk management.
- All three IWRSS agencies have different approaches for scoping collaborative projects and for producing flood inundation maps.
- Each agency has limited understanding of the approaches used by the others.
- Flood inundation map stakeholders and the public would benefit from the agencies adopting a consistent, common federal approach to flood inundation map content, format and dissemination.

### **Key Benefits**

Benefits of a more common federal approach to FIM are numerous and include:

- Cost efficiencies may result from sharing procedures, tools and possibly systems.
- Quality improvements may result from improved sharing of streamgage, stage forecast, reservoir regulation and other information, and data already developed by the partner agencies, which are necessary to produce accurate flood forecast inundation maps.
- Improved accessibility and understanding of flood inundation maps within stakeholder communities and the public will enhance flood risk communications and awareness.

### **Key Overarching Requirements**

The proposed overarching requirements for the National Flood Inundation Mapping Services are centered upon establishing a common operating picture and addressing stakeholders' needs. Fundamentally, the IWRSS agencies should (1) develop uniform mapping products and (2) establish a common operating picture to host the map products per agency release policies.

#### *Uniform Mapping Product Requirements:*

- Develop uniform flood inundation maps based on common standards and methods;
- Format mapping products consistently; and
- Scope products to meet stakeholder needs.

*Data Sharing Requirements:*

- Develop a common operating picture to create consistent maps and share data, models and maps;
- Enable online access to interactive maps;
- Ensure compliance with Open Geospatial Consortium (OGC) standards;
- Enable inundation maps to be downloaded and printed; and
- Provide access to complete project data, metadata and reports via download.

**Recommendations for the FIM Design Team**

The FIM Requirements Team recommends the FIM Design Team, at a minimum, address the following relatively low cost, high benefit activities:

- Finalize and adopt a set of common IWRSS FIM standards for published flood inundation maps that can be applied at all IWRSS agencies.
- Implement the FIM requirements related to the sharing of data across IWRSS agencies.
- Design an on-line IWRSS data registry and populate the database with a list of current/ongoing/planned inundation mapping projects and project development data to enhance interagency collaboration and inform IWRSS stakeholders of FIM activities.
- Define common scoping methods for IWRSS projects based upon recent collaboration with other federal and state agencies, River Basin Commissions and Compacts and the private sector to ensure more consistent and transparent procedures for generating maps.
- Develop a quality assurance/quality control (QA/QC) checklist to ensure properly scoped FIM projects follow common standards, employ common methods, and produce maps which are consistent in content and format.
- Develop common project documentation and reporting standards for IWRSS FIM projects to enable users to understand the content, methods, and assumptions.
- Consult a panel of stakeholders, at key evaluation periods, throughout the process of developing national flood inundation mapping services to make sure that the products remain relevant to the stakeholder group.



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# Section 1: Introduction

This report was commissioned by the Integrated Water Resources Sciences and Services (IWRSS) federal interagency consortium. IWRSS was established by a formal Memorandum of Understanding (MOU) signed by the National Weather Service (NWS), the U.S. Army Corps of Engineers (USACE) and the U.S. Geological Survey (USGS). A primary goal of the MOU is to leverage the expertise of the member agencies to develop mutual information services and modeling frameworks that enable the efficient and effective generation and provision of comprehensive water resources products and services, including flood inundation maps. In response to the demand for flood inundation maps, NWS, USACE and USGS have established a goal to work together to improve their mapping and communication capabilities and strategies.

As defined by the IWRSS partners, the Flood Inundation Mapping Requirements Team's (FIM-RT) purpose is to accomplish the following goals:

1. Define the requirements and technical specifications for static and dynamic flood inundation mapping products and services.
2. Evaluate and propose a viable flood-mapping concept of operations that efficiently and effectively leverages each agency's assets to generate inundation products.
3. Evaluate and specify the general requirements for the mutual modeling and information services frameworks (or common operating picture) to support the flood inundation mapping concept of operations.

The three federal agencies' common understanding of requirements needed to meet the above stated goals is described within this document. This document provides the process necessary, under their current respective authorities, for NWS, USACE and USGS to move forward within a common operating framework to develop, create and display flood inundation mapping services, and offers recommendations to the decision authority of IWRSS to send forward to a Flood Inundation Mapping Design Team (FIM-DT). A full list of FIM requirements are provided in Appendix A, but described in more detail within Sections 4 and 5.

## 1.1 Purpose and Scope

The purpose of this report is to specify requirements for the IWRSS National Flood Inundation Mapping Services. Within the report, requirements mutually agreed upon by FIM-RT are identified, and reasons for their inclusion in the collaborative process are provided. References are given for select requirements where more detail was deemed necessary by FIM-RT.

The scope of this document covers flood map standards, flood map specifications and a concept of operations for the production and viewing of the flood maps, including a common interagency operating picture. The document includes an evaluation of a viable flood-mapping concept of operations, and proposes one that efficiently and effectively leverages each agency's assets to generate inundation products, by characterizing the operational concepts required to support the flood maps. It evaluates and specifies the general requirements for an Information Services Framework (ISF), by describing the characteristics of the common operating picture required to support this concept. For this framework to be effective and the concept of operations to be cohesive, the document focuses on data sharing. The IWRSS System Interoperability and Data Synchronization Requirements Team (IDS-RT) is expected to address FIM requirements for data sharing.

This document describes the FIM users and stakeholders, and the document describes their interactions with the suite of flood inundation products. Based on the understanding of the user needs and use cases for flood fighting, this document provides specific requirements for the

hydraulic and elevation models, reach selection criteria, mapping and cartographic standards, quality assurance process and dissemination process for the suite of flood inundation maps and related information. The document includes recommendations for mapping quality assurances, controls and long-term map maintenance to ensure sustainable services for common flood inundation maps.

## **1.2 Background and Flood Inundation Mapping Benefits**

Flood inundation mapping can be a powerful tool for flood risk management. Real-time inundation maps based on USGS real-time streamgauge observations, NWS flood forecasts and USACE flood operations significantly enhance a community's flood warning and response system. Flood inundation maps applied during the planning process inform all parties of the risks and residual risks associated with the implementation of potential flood risk management alternatives. Event-based flood inundation maps can be delivered or generated on-demand and used when non-standard hydrologic situations require information not available from existing flood inundation maps.

The impacts of flooding would be even greater without the extensive flood risk management strategy in place in the United States which leverages the complimentary missions and routine collaborative efforts of USACE, USGS, NWS and the Federal Emergency Management Agency (FEMA). The strategy includes infrastructure such as dams and levees that provide flood protection. USACE alone has developed over 400 major lake and reservoir projects, constructed more than 8,500 miles of levees and dikes and developed hundreds of smaller local flood damage reduction projects ([USACE](#)).

The strategy also includes systems to predict flooding and to assess and manage risk. USGS maintains an extensive network of nearly 8,000 streamgages. Most of these streamgages provide real-time stage and streamflow data. NWS utilizes information from the USGS streamgauge network and USACE reservoir releases as inputs to generate forecasts of river levels and issue flood watches and warnings. This strategy also includes studies and plans supported by FEMA that use available federal resources to influence appropriate development in flood-prone areas and provide flood insurance to offset the economic consequences of flood damages. As a part of this strategy, FEMA administers the National Flood Insurance Program which, among other things, publishes digital flood insurance rate maps which are a form of flood inundation map. The IWRSS member agencies collaborating on this report are seeking a solution for integrating flood inundation mapping into existing flood warning systems thereby enhancing our nation's national flood risk management strategy.

## **1.3 Defining the Flood Inundation Map**

A flood inundation map informs the public of their flood risk by increasing public awareness of flood-prone areas, and providing the public with an enhanced situational awareness during flood warnings. Maps associated with a forecasted flood stage are more readily understandable by the public and emergency managers than present warning systems that only provide text-based river stage forecasts. Direct communication with, and surveying of, water resources decision makers over the past several years has revealed that the provision of text and/or observed/forecast hydrographs do not adequately convey the flood threat (NWS, 2004, 2008, 2013). There is a significant and increasing demand for flood inundation maps that are coupled to hydrograph forecasts. Flood inundation maps allow authorities to more efficiently and effectively provide emergency services and flood fighting resources by tailoring general response plans to the specific circumstances of the impending or existing flood.

Flood inundation maps displaying estimated flood extents and depth of floodwaters should be communicated to floodplain managers, emergency management, and the public to enable more informed decision making. The displayed flood extent should be based on the best-available knowledge of hydrologic conditions. A flood inundation map can be created by any agency or stakeholder to inform and communicate the flood risk and can be made available through IWRSS after being certified as meeting technical standards and passing adequate peer review. As defined by FIM-RT, the map should take one of three forms: (1) stream reach map, (2) event-based map or (3) historical flood documentation map. Each type of map has a specific purpose in mind and meets a specific need. The map library and the map types are defined as follows:

**Map Library.** A map library is a collection of electronic maps developed based on the same source data, modeling parameters, and common methods for an intended purpose. The flood inundation map types defined below should all be deployed as map libraries within the National Flood Inundation Mapping Services.

**Stream Reach Map.** A stream reach map contains a set of predetermined inundation boundary maps for a particular stream reach. The extent and depth of flood inundation is based on known, generally stable, channel geometry and land features. The maps are typically created at one-foot to two-foot stage intervals in the vicinity of a streamgage. These types of maps are sometimes labeled as “static maps.” The stream reach map limits the user to evaluate of a set of predetermined conditions at specific river locations, with an assumption that the duration of the flood event is significantly long, such that a steady-flow condition may be assumed. Non-steady flow conditions are generally not captured in a stream reach map. Geographically extending the inundation maps from a stream reach map upstream or downstream of the modeled reach is not recommended due to the non-linear response of river stage to flow.

**Event-Based Map.** An event-based map is a map connected to a specified set of real or anticipated hydraulic and/or land-feature boundary conditions. A map library of event-based maps must inform the user of the expected inundation based on current and/or forecasted hydrologic conditions for a selected location over a determined length of time covering the onset of flooding, flood crest and flood cessation. These maps are generally not applicable after the end of the modeled time period and at the cessation of the modeled hydrologic conditions. These types of maps are sometimes labeled as “dynamic maps.” For most flood events, it may be necessary to evaluate existing stream reach flood map libraries to identify the available map that most closely depicts the pending flood event and present that information as the “pending event map.” During critical flood fight situations it is in the interest of all IWRSS member agencies and all Flood Inundation Mapping (FIM) stakeholders that a single authoritative event-based map be provided.

Event-based maps are most useful when hydrologic events occur in a specific location with conditions that are not adequately represented by existing stream reach maps and render them less useful for those specific instances. In these cases, event-based flood inundation maps can more accurately depict the extent, timing and depth of flooding and provide additional benefits for the unique flood event. When there is a need to estimate the flood inundation and its timing during more complicated flooding events to account for phenomena such as extensive backwater flooding, flood routing, drawdown hydraulics, control structure degradation, hysteresis, tidal impacts and sediment transport, an event-based map would be generated to represent more current, forecast and operational hydrology, using a robust hydraulic model and a relevant digital elevation model.

**Historical Flood Documentation Map.** A historical flood documentation map shows the extent, and generally not depth, of peak flooding for a flood event as a record of flood inundation at a specific location and based on flood observations for a given flood event. This map type could also be modeled or derived from high water marks, satellite imagery or other in situ or remotely sensed data. It is a depiction of the actual extent of flooding, acts as a record for historical and planning purposes and can be used for inundation map calibration purposes.

In the absence of a stream reach map or an event-based map, a historical flood documentation map may be the best available map for emergency support purposes.

## 1.4 Conceptual Framework and Capabilities

The ability for the end user to visualize the impacts of flooding with respect to the extent and depth of floodwaters is imperative to identifying flood mitigation measures before, during and after a flood. To that end, this document proposes a common interagency operating picture which enables the user to clearly and consistently identify flood prone areas in reference to commonly available background layers. With an understanding of the diversity of end users of inundation maps, namely federal, state and local government authorities as well as the public, this document proposes mapping standards and recommend guidelines to support this conceptual framework.

**Concept of Operations.** A viable flood-mapping concept of operations should efficiently and effectively leverage each agency's assets to generate inundation products. Each federal agency has separate complementary goals and missions. The analysis performed at the working level often results in knowledge and products from which other agencies would derive great benefit if they were incorporated into the framework. This document specifies the general requirements for mutual modeling and information services frameworks to support the flood inundation mapping concept of operations.

**Mutual Framework.** A mutual modeling and information services framework provides the system capabilities to capture inputs, provide outputs, facilitate data sharing and support seamless flood inundation map production and display across agency boundaries. The framework should be able to support the inputs and outputs of an integrative, reproducible, scalable approach for one, two and three-dimensional hydraulic modeling for flood mapping. When integrated across agencies, these capabilities provide an environment where they can share data and pass parameters, allowing for model integration and if necessary, seamless production of flood inundation maps. A mutual modeling framework also could allow a corresponding update of inundation maps.

**Data Sharing in a Mutual Framework.** Collaboration and sharing of data among data providers and users enables efficient and effective generation and provision of comprehensive water resources products and services, including flood inundation maps. Information necessary for describing a river system is collected, stored, and distributed through various methods by multiple agencies. Hydrologic, reservoir and hydraulic models and recently available stage data are necessary for the forecast of river flows. Archived, current and forecasted data such as precipitation amount and intensity, air temperature, reservoir releases, streamflows and river stages would be made available through the framework as specified by IWRSS IDS-RT. The most recent data could be used in hydraulic models for developing event-based maps when needed.

**Expanded Capabilities.** This document calls for a broader approach to flood mapping, inclusion of various flood mapping products, and expanded capabilities to provide the best

available map for the given conditions. This requirements document identifies the key capabilities of an integrated and expanded flood inundation mapping concept of operations based on the science and services employed by NWS, USACE and USGS in the communication of flood risk, an interagency coordination of flood response, and the vision for a common operating picture for FIM users and stakeholders. As the use of flood inundation maps expands, so too will the need for FIM training to ensure there is correct understanding, interpretation and application of FIM products.

## **1.5 Conditions and Constraints**

The development of a National Flood Inundation Mapping Services concept by the FIM-RT is constrained by five conditions: (1) the initial conditions and scope outlined by the charter for the National FIM-RT, (2) the FIM-RT's translation of the goals and objectives specified in the charter into actionable requirements for IWRSS FIM-DT, (3) the level of participation by the federal agencies in implementing the requirements, (4) the agency resources available to implement the solution and (5) technical dependencies of work completed by related IWRSS teams.

## **1.6 Assumptions and Dependencies**

To the extent possible, the underlying assumptions of flood inundation mapping requirements are described, referenced, and listed in this requirements document. For planning purposes and requirements gathering, the assumptions for developing common flood inundation maps, products, and services were made based on the experiences of FIM-RT, advice from subject matter experts, guidance from agency points of contact and the comments from each respective agency's advisory team to this effort, as they relate to the scope and charge explained in the charter for FIM-RT.

Key dependencies related to stakeholders, member agencies, data, and the system were identified with three major dependent assumptions: (1) the FIM-RT assumes the agencies will contribute human capital resources and funding to design, develop and maintain the mutual mapping system; (2) sufficient data are available for flood-inundation mapping purposes and (3) that the mutual modeling and information services framework will serve as the flood inundation mapping system which, if properly designed, fully implemented, and continually maintained, will assimilate, process, generate, store, and provide flood-inundation maps and share data for their development and maintenance.

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## Section 2: Stakeholders

This section describes the stakeholders for the National Flood Inundation Mapping Services (NFIMS), summarizes stakeholder needs, and proposes a stakeholder involvement process.

### 2.1 Stakeholders

The primary stakeholders for NFIMS are local, state and federal agencies, and private organizations and individuals directly involved in flood-fighting efforts throughout the flood risk management lifecycle. Flood-fighting efforts are defined as the flood preparedness, flood-planning and mitigation activities that reduce the impacts of a flood event. The requirements for NFIMS described within this report are intended to meet the needs of the identified primary stakeholders including:

- **The Public:** respond to warnings, participate in flood fighting activities, heed evacuation orders and take action to protect life and property and commercial interests near rivers.
- **Emergency Managers:** plan and coordinate flood fighting efforts at the federal, state and local level.
- **First Responders:** conduct local evacuations, rescues and save lives and property at the federal, state and local level.
- **State and Local Government:** state and county level officials are responsible for flood fighting, evacuation, infrastructure protection and financial support for recovery.
- **Media:** communicate and reinforce the warning information to the public at the local, regional or national level.
- **Floodplain Managers:** conduct planning, mitigation and preparedness.
- **Public Infrastructure Managers:** maintain critical local public infrastructure such as water, sewer, natural gas, communications and electrical grids. Public Infrastructure Managers may represent public or private sector organizations.
- **Levee Infrastructure Managers:** maintain flood defenses at the federal, state or local level.
- **Dam Infrastructure Managers:** operate dam and other water management systems, to reduce flood impacts at the federal, state or local level.
- **Navigators:** Make operational and mitigation decisions to reduce economic impacts to industry and increase safety awareness.
- **IWRSS Partner Agencies:** support flood fighting by collectively evaluating flood risk, monitoring, forecasting and responding to flood events at all phases of the flood risk management life-cycle.

Although NFIMS is intended to meet the direct needs of primary stakeholders, a secondary stakeholder group also may benefit. This secondary stakeholder group may include parties interested in socioeconomic impacts, agricultural impacts, low water impacts, environmental response, ecological recovery and environmental cleanup.

## 2.2 Stakeholder Needs

The common attributes of NFIMS are core features that must be developed for all NFIMS products and services. These features have been expressed by various FIM users and stakeholders as recorded during stakeholder engagements, conducted outreach events, in programmatic assessment reports. Some of the documents, which have provided specific FIM requirements or recommendations, include:

- *Integrated Water Resources Science and Service Hudson River Basin Stakeholder Report June 27, 2013*
- *Integrated Water Resources Science and Service Susquehanna River Basin Commission Stakeholder Report February 28, 2013*
- *Integrated Water Resources Science and Service Potomac River Basin Stakeholder Report, February 6, 2013*
- *Integrated Water Resources Science and Service Science and Services Delaware River Basin Commission Stakeholder Report December 13, 2013*
- *Customer Satisfaction Survey for the NWS Hydrologic Services Program: 2004, 2006, 2008, 2011 with Optional Section on Hydrologic Services*
- *Aptima Report on Improving the Display of River and Flash Flood Predictions*
- *David Ford Report on Evaluation of NWS Flood Severity Categories and Use of Gage Station Flood History Information*
- *CFI Group Report on Probability Focus Groups*

Use case summaries were developed to facilitate the mapping of the stakeholders' requirements and aid in the overall development of this document. For further information, more-detailed use case descriptions are provided in Appendix B. Stakeholder needs were divided into four primary categories: (1) uniform mapping product needs; (2) custom mapping product needs; (3) multiple delivery format needs and (4) federal coordination needs. The following list is a generalized summary of stakeholder needs:

### *Uniform Mapping Product Needs:*

- Map libraries that display, at a minimum, flood extent and can be used to plan for a wide range of flooding events, from minor flood to flood events that are well above the flood of record.
- A single, coordinated and authoritative federal event-based map published for each major flood event, to ensure a consistent and informed flood response that provides:
  - A situational awareness view of flood event data, which aggregates the best available flood event-based map with a basemap, infrastructure layers, weather data, warning data and socioeconomic impacts to form a decision support tool.
  - A planning view of the data which aggregates all available flood mapping libraries, with a basemap and infrastructure layers.
- The ability to connect the flood forecast at streamgages to flood inundation mapping.
- The ability to visualize past historical events through flood inundation libraries. Access to and visualization of flood documentation studies and maps.
- A common public view of the flood map supporting data.

### *Custom Mapping Product Needs:*

- Flood depth products, with an estimate of the relative accuracy of flood depth data.
- The ability to visualize the spatial accuracy of the inundation map.
- Visualization and forecasting of flood impacts at bridges at three vertical thresholds:
  - Bridge approach is at risk of inundation or overtopped by floodwaters,
  - Bridge is at risk of overtopping by floodwaters,

- Bridge is overtopped by floodwaters. Bridge appropriately shown as inundated or not inundated within flood extent and depth layers when the information is available.
- The ability to visualize levee conditions, in a pre-event planning mode.
  - Methods to visualize levee overtop/breach impacts.
  - Methods to visualize levee freeboard and overtop status at selected river stages.
- The ability to visualize levee systems freeboard and overtop/breach risk, status and impacts during an event.

*Multiple Delivery Format Needs:*

- The ability to incorporate flood mapping data into stakeholder GIS systems with Open Geospatial Consortium (OGC) defined web services.
- The ability to download and print cartographic mapping products for offline use.
- The ability to download the data for use with GIS or other visualization systems.
- A data viewer accessible via mobile services and applications.
- Clear and consistent metadata documentation for all products.

*Federal Coordination Needs:*

- The ability to share flood inundation mapping classified as For Official Use Only (FOUO).
- A common operating picture for IWRSS stakeholders to coordinate flood planning and response.
- Tools to display the water forecast and impacts to levees, reservoirs and floodplains, incorporating the best available river observations, rating curves, future reservoir releases, current/predicted levee breaches, current/forecast precipitation and snow melt, tides and storm surge where appropriate.
- A common IWRSS partner view of the flood mapping data.
- A common framework for coordinating, sharing and disseminating flood mapping data.
- The ability to share and track versions of hydraulic models.
- Tools to calculate the potential population and infrastructure losses due to flooding.
- The ability to provide quick public access to levee breach and dam break Emergency Action Plan maps, when the structure failures are projected to be imminent and flood warnings must be issued.

## **2.3 Stakeholder Involvement**

A panel of stakeholders that represents a cross-section of individuals, agencies and organizations that have been identified as the primary stakeholders for NFIMS could be consulted at key evaluation periods throughout the process of developing NFIMS to make sure that the products remain relevant to the stakeholder group. Examples of key organizations known to FIM-RT that could be approached for stakeholder involvement are:

- International Association of Emergency Managers
- National Emergency Management Association
- Association of State Floodplain Managers
- National Hydrologic Warning Council
- Silver Jacket Flood Risk Management Groups
- National Association of Flood and Stormwater Management Agencies
- Association of State Dam Safety Officials
- International Commission on Large Dams
- NWS/USACE/USGS Fusion Team
- River Basin Commissions

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## **Section 3: IWRSS Partner Agency Missions and Internal Constraints for Flood Inundation Mapping**

A description of IWRSS agency missions in regards to flood inundation mapping and related tasks and any identified constraints to participating in a collaborative FIM effort are provided below in order to describe the varying procedures that may need to be coordinated or accommodated in a jointly operated IWRSS FIM system. Interagency guidelines need to consider and incorporate agency missions and, to the extent possible, all agency best-practices to develop a common flood inundation mapping service that serves each agency and all stakeholders in an efficient and cost-effective manner.

### **3.1 NOAA National Weather Service**

The NOAA National Weather Service is the designated federal agency mandated to forecast the Nation's rivers and provide warnings to communities, all in an effort to minimize flood impacts and save lives. Hydrologic forecasts and warnings are issued in the form of single-value river forecasts, 90-day probabilistic outlooks, short-term flood outlook, advisory, watch, warning products and static flood forecast inundation maps. NWS has undertaken an expanded effort to provide information on the spatial extent and depth of flood waters in the vicinity of NWS river forecast locations in the form of static flood forecast inundation maps.

The key NWS public product is the [Advanced Hydrologic Prediction Service](#) (AHPS). AHPS has a web-based flood forecast inundation mapping interface which allows users to display maps for various levels of flooding including observed and forecast stages, user-selected stages, and established flood categories. The development of flood forecast inundation maps involves significant financial resources, human capital, data requirements, and data analysis. NWS works with partners who can contribute financial resources and technical mapping expertise towards the development of flood forecast inundation maps for new areas. Offices at all levels of the NWS contribute to the process.

The AHPS flood forecast inundation map projects are constrained by the following issues: (1) availability of outside project funding, (2) identification of a technical mapping partner to develop the flood forecast inundation map project, (3) presence of or need for an AHPS flood forecast point at a proposed flood forecast inundation map location, (4) available topographic data and hydraulic modeling that meets NWS requirements, (5) NWS staff resource availability to participate in the project and (6) a location and reach of river suitable for static flood forecast inundation map development.

### **3.2 U.S. Geological Survey**

USGS develops flood-inundation map libraries through Water Science Centers (WSC) which are partly funded by the USGS Cooperative Water Program. WSC collaborates with local partners to choose the appropriate project reaches and develop the maps relevant to the community flood risk and needs. Typically, these projects are focused on a reach with a USGS streamgage that is used as a NWS flood forecast point. Real-time data are used to bring context to the map during a flood event. Each map produced has an accompanying USGS report (Scientific Investigations Map Series or Scientific Investigations Report Series) that details the model, base elevation data and methods used. Additionally, the map libraries can have other supporting information, such as Hazus flood loss reports for the reach at each flood stage and/or real-time webcams near the USGS streamgage to confirm flooding conditions. All of these tools are made available to the users together in the USGS Flood Inundation Mapper.

USGS flood-inundation map projects are constrained by the following issues: (1) projects are largely funded through the USGS Cooperative Water Program requiring that a local or state partner fund at least half of the expense of the project, (2) the presence and funding of a USGS streamgage for the map location, (3) available topographic data and hydraulic modeling that meets USGS requirements, (4) the delivery of a published USGS report to document the development and limitations of the map and (5) the availability of USGS staff to participate in the project.

### **3.3 U.S. Army Corps of Engineers**

USACE formulates projects, designs, builds, operates and maintains a diverse portfolio of flood risk management infrastructure throughout the United States consisting of dams and reservoirs, levees and channel improvement projects. The Corps Water Management System (CWMS) is used to support real-time operations of USACE flood risk management infrastructure, including development of flood inundation mapping. CWMS has been developed for the purpose of providing a single, integrated package of data management and near-term modeling tools to meet the needs of water control managers within USACE. Using an integrated suite of USACE Hydrologic Engineering Center (HEC) modeling applications, CWMS retrieves precipitation, river stage, gate settings and other data from field sensors and validates, transforms and stores those measurements in a database. The measurements are used for calibration and adjustment of hydrologic and hydraulic models to reflect current conditions. Once the models have been adjusted to reflect current hydro-meteorological conditions within a watershed, they can be executed to produce forecasts of hydrologic conditions, including flood inundation maps that will assist water managers in evaluating the effects of their operating decisions in the near future. Many USACE District Offices routinely produce flood inundation maps for internal use through CWMS via hydrologic and hydraulic modeling applications.

USACE works in close coordination with other federal, state and local agencies to ensure flood inundation mapping is available for emergency planning, response and mitigation activities. As part of the Dam Safety, Levee Safety and Critical Infrastructure Protection and Resilience Programs, the USACE develops flood inundation maps for a broad range of project scenarios, including overtop and breach scenarios. These maps are used within emergency action plans as well as to inform program investment priorities.

USACE standard policy is to mark flood inundation maps FOUO in accordance with Army regulations and manuals. Examples of stakeholders with which FOUO static (non-editable) information is routinely shared include federal agencies such as the Department of Homeland Security (DHS) and FEMA, adjacent and potentially impacted dam and levee owners, and state and local authorities who provide emergency services and/or notification. USACE intent is to assist local authorities in their mission of protecting public health, safety and welfare, while limiting the extent to which information could be used to threaten a project's security. Supporting (editable) data is only provided upon request and only through close coordination to assure appropriate use within model constraints.

USACE may release non-editable (static) inundation map data to the public when deemed necessary for public safety in extreme events, provided that all FOUO information is removed. During an emergency such as a flood or potential flood event, modeling is done in partnership with NWS by district offices or the Modeling, Mapping & Consequences Production Center (MMC) to support real time flood fighting efforts. USACE Divisions have the authority to release data developed to support real time flood inundation mapping to the public in support of flood fighting activities as well as making the public aware of potential consequences. Divisions may delegate the authority to their district offices. If the flooding event is of national significance,

USACE Headquarters may host the flood inundation data as a web service to the public to communicate the extent of flooding condition.

USACE flood-inundation map projects are constrained by the following issues: (1) availability of funding, (2) restrictions on authority and (3) restrictions on distribution of event-based products.

### **3.4 Key Findings and Benefits of IWRSS FIM**

The review of existing agency approaches to and constraints on developing agency specific flood inundation mapping services and the collaborative effort by FIM-RT produced the following key findings:

- All three agencies are actively developing valuable flood inundation maps for various purposes including project planning, emergency planning, emergency response and flood risk management.
- All three agencies have different approaches for scoping collaborative projects and for producing flood inundation maps.
- Each agency has limited understanding of the approaches used by the others.
- Most important, flood inundation map stakeholders and the public would benefit from the agencies adopting a consistent, common federal approach to flood inundation map, content, format, and dissemination.

The benefits of a more common federal approach to FIM are numerous and include the following key benefits:

- Cost efficiencies may result from sharing procedures, tools and possibly systems.
- Quality improvements may result from improved sharing of streamgage, stage forecast, reservoir regulation and other information and data already developed by the partner agencies and necessary to produce accurate flood forecast inundation maps.
- Improved accessibility and understanding of flood inundation maps within stakeholder communities and the public will enhance flood risk communications and awareness.

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## Section 4: Concept of Operations and Common Operating Picture Requirements

This section presents requirements to be considered during development of a concept of operations for flood inundation map data sharing and collaborative map production, as well as the common operating picture used to access these products. Four items are central to the goal of a shared concept of operations and common operating picture.

The first item is an **Information Services Framework** that, once designed and deployed, would meet all data format and content requirements defined in Section 5. This is a technical element of the solution that ensures all access to common data that meet uniform standards and specifications.

The second item is a searchable **data registry** deployed through ISF. The data registry solution could range from a comprehensive list of flood inundation mapping projects, to a complex centralized database housing the compiled map libraries of all member agencies. The final solution will be determined through the tradeoffs between defined needs and fiscal constraints.

The third item is a **common operating picture** produced from the content of ISF. The common operating picture could take the form of an application or applications designed to present inundation maps to a shared general guideline within all IWRSS member agencies regardless of who produced the data and provided it through ISF.

The fourth item is a **coordinated plan** for directing the design, development, deployment, quality assurance and change management processes and procedures necessary to fully realize ISF, the data registry and the common operating picture.

### 4.1 Current Operations

Current operations place constraints on solutions and present opportunities for quick successes. The context of how each member agency currently produces inundation maps must be understood to derive a viable concept of operations. The following summarizes current operations and recommended agency actions toward realizing national flood inundation mapping services. Further details are provided in Appendix C.

#### 4.1.1 NOAA NWS

NOAA NWS provides weather, hydrologic and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the purpose of protection of life and property. NWS processes require hydrologists to determine the spatial extent of flooding. IWRSS flood mapping products will enhance current NWS forecast and warning processes by providing additional sources of information that can be used to guide the spatial definition of outlook, advisory, watch and warning polygons. IWRSS flood inundation event-based maps, and derived products, will better guide the NWS in the process of issuing a more area-specific, event-driven and impact relevant warnings for targeted reaches of river.

NWS should continue to partner with state, local, and private sector agencies to develop stream reach flood inundation maps, but the revised process would align with IWRSS requirements and recommended standards. NWS could consider expanding operations to include operational production of event-based map products, leveraging existing models where possible.

Existing NWS warning products would be further enhanced by embedding known current and forecast conditions for levee systems and flood-control reservoirs within the NWS forecasts, including XML and RSS feeds. This process is dependent on other agencies communicating levee breach/overtop status. Tools should be developed that allow USACE and NWS to better coordinate the release of flow from reservoir systems and to communicate levee status.

Standard NWS flood impact statements could be spatially referenced to points. This would enable any AHPS data point or forecast point to be tagged for spatial flood impacts, and would not require the development of a flood inundation map. Bridge impacts could be addressed within this concept.

#### **4.1.2 USGS**

One of the primary missions of the USGS Water Mission Area is to collect stage and streamflow information from the streams and rivers of the United States and deliver those data to stakeholders. When stream and river levels rise to or exceed flood-action stages, real-time streamgauge data and NWS river forecasts are linked to available flood inundation map libraries to communicate areal extent of flood risk. USGS also develops rating curves for streamgages. During flood operations, USGS makes additional stream measurements and provides information to the public and other federal agencies

Most of the USGS activities that have produced flood inundation maps are cooperative projects with local partners, conducted within the USGS Cooperative Water Program ([U.S. Geological Survey Cooperative Water Program](#)). This program is designed to bring local water science needs and the need for decision-making tools together with USGS national capabilities, and other USGS resources. All projects adhere to USGS Fundamental Science Practices (FSP) ([U.S. Geological Survey Fundamental Science Practices](#)).

USGS will continue supporting the development and use of flood inundation maps by delivering the necessary hydrologic data and through cooperative projects developed by USGS Water Science Centers with support from the national Cooperative Water Program. These projects will be designed with a dual purpose of supporting local community needs and enhancing the nation's flood inundation mapping science capabilities by tackling complex modeling or data-display issues, documenting the results and making the results publicly available.

USGS will continue to advance flood inundation mapping science by testing new methods, models and geographic areas. The Cooperative Water Program projects will continue to be the center of the FIM Program and will keep the projects focused on local stakeholder needs. Additional research areas will include expanding the loss estimation model connections and ensuring they are documented and interpreted appropriately, and developing and documenting less resource intensive methods to deliver lower-level FIM products. Report capabilities and map printing tools will be refined to deliver better project documentation for lower costs to the projects. The USGS Flood Inundation Mapper will be enhanced to meet these advances.

#### **4.1.3 USACE**

The USACE missions that either provide information to support production or directly produce or consume flood inundation maps include water management, dam safety, levee safety, critical infrastructure protection, contingency operations (flood fights), planning studies, ecosystem restoration projects, habitat evaluation projects, hydraulic design studies, flood damage reduction studies, and navigation studies. USACE will continue to develop flood inundation

maps as necessary to achieve its missions. Flood inundation map dissemination is governed by Engineer Circular 1165-2-215 or future documents that supersede it.

USACE supports collaborative flood inundation mapping projects through cooperative and reimbursable projects. One example is the Silver Jackets program. Project scopes should be designed to meet the IWRSS requirements for national flood inundation maps through coordination with project cooperators, when appropriate.

USACE is developing tools, processes and procedures for real-time dynamic modeling and mapping during flood events and shares with NWS the vision of contributing such products to enhance existing forecasting and emergency warning systems.

USACE could align existing missions with the IWRSS flood inundation mapping concept of operations. Examples include evaluating IWRSS and other federal inundation map guidance during five-year reviews of Corps inundation map standards; adjusting CWMS, CorpsMap and National Levee Database (NLD) systems to integrate with and provide USACE-generated information to NWS and/or IWRSS systems. An especially timely action would be to align the ongoing CWMS national implementation to consolidate and prepare flood inundation map information for data sharing and reporting to IWRSS FIM requirements. USACE could also consider incorporating some of the flood inundation map layer requirements from this report into the Hydrologic Engineering Center River Analysis System (HEC-RAS) software.

## 4.2 Information Services Framework Requirements

This section contains the general system requirements for the IWRSS Information Services Framework. Detailed product and service requirements for ISF are listed throughout Section 5. Requirements for data exchange through ISF have been shared with IWRSS IDS-RT and are documented in both Appendix D and the IDS-RT document. The FIM requirements for IDS-RT are not duplicated within this document.

- R1 — The map development and production data should be exchanged through a central information technology system, to be known as the **IWRSS Information Services Framework**. The completed mapping products and services would be hosted by ISF or via technologies meeting ISF standards.
- R2 — ISF should support all **interagency functions and processes** for the development, submission, review, publication, data dissemination and display of flood inundation mapping products.
- R3 — ISF-supported joint collaborative operations for flood inundation map production require the seamless integration of partner agency data collection activities, FIM production processes, and quality control activities to produce a suite of IWRSS FIM products and services.
- R4 — ISF should support a repeatable, modular and standardized approach to developing the mapping data products. This allows for flood inundation mapping tasks to be divided or shared by agencies and other stakeholders. During a flood event, one agency could develop the hydrologic and hydraulic models, a second agency could focus on data collection tasks, while a third agency could take on the task of map production from the model results.
- R5 — Flood mapping data products and the data supporting these products should be transmitted between agencies by registering a data product with ISF, making it available to all IWRSS agencies and ultimately to the public if tagged as appropriate

for public release. Registration of standardized, consistent and documented data would strengthen the modularity of the IWRSS data products, thereby enabling IWRSS partner agencies to quickly identify existing products, develop new products or refine existing products.

- R6 — ISF should provide access to FEMA **model database information** such as hydrologic and hydraulic models, study locations, cross-sections and water surface profile information. Coordination between FIM studies and Digital Flood Insurance Rate Map (DFIRM) RiskMap studies currently under development or planned would benefit the National Flood Inundation Mapping Services and FEMA, both technically and financially.
- R7 — Agency Information Technology (IT) systems that are included within ISF should meet the minimum requirements for interoperability. **System interoperability** between agency IT systems is a key requirement and the enabling technology necessary for the IWRSS joint collaborative operations.
- R8 — Minimum requirements for IT system interoperability should be established.
- R9 — Individual IWRSS agency IT system and security constraints should be considered as the ISF design is developed.

Further explanation of the purposes of ISF, including some conceptual joint IWRSS-supported workflows for flood inundation mapping are provided in Appendix E.

### 4.3 Governance Requirements

- R10 — A **multi-agency governance structure** would be necessary to oversee and manage implementation under a strategy to develop a single federal suite of inundation map services. **Functions would include** report formats; quality management (reviews), maintenance and revision of data, map and information technology standards; liaison with technical and subject matter experts within the member agencies; funding and staffing for design and development for ISF, data registry, applications and loss estimation among others.

Some of the functions listed above are described in more detail below. An example governance structure is included in Appendix E.

### 4.4 Quality Management and Peer Review Requirements

- R11 — Each FIM library should have a proponent agency identified.
- R12 — The IWRSS member proponent agency for FIM libraries would be responsible for certifying the quality of the product and for defining purpose and use restrictions. Certification by the proponent agency would indicate that the products had been reviewed per proponent agency policies and meet defined IWRSS quality and content standards.
- R13 — The quality management process will be applied to both internal products deemed FOUO and external public products.
- R14 — Internal FOUO products may be subject to different quality review standards than the standards that are applied to the external public products.
- R15 — The quality management process will be developed and applied independently to the three categories of flood inundation maps, which include: (1) stream reach maps, (2) event-based maps, (3) historical flood documentation maps.

- R16 — Product quality should be certified by the proponent agency on a standardized quality assurance/quality control (QA/QC) checklist. The QA/QC checklist should be applied to all FIM products to ensure that the final requirements are met.
- R17 — Time critical event-based maps will be certified by the proponent agency that the maps meet the existing IWRSS quality standards, and no additional peer review policy will be required.
- R18 — The completed QA/QC checklist should be posted within ISF as QA/QC documentation for every project.
- R19 — To encourage strong member agency collaboration and continual improvement of IWRSS processes it is recommended that a recurring multi-agency review be conducted for a subset of map libraries recently posted within ISF. The scope of annual reviews could be flexed to align with funding constraints and volume of new map libraries provided within the review period.
- R20 — A periodic examination of existing map libraries should be considered. Periodic reviews could be mandatory, for example at minimum every ten years. In addition, periodic reviews could be triggered by events such as requests of stakeholders, upon the acquisition of detailed verification data from major flood events, or as a result of known topographic, infrastructure or river channel changes as a result of anthropogenic or natural events.
- R21 — Results of periodic map reviews should be documented within ISF.
- R22 — Upon identification of a degraded mapping product, the map may be temporarily or permanently removed from public access or permanently deleted depending upon circumstances.
- R23 — ISF will communicate map changes to the public and the local stakeholders that may be initiated by periodic review findings. Notification of the map change could be through the display of a note highlighting the change within IWRSS services and applications. The local stakeholders should be notified directly and be part of the update process.
- R24 — In addition, each map library should record the dates of production and the most recent review and revision and this information should be published with FIM products.

An example review process is provided in Appendix E.

## 4.5 Common Operating Picture Requirements

Presently, the agencies' existing enterprise FIM solutions (consisting of decision support systems, models, data, products and services) largely operate independently of one another. **A common operating picture would enhance coordination, support map production and allow dissemination of flood risks and unified mapping products.** A common operating picture is important to ensure all IWRSS member agencies and stakeholders are viewing up to date and consistent flood inundation maps, which are especially important for forecast flood events. The interrelated IWRSS member agency critical missions coming together to support flood inundation mapping is depicted in Figure 4.1.

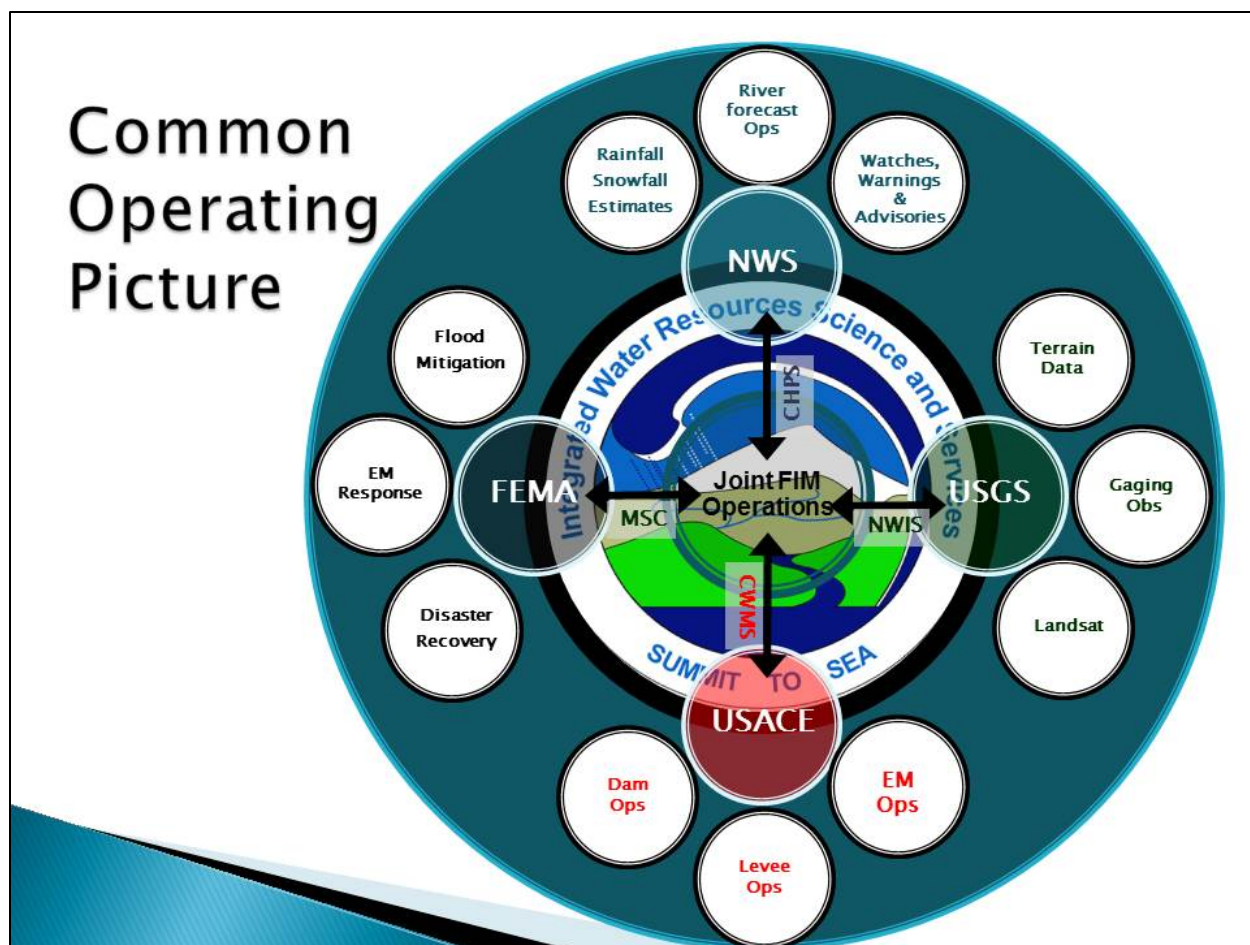


Figure 4.1. IWRSS Common Operating Picture.

- R25 — It is recommended that the common operating picture be deployed via products and services that draw on FIM libraries and the data registry published through ISF. This could be accomplished through the multiple product delivery formats described in Section 5.1.
- R26 — Regardless, the key to ensuring **common views of inundation maps** is the ability to reference map library unique identification numbers and inundation map unique identification numbers managed within the ISF, and to use a generally consistent presentation of map layers within all FIM applications and products. This would allow multiple applications to support viewing inundation maps via passing of common URL parameters for accessing information in the ISF.
- R27 — Low information display latency within the common operating picture should be a critical design criterion.
- R28 — To function effectively, the common operating picture should be coupled to an **information service framework data registry** that should include: (1) a data registry for the flood mapping products, (2) identification of the owner of each product, (3) the corresponding metadata and (4) the data location (to which the registry would direct the user). The data could be provided by the respective IWRSS agencies through OGC-compliant web services. Figure 4.2 displays a diagram of the interaction between the common operating picture and components of the information services framework

that include the data registry, the IWRSS agencies and individual agency data sources.

- R29 — In addition, the database could be considered for posting through the Federal Geoplatform on [data.gov](https://data.gov) to provide the IWRSS consortium and new stakeholders the ability to **discover FIM services and products**.

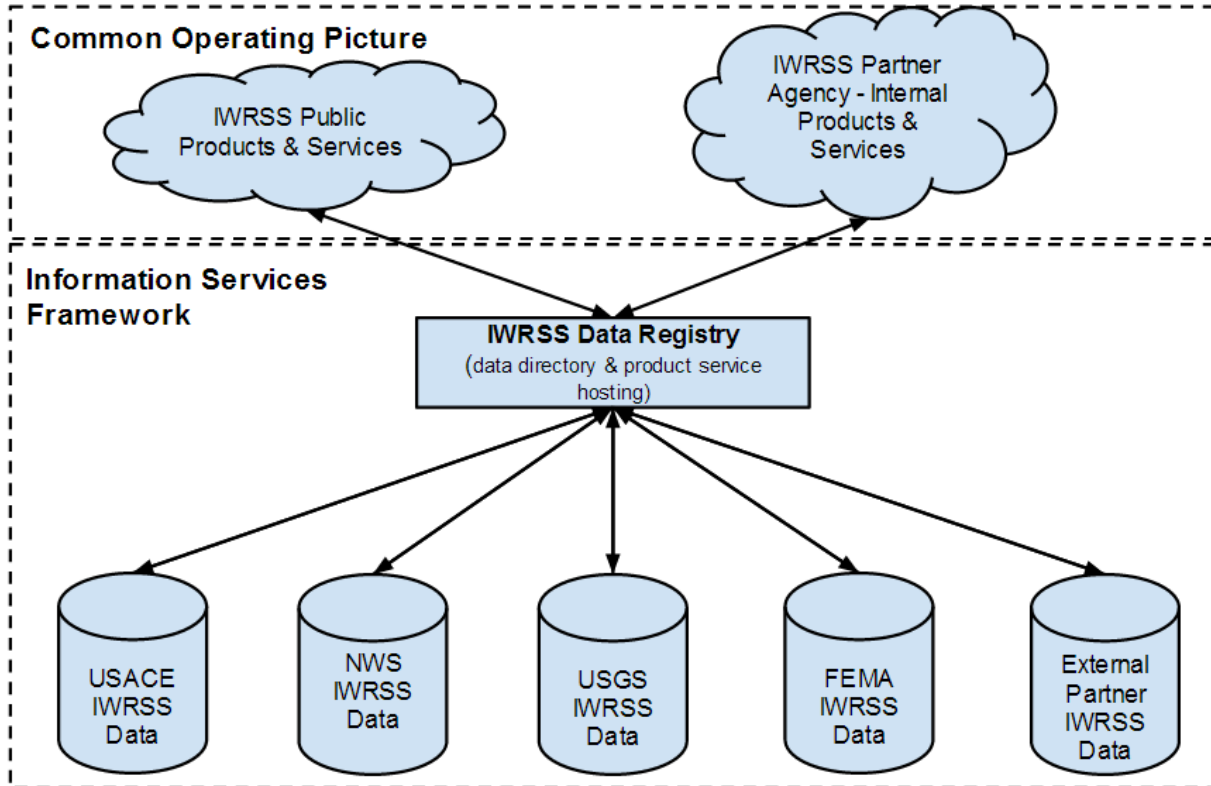


Figure 4.2. Relationship between the Common Operating Picture and Information Services Framework which contains the Data Registry and IWRSS data.

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## Section 5: National Flood Inundation Mapping Services Requirements, Standards, and Methods

This section presents the requirements for producing and sharing flood inundation maps leveraging common data formats, data attributes and map standards. Section 5.1 is an overview of the primary requirements for the three types of map libraries and four end products envisioned to be provided through the ISF, including: (1) OGC standard web services for maps and data features, (2) basic flood inundation web map applications, (3) electronic maps for download and (4) complete supporting data, metadata and reports for download. The later sections present additional requirements and recommendations for these end products as well as for processes that support their development. **The philosophy of common data formats, common data attributes and common general map standards drives these requirements.** These requirements are proposed as uniform standard to meet the needs of stakeholders for quality flood inundation maps, ultimately **to be made available within national watch and warning systems.**

### 5.1 Flood Inundation Map End Product Requirements

Development of online interactive maps, map services and feature services are recommended as a longer-term priority, due to: (1) their reliance on the ISF, (2) the more immediate importance of assuring commonality of data and map presentation and (3) the absence of a current multi-agency capability to host these products.

- R30 — ISF will host a collection of electronic map libraries, including: (1) stream reach maps, (2) event-based maps and (3) historical flood documentation maps.
- A **map library** is a collection of electronic maps which been developed with the same model, analyzed by the same methods, and generated with the same intended use.
  - A **stream reach map** contains a set of predetermined inundation boundary maps for a particular stream reach.
  - An **event-based map** is a map connected to a specified set of real or anticipated hydraulic and/or land-feature boundary conditions. It could be a map chosen out of an existing stream reach map library or a map generated specifically for the particular forecast, as available and appropriate for a flood event.
  - A **historical flood documentation map** shows the extent, and generally not depth, of peak flooding for a past flood event to record flood inundation at a location where a stream reach map is generally not available.
- R31 — All flood mapping data should be accessible either for official use only or to the public in **four common formats**: (1) OGC standard web services for maps and data features, (2) maps may be viewed interactively online through basic flood inundation web map applications, (3) electronic maps for download and (4) complete supporting data, metadata and reports for download.
- R32 — To the extent technically possible, **format and content** of flood inundation maps should be consistent across all end products. This provides consistency and continuity of information presentation that accelerates user understanding and reinforces that all products are produced through unified approaches and systems.

- R33 — All of the FIM end products should be categorized as **D 4.1 Disaster Monitoring and Prediction Information Type** from the National Institute of Standards and Technology Special Publication 800-600 for the purposes of infrastructure and security ([U.S. Department of Commerce NIST, 2008](#)). Security categories must be determined to satisfy the *Federal Information Security Management Act of 2002*.

Requirements defining the content of each of these end products are provided below.

### 5.1.1 Map and Data Services

- R34 — **OGC-compliant** spatial web map and web feature services (**web services**) should be provided that allow stakeholders to utilize flood inundation maps and data/layers in desktop and web applications. An example of a desktop application that may consume OGC Services is presented in Figure 5.1 below.
- R35 — The spatial web services should provide **access to all flood inundation map data**, segregating official use only data from public-accessible data.
- R36 — ISF spatial web map and web feature services should be made **discoverable** through the federal geoplatform on data.gov.
- R37 — Map services should present features using a **generally common map symbol standard**, such as the recommended symbology defined in Appendix F. The symbology specified works currently with commonly available imagery, road/street, and topographic services but was optimized for use with ESRI topography and street map services.

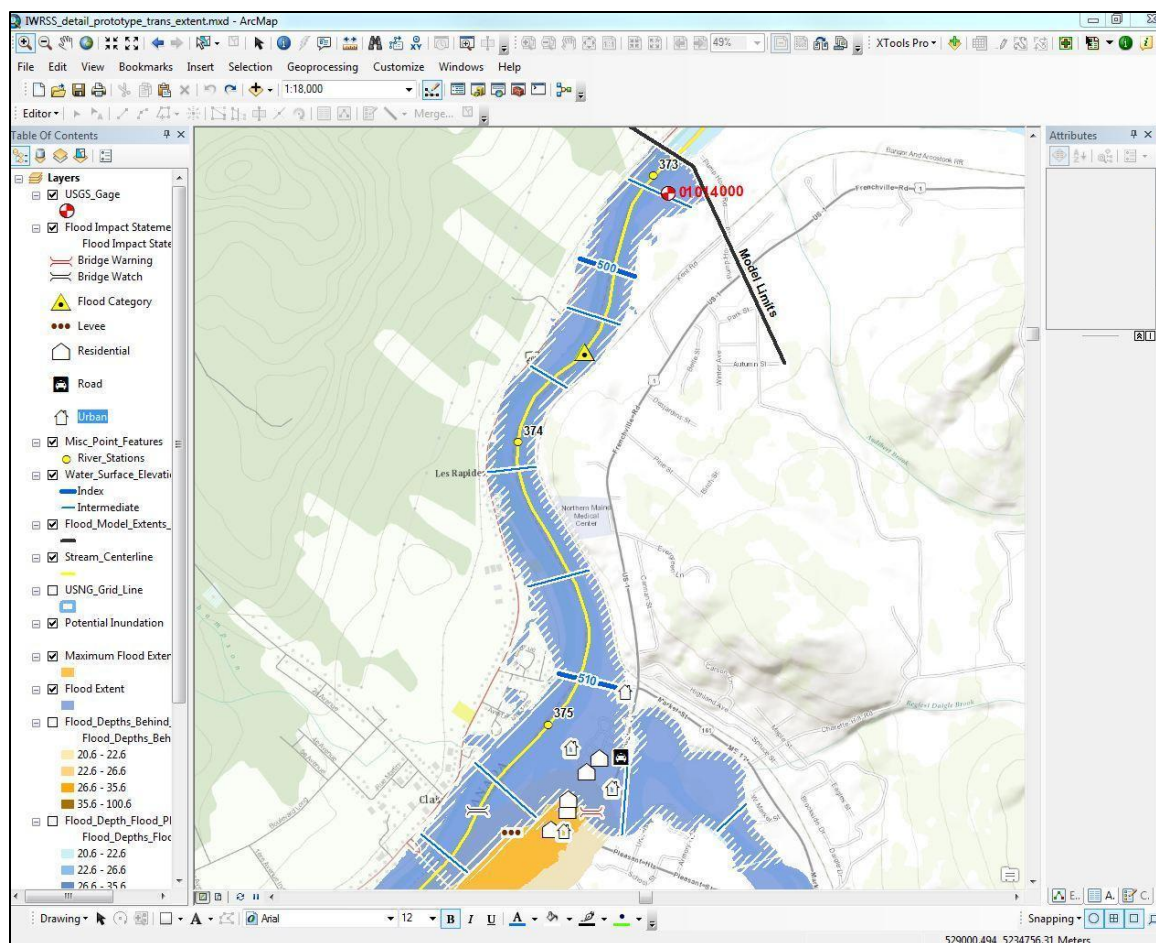


Figure 5.1. Use of National Flood Inundation Map Service in Desktop Software.

## 5.1.2 Web Map Viewer Applications

- R38 — A public FIM web map viewer application or applications should be maintained by the IWRSS members in order to provide access to the FIM maps and data.
- R39 — The FIM viewer(s) should function within **common desktop and mobile platforms**. The intent is to only provide basic tools that are geared towards an educated public user and provide a strong demonstration of the flood inundation map information available via the map and data services.
- R40 — The FIM viewer(s) should always **provide all of the available public maps** to users via an interface that allows selection of available map libraries (stream reach, event-based and historic flood documentation).

## 5.1.3 Inundation Maps

- R41 — Web services should provide the ability to extract static Portable Document Format (PDF)-formatted maps.

Two forms of **map printing/export** are required within applications:

- R42 — The first map printing function is the commonly implemented **ad hoc printing** approach of applying a user-specified title and system-generated legend and other ancillary map information combined with a rendering of the current map screen extent, allowing the user to customize which layers are shown.
- R43 — The second map printing function is intended to ensure production of a **cartographically-controlled official publication product** meeting the inundation map standards endorsed by IWRSS.
- R44 — The controlled map printing function should meet the specifications provided in this report for **map sheets**.
- R45 — More **flexibility of format and content** is allowable for the ad hoc map printing function, although the symbology guidelines should be adhered to in all end products. Figures 5.2 and 5.3 are example flood inundation maps produced according to the symbology guideline recommended in Appendix F.

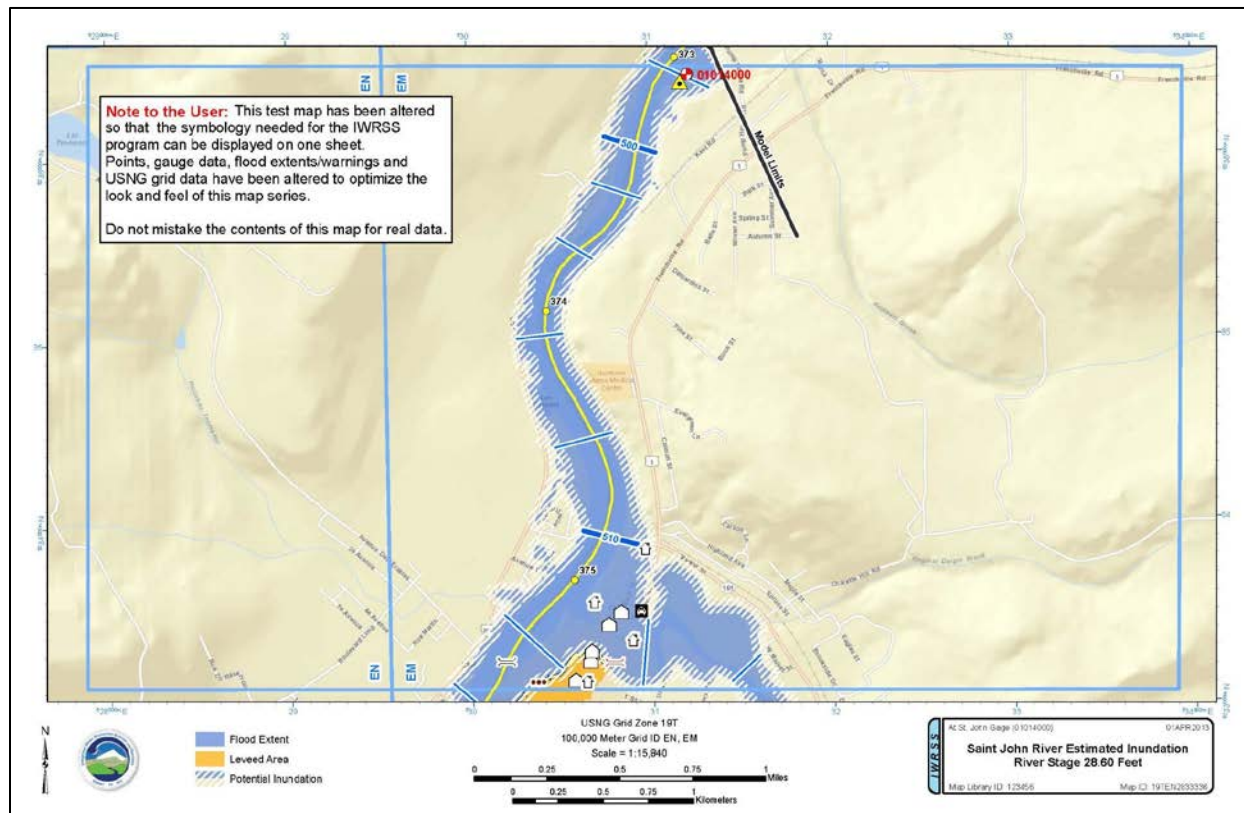
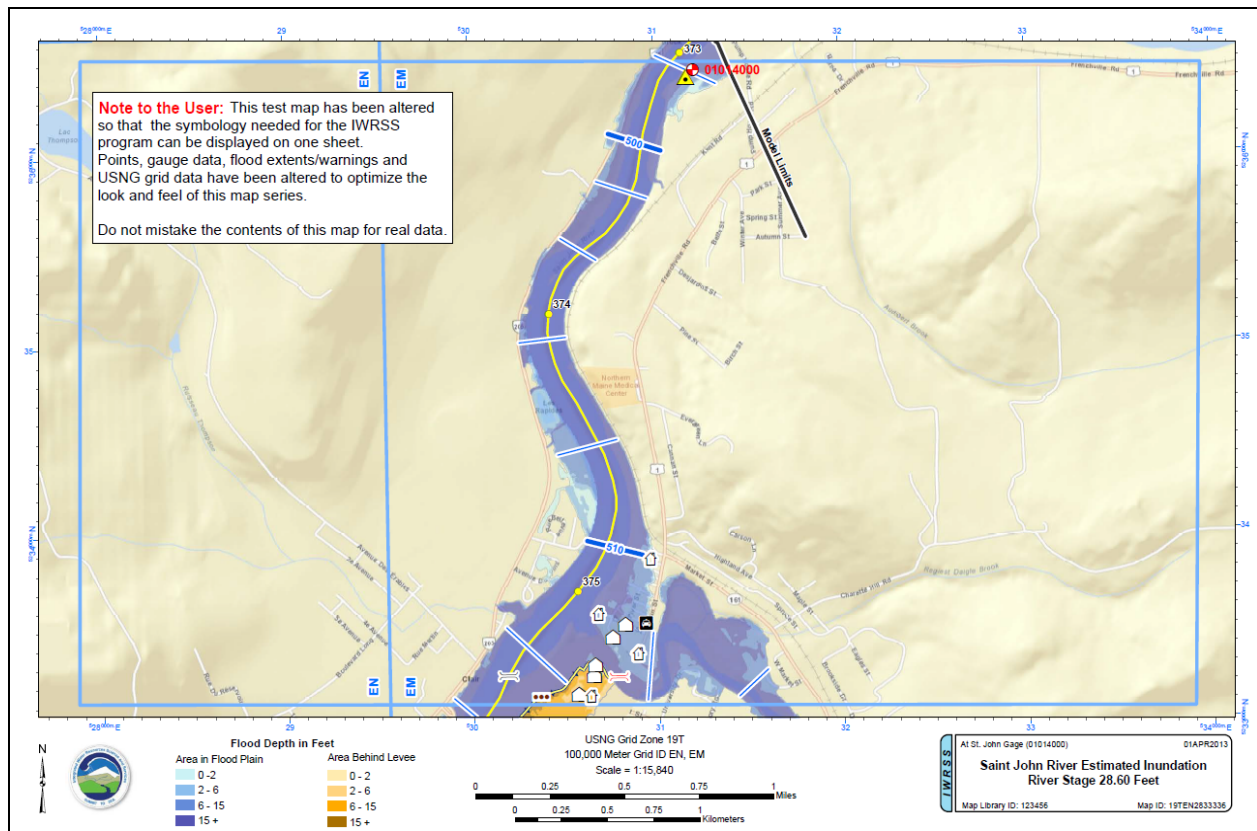


Figure 5.2. Flood Inundation Map Example, Flood Extent and Uncertainty Zone.



**Figure 5.3. Flood Inundation Map Example, Flood Depth.**

- R46 — The controlled map printing function should provide for reproducibility of maps and ensure **consistent presentation of printed FIM products**.
- R47 — The controlled map printing function should allow stakeholders to **request sets of maps** in PDF format covering a **user-defined extent** such as a municipal boundary at a **user-specified map scale**.
- R48 — The controlled map printing function should allow for **maps** to be requested **via simple URL requests** rather than via a graphical map interface, which can be used to meet Americans with Disabilities Act Section 508 compliance and provides for other systems and websites to post **links to specific IWRSS-published maps in PDF format**.

The following list of map layers, incorporated with national basemap services, is used to construct flood inundation maps. The most basic form of flood inundation map presents only the flood extent layer. Stakeholder needs for evacuation planning and consequence assessment, among others, would require depth information as well.

- R49 — **Flood extent and depth map layers** and the supporting depth grid model outputs are the most critical information needed for effective use of flood inundation maps.
- R50 — Inundation map layers defined in this report, other than extent and depth, are useful information and any implementation of national flood inundation mapping services should provide the ability to store and display all of them, although **most are not required**.



- R51 — Map layers are to be categorized as required, desired, optional or provided.
- **Required** layers must be used in all applications, with no exceptions.
  - **Desired** layers are optional, but should be strongly considered for implementation, because of their importance to the majority of FIM stakeholders.
  - **Optional** layers are not required and may be added as a custom feature.
  - **Provided** layers are a default layer provided by the ISF or a source from outside ISF.
- R52 — These **map layers**, defined below, should be **managed by ISF**: flood extent, study extents/limits of inundation model, flood depth, flood extent in leveed areas, potential inundation area, stream centerline, model cross-sections, river station/river mile, water surface elevation contours, U.S. National Grid (USNG) zones, USNG 100,000 meter grid ID.
- **Flood extent** *[required]* – A polygon defining the estimated extent of flooding. This polygon is the only required polygon layer for a valid flood inundation map. Within a stream reach map library the flood extent polygon should be tied to a discrete elevation at a streamgage or multiple streamgages. Flood extent polygons may be blocky in appearance or post-processed to provide a smoothed appearance that conforms to the contours of the adjoining terrain.
  - **Study extents/limits of inundation model** *[required]* – A line or polygon feature displayed in locations where it is necessary to delineate model limits to indicate that the likely flood extent has been truncated on the map.
  - **Flood depth** *[desired]* – A continuous (raster) dataset, symbolized as a series of areas or polygons depicting varying depths of flood waters. Flood depth layers should be available when appropriate as determined by model and elevation model accuracy standards. This layer also supports queries of flood depths at selected locations.
  - **Flood extent in leveed areas** *[optional]* – Also a flood extent polygon feature, but with altered symbology to indicate areas where flood risk is contingent upon the designed performance of a levee or levees.
  - **Potential inundation area** *[optional]* – A polygon depicting the area where modeled flood extent results are uncertain, i.e. area on either side of the modeled “best guess” flood extent boundary that may or may not be flooded. It can incorporate elements of forecast, model and terrain uncertainty as appropriate per the given mapped scenario.
  - **Stream centerline** *[optional]* – A measured line feature, used for labeling stream location on map products and supporting some query functions. Useful for quick map orientation in areas with long modeled reaches.
  - **Model cross-sections** *[optional]* – A line feature, used for identifying the locations where elevation transects were taken for hydraulic modeling and represent the study limits.
  - **River station/river mile** *[optional]* – Labels produced dynamically from the measured stream centerline.
  - **Water surface elevation contours** *[optional]* – A line feature representing uniform contours of the model calculated water surface; index contours are labeled.
  - **U.S. National Grid zones** *[provided]* – A polygon feature not shown in the map area but used to identify the USNG grid zone location for a map location. Information about the USNG is available at <http://www.fgdc.gov/usng>.
  - **USNG 100,000 meter grid ID** *[provided]* – A labeled polygon feature displaying boundaries between USNG 100,000 meter grids.

R53 — These **map layers**, defined below, should be **acquired from sources outside ISF**: levee centerlines, leveed area, active streamgages, flood forecast locations, base map layers, radar and other flood warning services, georeferenced flood impact statement points and flood warning polygon.

- **Levee centerlines** *[provided]* – A line feature, used for labeling levee location on map products and supporting some query functions. USACE NLD is the appropriate source for such data. It is a combination of the NLD levee centerline, floodwall and closure structure features.
- **Leveed area** *[provided]* – A polygon depicting the maximum areal extent behind a levee where flood risk is contingent upon levee performance. USACE NLD is the appropriate source for such data.
- **Active streamgages** *[provided]* – Streamgages operated by USGS and others where near real time continuous record data suitable for flood monitoring purposes are available. These data should be obtained from USGS National Water information System (NWIS) and other sources.
- **Flood forecast locations** *[provided]* – These locations are generally a subset of the active streamgages and co-located sites should be designated. These data should be obtained from NWS AHPS
- **Base map layers** *[provided]* – All base map layers should be obtained from common geospatial data vendors and not managed by the national flood inundation mapping services.
- **Radar and other flood warning services** *[provided]* – Meteorological and hydrological information related to flood monitoring and response activities (e.g. QPF, Watch/Warning polygons, and Flash Flood guidance). These data should be obtained from NWS web services.
- **Georeferenced flood impact statement points** *[provided]* – A point layer having supporting data that describes the types of impacts likely to be experienced at that location at selected river stages.
- **Flood warning polygon** *[provided]* – The area defining the extents of a flood warning issued by the National Weather Service. These data should be obtained from NWS web services.

#### 5.1.4 Data and Reports

R54 — Users should have the capability to **export** flood inundation **maps** and related **reports** as well as their **supporting data**, based on FOUO or public designation.

R55 — **Supporting data**, that should be available for download, **includes the hydraulic models** used to produce flood inundation maps and data layers managed by ISF.

R56 — The **complete project data**, including **layer metadata** and project report or project report metadata, should be made available for download through the services and applications.

R57 — **Basemap layers** and layers served from other sources should **not** be made **available for download**.

R58 — In addition to flood inundation maps, ISF should support the ability to **generate consistent FIM technical reports** available for electronic viewing and printing.

R59 — Reports should be made available for download through **all** services and applications, including via **URL hyperlink requests** that reference map library ID numbers.

R60 — Reports should also include a unique **IWRSS FIM report identification number** for citation and tracking purposes and based on information in ISF. An example summary report, presented as a flood inundation map information page is shown in Figure 5.4 and in Appendix F.

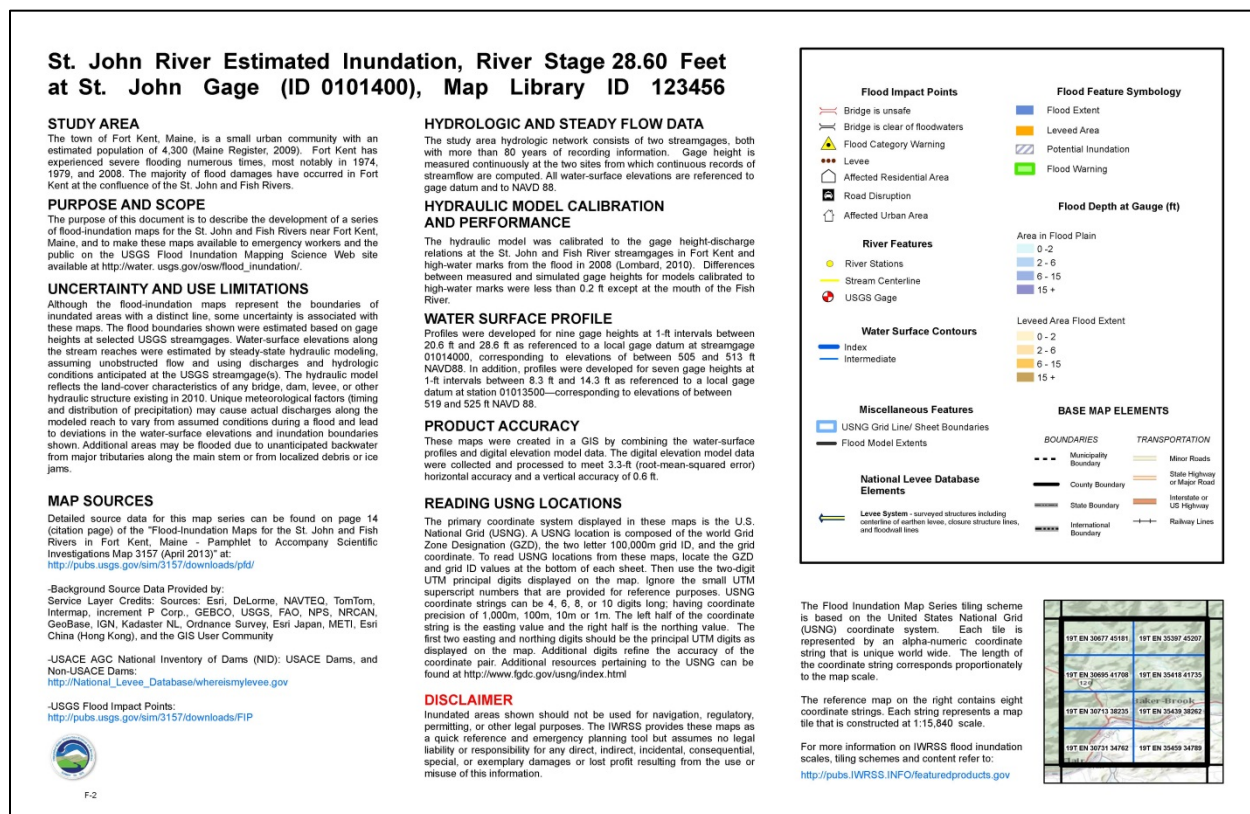


Figure 5.4. Flood Inundation Map Information Page.

R61 — The **map information page/summary report** should be a concise one page summary of a more detailed project report. Appendix F summarizes recommended project report content. The advantages of this strategy are:

- Removes the burden for any individual agency to incur the expense of writing and printing reports, but ensures that map and data purpose, use and disclaimers are prominent and consistently incorporated.
- All projects, by simply submitting their data and documentation to ISF and regardless of the originating entity, have the ability to easily make reports available that meet sound documentation standards.

R62 — Other types of **standard reports** could be made available for generation using ISF and may take the form of complete reports linked to agency publication repositories, short topical reports dealing with a specific technical area such as a hydraulic model description or GIS techniques, brief bulleted fact-sheets, and location-based topical reports, such as one describing flood inundation impacts for a landowner's particular area of interest or a description of loss estimation data and results for a selected community.



## 5.2 Collaborative FIM Project Scoping Requirements

- R63 — Recognizing local partner issues and needs are greatly varied, IWRSS partners should follow a **uniform scoping procedure** when undertaking projects that involved multi-agency, state and local or private sector collaboration. The intent is to ensure IWRSS requirements, standards and methods are adhered to, so that consistent and credible inundation maps are generated and broadly available through national services.
- R64 — Past, current and future flood inundation mapping **projects** should be registered within a **consolidated list** that could be made broadly available through the ISF data registry. This is to ensure that IWRSS member agencies and stakeholders are aware of existing, ongoing and planned projects. Documentation and tracking of existing, proposed and ongoing IWRSS FIM projects would promote efficient and effective planning and coordination of FIM product development. For example, with successful early communication two neighboring projects could be combined for a cost savings or new tools could be developed to display a unique flooding situation in time for the map release.
- R65 — The **listed project information** should include, but not be limited to, the spatial extent, the vertical height (stage) extent, the streamgauge or streamgages included, the technical team, the local stakeholders, the intended resolution of the maps, and any optional mapping features that will be developed.
- R66 — Collaborative project **scoping and project development tools** should be produced and made available to all IWRSS mapping partners. These tools could be delivered as printed or web-based documents and checklists designed to guide IWRSS mapping partners through the project development and scoping process and should describe agency specific coordination and data gathering activities. Examples of such documents include the [FIM Toolbox](#) (U.S. Geological Survey) and the [NOAA FIM Project Development Template](#) (NWS), and the [NOAA Partnered Guidelines](#) (NOAA).
- R67 — A uniform scoping procedure should encourage local stakeholder interaction and engagement in the map development process.
- R68 — Local stakeholder interactions and engagement should be documented in the QA/QC checklist.
- R69 — IWRSS mapping partners may choose to document the optional coordination tasks within the **optional checklists**.
- R70 — The optional **checklists may be submitted** with the project data, in order to expedite the review and approval process. Examples of such coordination and data gathering tasks include, but are not limited to, the following activities:
- Consult the United States Interagency Elevation Inventory for high-accuracy topographic and bathymetric data for the United States and its territories at <http://www.csc.noaa.gov/digitalcoast/tools/inventory> (NOAA, 2012).
  - Consult the local FEMA region on the availability of existing hydraulic models, elevation data, and recent, ongoing or future flood insurance studies.
  - Consult the local NWS hydrology program manager on the location of existing and planned AHPS flood forecast points, the location of existing and planned flood impact category statements, the relevance of the proposed study reach length to existing flood impacts, the relevance of the study vertical height (stage) limits to existing flood impacts, the acquisition and review of RFC operational rating curves, and the review of flood history at AHPS forecast points.
  - Consult the local USACE district public affairs office on the availability of Corps Water Management System within the basin, existing hydraulic models, availability

of terrain data, availability of bathymetric data, NLD data, levee construction as-built plans, future levee construction plans, future levee setback plans and future flood damage reduction plans.

- Consult local USGS water science center on the location of USGS streamgage stations, future plans for USGS streamgage relocation or installation, acquisition and interpretation of measured rating curves, availability of annual peak flow history, availability of lidar, terrain and bathymetry data, availability of existing hydraulic models, availability of flood documentation studies and the availability and quality of USGS streamgage station's vertical datum (NGVD29 or NAVD88) measurements.
- Consult local stakeholders on the scoping of the study reach length and stream stage range, availability of lidar data, availability of bathymetric data, flood history, flood impacts, existing and planned flood control systems, undocumented levee alignments, levee as-built plans, stormwater system maps, emergency action plans, future bridge and levee construction plans, locally documented high water marks, and documented stakeholder preferences for bridge impact modeling.

### 5.3 Hydraulic Modeling Requirements

- R71 — The **hydraulic modeling software** used for the analysis should be well documented, well established, and widely accepted in the hydraulic engineering community.
- R72 — The development of geometric data used in the hydraulic model, model version, geometric parameters selected, flow and boundary conditions used and modeling decisions should be well supported through **documentation** that is **submitted with the completed maps**. Further discussion of hydraulic modeling to support flood inundation mapping is provided in Appendix H.

### 5.4 Georeferenced Flood Impact Statement Requirements

- R73 — Georeferenced flood impact statements should be delivered through OGC compliant web services and maintained by NWS.
- R74 — Existing NWS flood impact statements should **include new fields** to allow for georeferencing and provide warning/response information to the public. This should help communicate flood impacts, infrastructure concerns such as highway bridges, and tie all the impacts to flood maps where available. Using this system to communicate flood impacts, bridges and levees can be represented differently at different stages. An example of general flood impacts for a community is shown on the Appendix F maps and in tabular format in Appendix I.
- R75 — Required **flood impact attributes** include: latitude/longitude (center of bridge, levee centerpoint, address of building, etc.), critical stage(s) and elevation(s), associated USGS/other streamgage, impact category tag (bridge, levee, road, etc.), flood impact statement (warning/response).
- R76 — Optional **flood impact attributes** include: Weather Forecast Office and River Forecast Center responsible (tracked, not displayed) and stakeholder agency contact (tracked, not displayed).
- R77 — The latitude/longitude information should represent the geographic center of the impact area.

Unlike flood inundation polygons, flood impact statement points can be viewed at relatively coarse scales. This solution would provide stakeholders with the ability to view more wide-area impacts, such as the passable or impassable status of all tracked bridges in a metropolitan

area. Similar needs exist for levees, where a community could relate levee concerns to river stage based on an estimated overtopping elevation and/or experience from past floods. The overtopping elevation would be related to the appropriate nearby streamgage. Lower river stages could be related to estimated levels of freeboard and assigned color codes for increased and critical surveillance.

## 5.5 Bridge Requirements

### Bridges in Flood Impact Statements

R78 — Georeferenced flood impact statements at **bridges** will be standardized for every bridge registered as an impact point. A three tiered system will be developed to illustrate that the bridge is clear of floodwaters, the bridge is at risk and the bridge is unsafe. Bridge impact statement examples are illustrated in Figure 5.5.

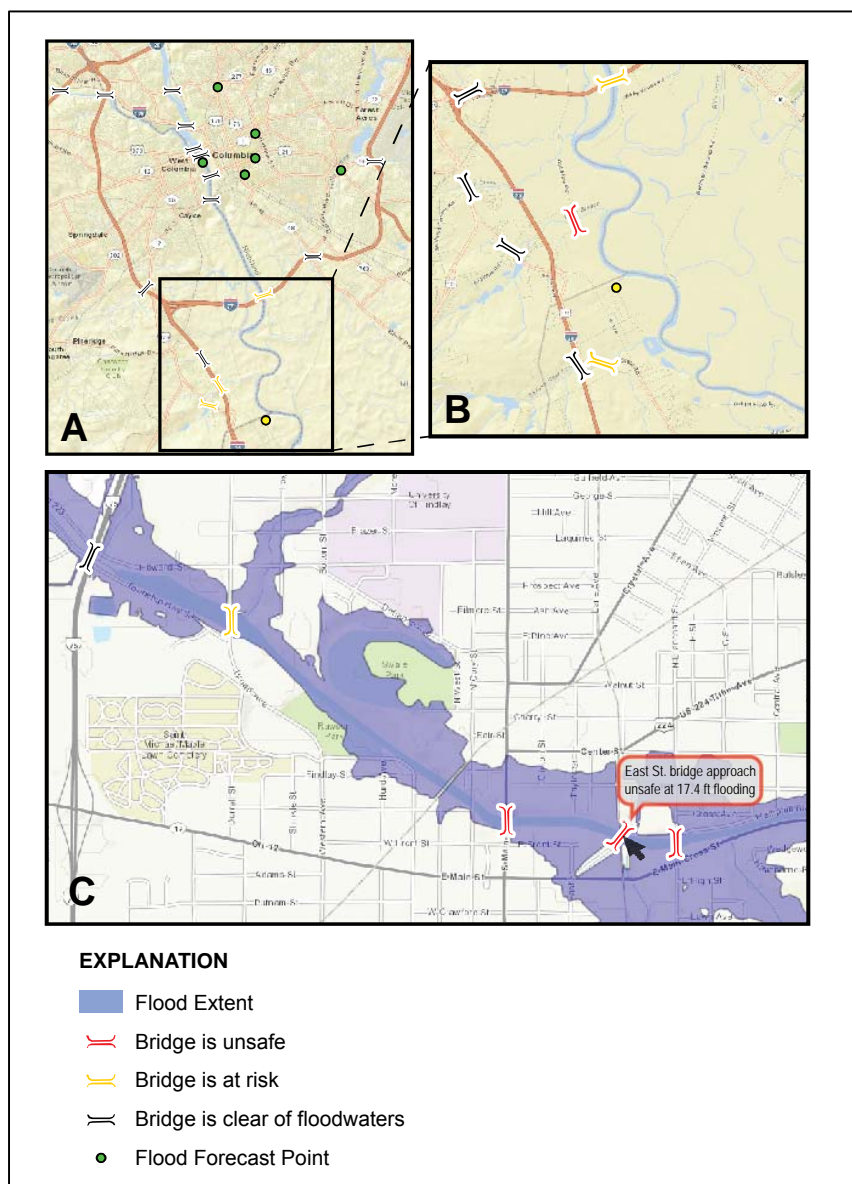


Figure 5.5. Example Depicting Georeferenced Flood Impact Statements At Bridges.

### Bridge Clipping Best Practice

Input received from stakeholders during past collaborative projects indicates the importance of identifying impacts to bridges during flooding.

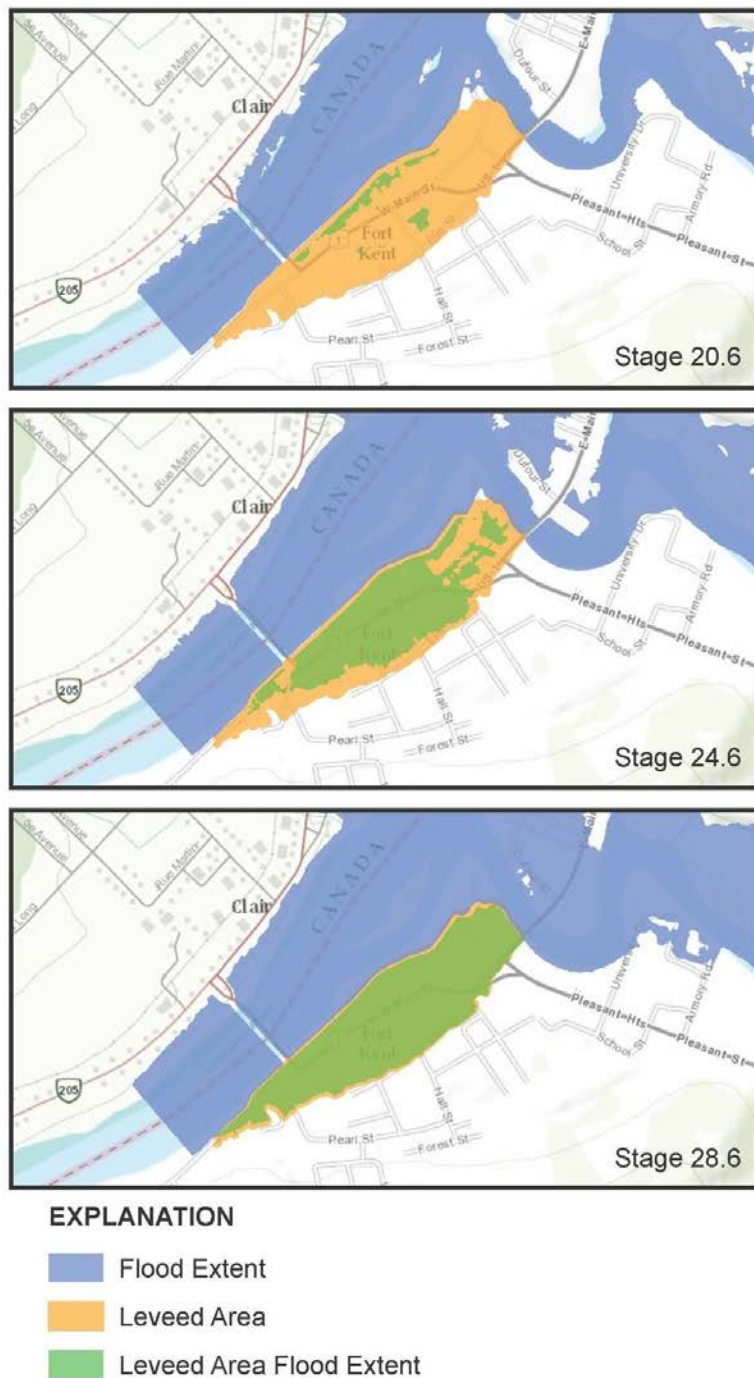
- R79 — When possible within the scope and constraints of a project it is suggested that in addition to populating bridge flood impact statement points as described in Section 5.4 **bridge decks should be clipped from the inundated area polygons and/or depth grids** once the hydraulic model indicates that water obstructs the opening beneath the low chord of the bridge. This step is necessary because elevation models typically do not incorporate bridge decking elevations or low-chord elevations. Rather, they depict the “bare earth” channel or surface elevation below the bridge.
- R80 — IWRSS mapping partners should describe the benefits of bridge clipping and recommend bridge clipping as a best practice to the local stakeholders as a part of the **uniform scoping procedure**.

## 5.6 Levee Requirements

- R81 — **Levee centerlines** should be available for display in online and map sheet products.
- R82 — The entire spectrum of **levee systems**, which may range from a federally constructed/maintained levee system to an agricultural levee system, accredited or non-accredited, certified or not certified **should be treated equally as hydraulic features**.
- R83 — **Levee centerlines** should be acquired and displayed from NLD and **should not be redundantly stored in ISF**. The NLD levee centerline to be displayed is an aggregate of the horizontal alignment of all levees, floodwalls, and closure structures throughout a study extent.
- R84 — If a levee within the FIM project scope does not exist in NLD, it is the responsibility of the project to **submit the necessary data to NLD** for proper display in FIM end products. Information on how to submit data to NLD is available from the NLD Help Desk, contact information is provided at [nld.usace.army.mil](mailto:nld.usace.army.mil).
- R85 — The NLD data submission process should be included within the uniform scoping procedure and documented in the QA/QC checklist.
- R86 — If a map distinguishes inundation in leveed areas from inundation in non-leveed-areas, the inundation polygons should be displayed in a separate layer as the potential **flood extent in leveed areas**.
- R87 — Care must be taken to ensure that for maps developed at stages above the effective elevation of the levee, areas behind levees are not shown as “flood extent in leveed areas” but rather as inundation in a non-leveed area.
- R88 — There should be three main layers that depict **flooding around levees**, as defined below: levee centerline, leveed area and leveed area flood extent.
  - **Levee Centerlines:** The horizontal alignment of all levees, floodwalls and closure structures throughout a study extent. If not already available in NLD, this layer should be submitted directly to NLD for display in the IWRSS FIM Map Viewer(s).
  - **Leveed Area:** The area on the landward side of a levee system (the interior area) that is flooded at the overtopping elevation. If not already available in NLD, this layer should be submitted directly to NLD for display in the IWRSS FIM Map Viewer(s).
  - **Leveed Area Flood Extent:** A polygon describing the potential extent of flooding on the landward side of a levee system (interior area). Each flood extent polygon,

within the leveed area, must contain a levee flood extent polygon for those elevations where inundation may occur on the landward side of the levee. These layers are not submitted to NLD and should be maintained as part of the individual map for display in the IWRSS FIM map viewer(s).

- R89 — Where available, **the leveed area flood extent** should show inundation conditions on the landward side of the levee (Figure 5.6). They can be controlled in a disconnected fashion from the reach map in a manner that allows individual leveed areas to be connected and adjusted in coordination with an event-based inundation simulation.
- R90 — The default setting for an event-based **map displaying levee information** should show no flooding behind the levee system unless the levee is confirmed overtopped or breached.
- R91 — Once flooding occurs, or is forecast to occur behind a levee (overtopping or breach), the landward **levee profile of a stream reach map library** should be activated and displayed according to the event forecast information.



**Figure 5.6. Leveed Area Flood Inundation Map Example.**

## 5.7 Data Requirements

The data requirements in this section expand upon the higher level data requirements defined in Section 5.1.

### 5.7.1 Elevation Data

- R92 — The **best available topographic data** referenced to the North American Vertical Datum of 1988 (**NAVD88**) should be used for the development of geometric data for hydraulic model inputs and the generation of flood inundation map products from hydraulic model results.
- R93 — Further, the **vertical accuracy** of the terrain model used for analysis should be appropriate for the intended use of the underlying river hydraulics model and the topography of the study area.
- R94 — The horizontal and vertical data accuracy of the elevation data should be **clearly documented** according to Federal Geographic Data Committee (FGDC) standards ([Federal Geographic Data Committee, 1998](#)).

Existing elevation data standards pertinent to flood inundation mapping include:

- National Standard for Spatial Data Accuracy (NSSDA), <http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3>
- USGS *lidar base specifications*, designed to meet FEMA flood insurance study standards, currently serve as the minimum standard for lidar collection ([Heidemann, 2012](#)).
- The 3D Elevation Program (3DEP) is an emerging program with defined quality standards, <http://nationalmap.gov/3DEP/>.

Recommendations for terrain model development considerations pertinent to modeling and flood inundation mapping are provided in Appendix H.

### 5.7.2 Projections and Datums

- R95 — All flood mapping products, models and reports should be submitted to the IWRSS FIM system according to a documented and **common measurement system, geodetic datum and projection**.
- R96 — All mapping products should use a **common vertical datum**, the North American Vertical Datum of 1988 (NAVD88).
- R97 — All mapping products should use a **common horizontal datum**, the North American Datum of 1983 (NAD83).
- R98 — All mapping projects should be submitted with a **defined projection** that is appropriate for the study. Albers Equal Area Conic USGS is recommended as a suitable model projection projects within the continental U.S.
- R99 — All flood inundation map **services hosted by ISF should use a common projection** for map data and mapping services; recommended is the World Geodetic System (WGS) 1984 Web Mercator (Auxiliary Sphere) projection.



### 5.7.3 Project Documentation and Metadata

- R100 — When a flood map is submitted to IWRSS ISF, a minimum standard for **project documentation** should be met as identified in Appendix G. Projects should be encouraged to submit as much documentation as necessary to conduct a proper peer review and ensure scientific reproducibility of the effort.
- R101 — All spatial data submitted should include FGDC compliant **metadata** in addition to the project documentation ([Federal Geographic Data Committee](#)).
- R102 — **Common ISF metadata elements** need to be standardized specific to IWRSS services, specifying required minimums for the data submission process.

### 5.7.4 Loss Estimation Reports

Estimating the potential socio-economic losses due to flooding is a logical extension of flood inundation mapping and has significant interest within the stakeholder community. The ability to provide tabular reports of estimated loss data associated with a selected flood inundation map further increases the map's utility and value to the user.

- R103 — If implemented within flood inundation mapping services the **supplied loss estimation data** should include estimates of population at risk, loss of life and structure and content damage (residential, commercial, industrial).
- R104 — Damage to agricultural areas and general indirect economic impacts to all locations may also be considered within loss estimates.
- R105 — It is suggested that these **broad loss estimation reporting categories** be defined to allow loss estimates to be reportable from several loss-estimation models, such as FEMA's Hazus software or USACE's Hydrologic Engineering Center Flood Impact Analysis (HEC-FIA) software.
- R106 — Regardless of the loss estimation method chosen, it must be **citable and reproducible** and the methods and tools used should be provided along with the results.
- R107 — If displayed on maps, consequences information should **only be displayed at aggregated (county, etc.) levels**.

### 5.7.5 Data Submission

The purpose of the data submission requirements is to ensure that the FIM study can be recreated from the data submitted to the system.

- R108 — When agencies and partners complete studies the **project data submissions** will need to include the following information in order for the **minimum ISF capabilities** to be available: digital elevation model location for review and/or retrieval, hydraulic model location for review and/or retrieval, location of cross-sections or mesh used to create the model for review and/or retrieval, inundation mapping layers required/optional per Section 5.1, documentation and metadata, optional loss estimation information, QA/QC checklist documentation and certification by agency proponent that product has been reviewed.



- R109 — When agencies and partners complete studies the **project data submissions** will need to include the following information in order for the **fully implemented ISF** capabilities to be available: digital elevation model, hydraulic model, cross-sections or mesh used to create model, inundation mapping layers required/optional per section 5.1, documentation and metadata, optional loss estimation information, QA/QC checklist documentation and certification by agency proponent that product has been reviewed.
- R110 — The **final data parameters** in ISF should be determined by a far-reaching survey of existing studies and cooperators to ensure a balance between completeness and usability.
- R111 — Further effort is needed to evaluate the full range of data that could be included to IWRSS ISF and develop a **comprehensive list of data elements**.
- R112 — Detailed requirements should be developed for populating pertinent **FGDC metadata tags**. These requirements may restate existing FGDC requirements for metadata tags or may introduce IWRSS specific requirements on how to populate specific elements of the metadata.
- R113 — A set of **detailed examples of completed metadata should be developed** for each database element and made available alongside the QA/QC checklist and other tools.

## 5.8 Map Requirements

The map requirements in this section expand upon the higher level map requirements defined in Section 5.1.

### 5.8.1 Basemap Layers

- R114 — Common vendor-provided **basemap services should be used** for exported maps and for applications. Some basemap layers must include **licensure** that allow for publication of maps to map sheet formats and printing for public distribution.
- R115 — The current scope of the IWRSS FIM system **does not include development or maintenance of a unique basemap** or of any map annotation beyond what is displayed on the basemaps. Stakeholders and customers needing these capabilities can utilize IWRSS FIM map services and other desktop or online systems to meet their specific needs for basemaps or additional feature labeling.
- R116 — The range of **basemaps** available should, at a minimum, include topographic, aerial/imagery and road/street map services.

### 5.8.2 Flood Depth

- R117 — **Depths should be symbolized consistently** within all map libraries and end products using a range of blue shades with transparency as defined in Appendix F.
- R118 — Depths to be mapped should be defined by the study provider, because **appropriate depth ranges** must be based on considerations of map purpose and usability as well as underlying elevation data and model accuracy considerations.
- R119 — Depth ranges should be **consistently represented** in all products within a map library, both exported versions and those presented in applications.

### 5.8.3 Conveying Uncertainty

The potential inundation layer depicted in the map examples in Appendix F is not a standard product of current hydraulic modeling software products. USACE should consider incorporating this capability into HEC-RAS.

- R120 — Uncertainty should be displayed on maps via the **potential inundation area** feature as defined in Appendix F.
- R121 — The potential inundation layer should be **available as an option**, and not as part of the standard presentation of an inundation map.
- R122 — Documentation must be captured regarding the sources of uncertainty used to define the area (terrain, model, forecast, and other considerations). The intent is to convey an area of uncertainty bounding the “best guess” extent of inundation. This feature can be displayed with the depth layer, but there is no intent to visually depict depth uncertainty, other than via the depth ranges provided in depth queries.

### 5.8.4 Exportable and Printable Maps

The ad hoc printing and exporting requirement is provided in Section 5.1.

- R123 — The cartographically-controlled maps should be produced through ISF in **PDF format**.
- R124 — A national tiling scheme based on existing USGS 7.5 minute quadrangles should be used for the controlled map sheets.
- R125 — The tiling scheme for controlled maps should at minimum provide for printing and exporting at fixed scales from a largest scale of 1:7,920 to a smallest scale of 1:126,720 with each scale increment being two times the scale of the previous map.
- R126 — North should always be the top of the map for printed maps.
- R127 — When the user requests a map the PDF returned by ISF should be a file that includes a **map information page** as page one, followed by one or more map sheets meeting the user request.
- R128 — The map information page is also recommended to be provided with maps requested through the ad hoc printing function.

Example controlled map products are shown in Figure 5.2 and 5.3. Detailed specifications for these products are provided in Appendix F.

- R129 — The map information page should provide map title, purpose and use, disclaimer, data sources, map notes and legend. An example is provided as Figure 5.4 and in Appendix F.
- R130 — The controlled map sheet(s) should include the map area, title block, Universal Transverse Mercator (UTM)/USNG reference tics, USNG grid zone and 100,000 meter grid ID designation, scale statement and join sheet labels.
- R131 — Join sheet labels of controlled maps should serve as hyperlinks to adjoining sheets.
- R132 — The map **title block** should display the same title as presented on the map information page, the unique map sheet identifier and the IWRSS logo.
- R133 — The **map area** should present the basemap service selected by the user, the flood inundation map layers that are on and visible in the interactive map, the map tile boundary, and labels showing adjoining map sheet numbers.
- R134 — Printed and exported maps should be uniquely identified by the bounding box defined by their USNG 1,000 meter identifiers per the following examples: 1:31,680 scale map - 15SUD59713238; 1:15,840 scale map - 15SUD60653638.

- R135 — These **unique USNG identifiers** will serve as map sheet numbers. A benefit of this approach is that all maps at all scales nationwide are uniquely identified.
- R136 — In combination, the map library ID and map sheet number should serve as the **IWRSS ID** for any map sheet.
- R137 — Geographic reference tics should be displayed on map sheets; UTM 1,000 meter tics are required for USNG referencing, and latitude/longitude tics are optional.
- R138 — Map sheets should present all information needed to **uniquely identify locations based on the USNG**: USNG Grid Zone, e.g. 15S; 100,000 meter grid unique identification numbers, e.g. YC, BH; and 1,000 meter tics.

### 5.8.5 Mapping Scales and Standards

- R139 — **Scale bars** in both feet/miles and meters/kilometers and ratio scales (e.g. 1:15,840) should be provided for all online map applications and map sheets. Engineering scales (e.g. 1" = 10,000') are not recommended for flood inundation map products.
- R140 — The unit of vertical measurement for map scales should be U.S. survey feet.
- R141 — The unit of horizontal measurement for map products should be scale dependent, and may vary between either U.S. survey feet or miles.
- R142 — Scales should be consistently represented in all versions of maps, both exported versions and those presented in applications.

### 5.8.6 Map Purpose

- R143 — For each map presented, a narrative describing the **map purpose** should be made available, on the map or map information page for map sheets, via a menu option in online interactive maps and via either attribute or metadata from map services. Example purpose statements are provided in Appendix F.

### 5.8.7 Dates

- R144 — All **dates** should be presented in format DDMONYYYY, for example, 01MAY2005.
- R145 — Dates should be consistently represented in all versions of maps, both exported versions and those presented in applications.
- R146 — **Times** when appropriate should be 24-hour and reference time zone, e.g. 1200 EST.
- R147 — The **study date** should always be presented in the map title. The study date is the publication date of the map.
- R148 — The **forecast date** should be presented in the map title for all event-based maps that predict flooding at a future time based on a forecast river stage profile.

### 5.8.8 Map Titles

- R149 — Map titles should have a summary title and detailed sub-title component consistent with the following examples. Information included in the [brackets] is specific to each map generated.

- a. **Stream reach map**  
**Mississippi River Estimated Inundation, River Stage 40.25 Feet**  
 At Memphis Streamgage (Streamgage ID and Name), Map Library (Library ID), May 2009
- b. **Event-based map (forecast peak/crest)**  
**Mississippi River Estimated Peak Inundation, MAY 2005 Flood Event**  
 01MAY2005 0815 PST Based on NWS River Stage Forecast, [Streamgage ID and Name or Upstream Streamgage ID and Name-Downstream-Streamgage ID and Name]
- c. **Event-based map (forecast time)**  
**Mississippi River Estimated Inundation for 09MAY2005 1200 PST**  
 Based on above NWS River Stage Forecast published 01MAY2005 0815 PST, [Streamgage ID and Name or Upstream Streamgage ID and Name-Downstream-Streamgage ID and Name]
- d. **Historical flood documentation map**  
**Mississippi River Peak Inundation, May 2008 Flood Event**  
 JUL 2010 Based on [procuring agency] Imagery and [procuring agency(s)] High Water Marks, [Streamgage ID and Name or Upstream Streamgage ID and Name-Downstream-Streamgage ID and Name]

R150 — **Map titles** should be consistently represented in all versions of maps, both exported versions and those presented in applications.

## 5.9 Application Requirements

The application requirements in this section expand upon the higher level application requirements defined in Section 5.1 and are those not previously defined in other sections.

### 5.9.1 Geocoding

R151 — Standard **geocoding** functions should be available that at minimum allow for geocoding by street address, latitude/longitude and USNG coordinates.

### 5.9.2 Depth Layers and Queries

Depth grids stored by the system should provide for the following capabilities in addition to those discussed already.

R152 — **Depths** should be reported in U.S. feet.

R153 — **Depth data**, while highly desired, may not be available and **is not required for all studies**.

R154 — A **depth layer** should be available for display in all methods of delivery if the data are available.

R155 — If depth data are available, the applications should allow the user to **query the depth grid** and request depth at a selected location.

R156 — The query feature should report the depth grid value and should also provide an **accuracy range** rounded to the nearest 0.1 ft.

- R157 — Disclaimers or **accuracy statements** for depth maps and depth queries should display the accuracy of the result; the statement should state that the accuracy of results are limited by the quantified accuracy of the terrain dataset and the uncertainties inherent in the hydraulic model and river forecast.

### 5.9.3 Exporting Maps

- R158 — **Exported maps** should be requested via online interactive maps via common point and area selection functions.
- R159 — Exported maps should also be accessible **through URL hyperlink** requests that include latitude/longitude, USNG coordinate, USNG bounding box and/or unique map library identification numbers.
- R160 — The URL-based requests for exporting maps should serve as the alternative map access for Americans with Disabilities Act Section 508 compliance of the Rehabilitation Act requirements for access to maps.

### 5.9.4 Clearly Identifying Event-Based Maps

- R161 — There shall be one federal event-based map for a reach of river during a flood event. During a significant flood event, it will be important to ensure that the best available map representing the forecast conditions, should it exist, be clearly identified to assist users in a flood-warning situation.
- R162 — The event-based map should always be the prominent mapping feature that is displayed through the multiple delivery formats described in Section 5.1.
- R163 — Stream reach maps and historical flood documentation maps will be made available to the public stakeholders at all times, in addition to the one federal event-based map that is designated for a reach of river.
- R164 — A mechanism to quickly display *the* event-based map for active flood events, and provide a level of visibility that gives the event map primary focus, should be considered. It should be different from the standard workflow for selecting layers from map libraries, as it would keep users from having to manually select the most appropriate map layer(s) representing an ongoing flood event from all those that exist in available map libraries. An event-based map could be identified from an event-based map library created based on a recent forecast, or an existing stream reach map library inundation layer most near to the current stage or forecasted flood stage. The most current and best-available map scenario should be presented to the user.
- R165 — Further effort is needed to determine, within the concept of operations, the process and responsibility for identifying event-based maps from existing map libraries or for ordering real time modeling and mapping procedures to be undertaken to produce event-based maps.

### 5.9.5 Displaying Multiple Flood Extent Layers

- R166 — The multiple delivery formats described in Section 5.1 should be capable of delivering and displaying multiple flood extent layers simultaneously from a single map library.
- R167 — The multiple delivery formats described in Section 5.1 should be capable of delivering and simultaneously displaying flood extents from more than one map library.
- R168 — When multiple flood extents are displayed on one map, they should be symbolized in a manner to ensure they are clear and distinct, possibly as lines rather than filled polygons with differing line weights, line styles and colors.

### **5.9.6 Displaying Historical Flood Documentation Maps**

- R169 — The historical crest record at the streamgage should be displayed at each mapping location.
- R170 — Each historical crest record should be linked to the best available map, using the following selection procedure: (1) If a historical flood documentation study was conducted for the chosen event, the appropriate map should be displayed along with the accompanying link to the full study; (2) If an event-based map was created for the chosen event, then the event-based map should be displayed with all the timestamp information shown; (3) If a map out of the stream reach map library is determined to be relevant and representative of the historical crest, the appropriate stream reach map library should be displayed; and (4) If an appropriate map cannot be identified, then no historical flood map will be displayed for the crest record.

## **5.10 Training Requirements**

- R171 — Mapping partners involved in the production of flood inundation maps will need training on the following topics: (1) requirements which must be met before flood inundation maps are to be disseminated, (2) scoping procedures, (3) QA/QC checklist, (4) project documentation (metadata, data registry) and (5) reporting standards.
- R172 — Mapping partners involved in the production of flood inundation maps will need training to understand how to effectively use the data registry to identify existing projects, available datasets, and report access. Data registry user training should include the following topics: (1) the registry's data fields, (2) the registry's features and (3) the registry's access to available data sets.
- R173 — Stakeholders that will be accessing and using the uniform mapping services to make flood risk management decisions require training on the following topics: (1) interpretation of uniform flood mapping products, (2) interpretation of customized flood mapping products and (3) data access through the four delivery formats.

## Section 6: Recommendations

This section summarizes the key overarching requirements and recommendations for developing the National Flood Inundation Mapping Services.

### 6.1 Key Requirements

The proposed overarching requirements for the National Flood Inundation Mapping Services are centered upon establishing a common operating picture and addressing stakeholders' needs. Fundamentally, the IWRSS agencies should (1) develop uniform mapping products and (2) establish a common operating picture to host the map products per agency release policies.

#### *Uniform Mapping Product Requirements:*

- Develop uniform flood inundation maps based on common standards and methods;
- Format mapping products consistently; and
- Scope products to meet stakeholder needs.

#### *Data Sharing Requirements:*

- Develop a common operating picture to create consistent maps and share data, models and maps;
- Enable online access to interactive maps;
- Ensure compliance with Open Geospatial Consortium standards;
- Enable inundation maps to be downloaded and printed; and
- Provide access to complete project data, metadata and reports via download

### 6.2 Key Recommendations

The following items are recommended as the highest priority immediate activities for the FIM-DT. The activities are considered relatively low cost, high benefit activities that serve as the foundation for organizing uniform products and services for the common operating picture. The FIM-DT should act on the recommendations within this section, as soon as feasible, in order to establish a foundation for the longer term implementation of the common operating picture. Recommendations are presented in the order of priority and according to task dependencies.

Recommendation 1: Finalize and adopt a set of common IWRSS FIM standards for published flood inundation maps that can be applied at all IWRSS agencies. The map display standards must be finalized before the recommendations related to scoping, QA/QC or documentation can be developed.

Recommendation 2: Implement the FIM requirements related to the sharing of data across IWRSS agencies. A set of FIM requirements has been provided to IDS-RT and are published in Appendix D.

Recommendation 3: Develop a data registry listing all completed, current or scheduled inundation mapping projects. The initial implementation could be as simple as a consolidated spreadsheet shared by all member agencies. This would help to define the scope of ongoing inundation mapping activities and assist in identifying opportunities for collaboration. This recommendation is further described in Section 4.5.

Recommendation 4: Define common scoping methods and checklists for collaborative projects and make them available to all IWRSS member agencies. Scoping methods should be defined for IWRSS projects based upon recent collaboration with other federal and state agencies, River Basin Commissions and Compacts and the private sector to ensure more consistent and

transparent procedures for generating maps. The details of this recommendation are described in Section 5.2.

Recommendation 5: Develop a standardized QA/QC checklist to ensure FIM projects follow common standards, employ common methods and produce maps which are consistent in content and format. The details of the uniform QA/QC checklist are described in Section 4.4.

Recommendation 6: Develop common project documentation and reporting standards for IWRSS FIM projects to enable users to understand the content, methods and assumptions. Project documentation and reporting is discussed in Sections 5.1, 5.3, 5.7 and Appendix G.

Recommendation 7: Consult a panel of stakeholders, at key evaluation periods, throughout the process of developing NFIMS to make sure that the products remain relevant to the stakeholder group. The panel of stakeholders should represent a cross-section of individuals, agencies and organizations that have been identified as the primary stakeholders for NFIMS. These stakeholder groups are listed in Section 2.3.

## **6.3 Suggested Implementation Strategy**

The key recommendations, identified in Section 6.2, are designed for immediate implementation by FIM-DT. Beyond these key immediate recommendations, FIM-RT identified two longer-term, general strategies for implementation of a concept of operations and common operating picture. The two general implementation strategies are presented with the assumption that the key recommendations in Section 6.2 will be in place. Organizational constraints and challenges to define funding, staffing, governance, policies and information technology strategies will, in large part, drive the chosen strategy.

### **6.3.1 Strategy One: Partial Implementation**

Strategy one is a partial implementation of the proposed concept of operations and common operating picture. This approach would include: (1) an independent requirements implementation by each IWRSS agency, (2) independent data/map services, web applications and map, hosted by each IWRSS agency, (3) a partial data registry implementation that would not include the archive of project data in a centralized database and (4) agency operations and operational data sharing is partially integrated.

IWRSS member agencies would continue to collaborate to develop guidance and recommended standards for inundation map procedures, format and content. These would then be evaluated and used by each member to align their current projects and programs to meet IWRSS goals. Stakeholders would access products from the services deployed by the agency that developed them, but map and data format and content would be reasonably similar.

### **6.3.2 Strategy Two: Full Implementation**

Strategy two is a full implementation the proposed concept of operations and common operating picture. This approach would include: (1) uniform requirements implementation by all IWRSS agencies, (2) a single IWRSS data/map service, web application and map hosted by IWRSS, (3) a full data registry implementation that would archive project data in a centralized database and (4) agency operations and data sharing are fully integrated.

The second strategy would require additional effort, but result in a single, seamless federal suite of inundation map services. In essence, IWRSS member agencies would strongly collaborate to develop and deploy a single set of IWRSS services, applications, maps and data. Stakeholders



would have a single point of access to these products, regardless of which agency or agencies developed them.

### 6.3.3 Strategy Comparison

Each suggested strategy has its benefits and risks. These factors are compared below.

**Benefits of the first strategy**, when compared to the second, include: (1) less effort required to migrate from current business processes, (2) less organizational change will be required, (3) lower implementation costs will be incurred, (4) faster implementation may be realized and (5) less solution risk.

**Benefits of second strategy**, when compared to the first, include: (1) stakeholder needs are fully met, (2) long-term operations and maintenance costs may be lower and (3) a fully synchronized implementation of a common operating picture is developed.

**Risks of the first strategy**, when compared to the second, include: (1) the solution may not fully meet stakeholder needs, (2) long-term operations and maintenance costs may be higher and (3) a synchronized common operating picture may not be possible.

**Risks of the second strategy**, when compared to the first, include: (1) more effort required to migrate from current business processes, (2) more organizational change will be required, (3) higher implementation costs will be incurred, (4) slower implementation may be realized and (5) more solution risk.

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## Glossary

**Common Operating Picture:** Broad IWRSS definition related to the shared comprehensive view of the water resources landscape. IWRSS FIM is more focused on the sharing tools and data, especially public, FOUO and supporting project data for flood mapping. This data-centric approach to the common operating picture is to be supported by the Information Services Framework.

**Concept of Operations:** The quantitative and qualitative characteristics of IWRSS from the perspective of the user and stakeholder. In general, the IWRSS concept of operations responds to the demand for additional operational water resources information and integrated services. A viable flood-mapping concept of operations would efficiently and effectively leverage IWRSS members, partners and stakeholder assets to generate flood inundation products.

**Datum:** The relative reference of a particular point on the earth's surface. FIM is based on FGDC standards where currently the horizontal datum is specified in a latitude and longitude coordinate positions in terms of NAD83 and vertical datum in heights feet NAVD88.

**Digital Elevation Model:** A digital computer representation of the ground surface elevation heights of the bare earth. For FIM, DEM usually is provided as a grid of raster cells of 2, 3 or 5 meter resolution with horizontal and vertical accuracies dependent on the specified stakeholder requirements for the flood maps.

**Digital Terrain Analysis:** A type of analysis employing a methodical process or approach to examine the land surface derived from the digital elevation model (DEM) and water surface profiles from hydraulic analyses to determine the flood depths for each particular cell of the terrain. Terrain analysis is a key component of developing flood inundation maps.

**Event-Based Map:** An IWRSS flood inundation map based on a specified set of real or anticipated hydraulic conditions for which floodwaters are predicted and forecast. An event-based map considers current and/or forecast hydrologic conditions for selected location(s) for a determined time period and timing of peak floodwaters. They are generally not applicable after the end of the modeled time period and at the cessation of the modeled hydrologic conditions. If applicable, this map could be based on an existing stream reach map library or pre-generated specifically for the forecast flood event and predicted flood operations. These types of maps are sometimes referred as dynamic maps but essentially are maps specific to a predicted circumstance or expected flood event.

**Historical Flood Documentation Map:** An IWRSS flood inundation map that minimally shows the extent of flooding of peak flows for a past flood event, but may also include the depth of floodwaters collected from high water mark surveys for that event. This map type could also be modeled or derived from high water mark surveys, satellite imagery, other remotely sensed or in-situ data to depict the actual flooding. These maps are useful for historical reference, planning purposes and calibrating models for developing inundation maps.

**Flood Inundation Mapping Stakeholder(s):** The local, state, and federal agencies and private organizations and individuals directly involved in flood-fighting efforts throughout the flood risk management lifecycle.

**Flood Risk Management Lifecycle:** The lifecycle process in which partners come together to responsibly share in managing and reducing the flood risk throughout the four phases: (1) Preparation/Training (before the event); (2) Response (during the event); (3) Recovery (immediately after the event) and (4) Mitigation (pre-event/post-event/ long range planning) by managing floodwaters responsibly to reduce the probability of flooding and by managing the floodplains to reduce the consequences of flooding

**Geospatial Analyses:** A type of analysis employing a methodical process or approach using GIS to inspect, review, and understand the geographical aspects of the land, water and man-made infrastructures in the floodplain.

**Hydraulic Analyses:** A type of analysis employing a methodical process or approach to compute the water surface elevation, depth of flow and velocities in a stream or river. Hydraulic analyses are a key component of developing flood inundation maps.

**Information Services Framework:** A particular IWRSS collaborative framework, which supports all technical aspects of the national water resources information system, including system interoperability and data exchanges, eGIS and geo-Intelligence, integrated information delivery, the acquisition and management of observations and surveillance and technological research and development. For IWRSS FIM, this is the central information technology system through which map development and production data should be exchanged through.

**Integrated Water Resources Science and Services:** A consortium of United States federal agencies with complimentary water resources missions together to share resources to help solve the nation's water resources issues with an overarching objective to enable and demonstrate a broad, interactive national water resources information system serving as a reliable and authoritative means for adaptive water related planning, preparedness and response activities.

**IWRSS Partners:** Agencies, groups, or individuals who are directly collaborating with the IWRSS Consortium members, which currently include NWS, USACE and USGS.

**Levee Centerlines:** A line, which represents the middle horizontal alignment of all levees, floodwalls and closure structures in a levee system

**Leveed Area:** The lands from which flood water is excluded by the levee system at the overtopping elevation [Source: [USACE Program Levees](#)].

**Leveed Area Flood Extent:** A graphical representation describing the estimated extent of flood water on the landward side of a levee system (interior area) for all mapped elevations. IWRSS FIM requires this display for maps with levees to help convey potential risks, these layers are not submitted to NLD but maintained as part of the individual map for display in the IWRSS FIM Map Viewer(s).

**Lidar:** A remote sensing technique, which uses discrete light pulses and measured travel times to determine point elevations rapidly collect over a large area. Light Detection and Ranging (lidar) data of densely spaced highly accurate geo-referenced elevation points are processed and conditioned to determine the earth's surface [Source: [NOAA CSC's What is Lidar](#)].

**Map Library:** A collection of electronic maps which been developed with the same model, analyzed by the same methods, and generated with the same intended use. Map libraries are to be the main output products of the National Flood Inundation Mapping Services.

**Mutual Modeling Framework:** An IWRSS framework which enables the systems to capture inputs, provide outputs, and support seamless flood inundation map production for display across agency boundaries. The framework would facilitate more efficient data access for an integrative, reproducible, scalable approach for one, two, and three-dimensional hydraulic modeling for flood mapping. When integrated across agencies, these capabilities would provide an environment in which agencies can share data and pass parameters, allowing for model integration, performing mutual modeling, and seamless producing flood inundation maps.

**National Flood Inundation Mapping Services:** The uniform federal flood inundation mapping services to be provided to the public by the IWRSS Consortium. The services provide the



following uniform map products for the public: (1) stream reach maps, (2) event-based maps and (3) historical flood documentation maps.

**Stream Reach Map:** An IWRSS flood inundation map which minimally shows the extent of flooding for a pre-specified stream reach and also include depths of floodwaters where appropriate. The extent and depth of flooding are normally modeled based on steady flows across known, generally stable, channel geometry, cross-sections, and land features. A series of maps, typically created at one-foot to two-foot stream stage intervals in the vicinity of a streamgage station, comprises a stream reach map library. Geographically extending the inundation maps from this pre-specified limited reach length upstream or downstream of the modeled section is not recommended due to the non-linear response of river stage to flow. These types of maps are commonly referred as static maps.

**System Interoperability:** A collaborative operational workflow in which data and information flow seamlessly between systems. Models, tools and other applications would benefit from this exchange thus allowing for more integrative analysis of the information and improved collaborative workflow.

**Water Surface Profile:** A profile outlining the water surface elevations in the longitudinal direction along the slope of a stream or river.

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# **Appendix A:**

## **Agency Ranked Requirements**

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		REQ#	REQUIREMENT	NWS	USACE	USGS
<b>Section 4: Concept of Operations and Common Operating Picture Requirements</b>						
<b>4.2 Information Services Framework Requirements</b>						
			The map development and production data should be exchanged through a central information technology system, to be known as the IWRSS Information Services Framework. The completed mapping products and services would be hosted by the ISF or via			
		R1 -	technologies meeting ISF standards.	MEDIUM	MEDIUM	HIGH
		R2 -	The ISF should support all interagency functions and processes for the development, submission, review, publication, data dissemination and display of flood inundation mapping products.	LOW	MEDIUM	MEDIUM
		R3 -	ISF supported joint collaborative operations for flood inundation map production require the seamless integration of partner agency data collection activities, FIM production processes, and quality control activities to produce a suite of IWRSS FIM products and services.	LOW	MEDIUM	LOW
		R4 -	The ISF should support a repeatable, modular and standardized approach to developing the mapping data products. This allows for flood inundation mapping tasks to be divided or shared by agencies and other stakeholders. During a flood event, one agency could develop the hydrologic and hydraulic models, a second agency could focus on data collection tasks, while a third agency could take on the task of map production from the model results.	LOW	MEDIUM	LOW
		R5 -	Flood mapping data products and the data supporting these products should be transmitted between agencies by registering a data product with the ISF, making it available to all IWRSS agencies and ultimately to the public if tagged as appropriate for public release. Registration of standardized, consistent and documented data would strengthen the modularity of the IWRSS data products, thereby enabling IWRSS partner agencies to quickly identify existing products, develop new products, or refine existing products.	LOW	LOW	LOW
		R6 -	The ISF should provide access to FEMA model database information such as hydrologic and hydraulic models, study locations, cross-sections and water surface profile information. Coordination between FIM studies and Digital Flood Insurance Rate Map (DFIRM) RiskMap studies currently under development or planned would benefit the National Flood Inundation Mapping Services and FEMA, both technically and financially.	LOW	LOW	LOW
		R7 -	Agency Information Technology (IT) systems that are included within the ISF should meet the minimum requirements for interoperability. System interoperability between agency IT systems is a key requirement and the enabling technology necessary for the IWRSS joint collaborative operations.	LOW	LOW	LOW
		R8 -	Minimum requirements for IT system interoperability should be established.	LOW	LOW	MEDIUM
		R9 -	Individual IWRSS agency IT system and security constraints should be considered as the ISF design is developed.	LOW	LOW	MEDIUM
<b>4.3 Governance Requirements</b>						
		R10 -	A multi-agency governance structure would be necessary to oversee and manage implementation under a strategy to develop a single federal suite of inundation map services. Functions would include report formats; quality management (reviews), maintenance and revision of data, map and information technology standards; liaison with technical and subject matter experts within the member agencies; funding and staffing for design and development for the ISF, data registry, applications, and loss estimation among others.	MEDIUM	MEDIUM	MEDIUM
<b>4.4 Quality Management and Peer Review Requirements</b>						
		R11 -	Each FIM library should have a proponent agency identified.	HIGH	MEDIUM	HIGH
		R12 -	The IWRSS member proponent agency for FIM libraries would be responsible for certifying the quality of the product, and for defining purpose and use restrictions. Certification by the proponent agency would indicate that the products had been reviewed per proponent agency policies and meet defined IWRSS quality and content standards.	HIGH	MEDIUM	HIGH
		R13 -	The quality management process will be applied to both internal products deemed FOUO and external public products.	HIGH	MEDIUM	MEDIUM
		R14 -	Internal FOUO products may be subject to different quality review standards than the standards that are applied to the external public products.	HIGH	MEDIUM	MEDIUM
		R15 -	The quality management process will be developed and applied independently to the three categories of flood inundation maps, which include: (1) stream reach maps, (2) event-based maps, (3) historical flood documentation maps.	HIGH	MEDIUM	LOW
		R16 -	Product quality should be certified by the proponent agency on a standardized QA/QC checklist. The QA/QC checklist should be standardized and applied to all FIM products to ensure that the final requirements are met.	HIGH	MEDIUM	HIGH
		R17 -	Time critical event-based maps will be certified by the proponent agency that the maps meet the existing IWRSS quality standards, and no additional peer review policy will be required.	HIGH	HIGH	MEDIUM
		R18 -	The completed QA/QC checklist should be posted within the ISF as QA/QC documentation for every project.	MEDIUM	MEDIUM	HIGH
		R19 -	To encourage strong member agency collaboration and continual improvement of IWRSS processes it is recommended that a recurring multi-agency review be conducted for a subset of map libraries recently posted within the ISF. The scope of annual reviews could be flexed to align with funding constraints and volume of new map libraries provided within the review period.	MEDIUM	MEDIUM	MEDIUM
		R20 -	A periodic examination of existing map libraries should be considered. Periodic reviews could be mandatory, for example at minimum every ten years. In addition, periodic reviews could be triggered by events such as requests of stakeholders, upon the acquisition of detailed verification data from major flood events, or as a result of known topographic, infrastructure, or river channel changes as a result of anthropogenic or natural events.	MEDIUM	MEDIUM	LOW
		R21 -	Results of periodic map reviews should be documented within the ISF.	MEDIUM	MEDIUM	LOW
		R22 -	Upon identification of a degraded mapping product, the map may be temporarily or permanently removed from public access, or permanently deleted depending upon circumstances.	HIGH	MEDIUM	HIGH
		R23 -	The ISF will communicate map changes to the public and the local stakeholders that may be initiated by periodic review findings. Notification of the map change could be through the display of a note highlighting the change within IWRSS services and applications. The local stakeholders should be notified directly and be part of the update process.	LOW	MEDIUM	LOW

		REQ#	REQUIREMENT	NWS	USACE	USGS
		R24 -	In addition, each map library should record the dates of production and the most recent review and revision, and this information should be published with FIM products.	HIGH	HIGH	HIGH
<b>4.5 Common Operating Picture Requirements</b>						
		R25 -	It is recommended that the common operating picture be deployed via products and services that draw on FIM libraries and the data registry published through the ISF. This could be accomplished through the multiple product delivery formats described in Section 5.1.	MEDIUM	MEDIUM	MEDIUM
		R26 -	Regardless, the key to ensuring common views of inundation maps is the ability to reference map library unique identification numbers and inundation map unique identification numbers managed within the ISF, and to use a generally consistent presentation of map layers within all FIM applications and products. This would allow multiple applications to support viewing inundation maps via passing of common URL parameters for accessing information in the ISF.	MEDIUM	HIGH	MEDIUM
		R27 -	Low information display latency within the common operating picture should be a critical design criterion.	MEDIUM	MEDIUM	HIGH
		R28 -	To function effectively, the common operating picture should be coupled to an information service framework that should include: (1) a data registry for the flood mapping products, (2) identification of the owner of each product, (3) the corresponding metadata, and (4) the data location (to which the registry would direct the user). The data could be provided by the respective IWRSS agencies via OGC-compliant web services. Figure 4.2 displays a diagram of the interaction between the common operating picture and components of the information services framework that include the data registry, the IWRSS agencies, and individual agency data sources.	MEDIUM	MEDIUM	HIGH
		R29 -	In addition, the database could be considered for posting through the Federal Geoplatom on data.gov to provide the IWRSS consortium and new stakeholders the ability to discover FIM services and products.	MEDIUM	LOW	LOW
<b>Section 5: National Flood Inundation Mapping Services Requirements, Standards, and Methods</b>						
<b>5.1 Flood Inundation Map End Products Requirements</b>						
		R30 -	The ISF will host a collection of electronic map libraries, including: (1) stream reach maps, (2) event-based maps, and (3) historical flood documentation maps.	HIGH	HIGH	HIGH
		R31 -	All flood mapping data should be accessible either for official use only or to the public in four common formats: (1) OGC standard web services for maps and data features; (2) maps may be viewed interactively online through a basic flood inundation web map applications; (3) electronic maps for download; and (4) complete supporting data, metadata and reports for download.	HIGH	HIGH	HIGH
		R32 -	To the extent technically possible, format and content of flood inundation maps should be consistent across all end products. This provides consistency and continuity of information presentation that accelerates user understanding and reinforces that all products are produced through unified approaches and systems.	HIGH	HIGH	MEDIUM
		R33 -	All of the FIM end products should be categorized as D 4.1 Disaster Monitoring and Prediction Information Type from the National Institute of Standards and Technology Special Publication 800-600 for the purposes of infrastructure and security (U.S. Department of Commerce NIST, 2008). Security categories must be determined to satisfy the Federal Information Security Management Act of 2002.	HIGH	LOW	HIGH
<b>5.1.1 Map and Data Services</b>						
		R34 -	OGC-compliant spatial web map and web feature services (web services) should be provided that allow stakeholders to utilize flood inundation maps and data/layers in desktop and web applications. An example of a desktop application that may consume OGC Services is presented in Figure 5.1 below.	MEDIUM	MEDIUM	HIGH
		R35 -	The spatial web services should provide access to all flood inundation map data, segregating official use only data from public-accessible data.	MEDIUM	MEDIUM	MEDIUM
		R36 -	ISF spatial web map and web feature services should be made discoverable through the federal geoplatom on data.gov.	MEDIUM	LOW	LOW
		R37 -	Map services should present features using a generally common map symbol standard, such as the recommended symbology defined in Appendix F. The symbology specified works currently with commonly available imagery, road/street, and topographic services but was optimized for use with ESRI topography and street map services.	HIGH	HIGH	HIGH
<b>5.1.2 Web Map Viewer Applications</b>						
		R38 -	A public FIM web map viewer application or applications should be maintained by the IWRSS members in order to provide access to the FIM maps and data.	MEDIUM	MEDIUM	MEDIUM
		R39 -	The FIM viewer(s) should function within common desktop and mobile platforms. The intent is to only provide basic tools that are geared towards an educated public user and provide a strong demonstration of the flood inundation map information available via the map and data services.	MEDIUM	MEDIUM	MEDIUM
		R40 -	The FIM viewer(s) should always provide all of the available public maps to users via an interface that allows selection of available map libraries (stream reach, event-based, and historic flood documentation).	MEDIUM	MEDIUM	HIGH
<b>5.1.3 Inundation Maps</b>						
		R41 -	Web services should provide the ability to extract static Portable Document Format (PDF) formatted maps.	MEDIUM	MEDIUM	LOW
		R42 -	The first map printing function is the commonly implemented ad hoc printing approach of applying a user-specified title and system-generated legend and other ancillary map information combined with a rendering of the current map screen extent allowing the user to customize which layers are shown.	MEDIUM	MEDIUM	HIGH
		R43 -	The second map printing function is intended to ensure production of a cartographically-controlled official publication product meeting the inundation map standards endorsed by IWRSS.	MEDIUM	HIGH	MEDIUM
		R44 -	The controlled map printing function should meet the specifications provided in this report for map sheets.	MEDIUM	HIGH	LOW

			REQ# REQUIREMENT	NWS	USACE	USGS
			<b>R45</b> - More flexibility of format and content is allowable for the ad hoc map printing function, although the symbology guidelines should be adhered to in all end products. Figures 5.2 and 5.3 are example flood inundation maps produced according to the symbology guideline recommended in Appendix F.	MEDIUM	HIGH	MEDIUM
			<b>R46</b> - The controlled map printing function should provide for reproducibility of maps and ensure consistent presentation of printed FIM products.	MEDIUM	HIGH	HIGH
			<b>R47</b> - The controlled map printing function should allow stakeholders to request sets of maps in PDF format covering a user-defined extent such as a municipal boundary at a user-specified map scale.	MEDIUM	MEDIUM	MEDIUM
			<b>R48</b> - The controlled map printing function should allow for maps to be requested via simple URL requests rather than via a graphical map interface, which can be used to meet Americans with Disabilities Act section 508 compliance and provides for other systems and websites to post links to specific IWRSS-published maps in PDF format.	MEDIUM	MEDIUM	LOW
			<b>R49</b> - Flood extent and depth map layers and the supporting depth grid model outputs are the most critical information needed for effective use of flood inundation maps.	HIGH	HIGH	HIGH
			<b>R50</b> - Inundation map layers defined in this report, other than extent and depth, are useful information and any implementation of national flood inundation mapping services should provide the ability to store and display all of them, although most are not required.	HIGH	MEDIUM	MEDIUM
			<b>R51</b> - Map layers are to be categorized as required, desired, optional or provided.	HIGH	MEDIUM	HIGH
			<b>R52</b> - These map layers, defined below, should be managed by the ISF: flood extent [required], study extents/limits of inundation model [required], flood depth [desired], flood extent in leveed areas [optional], potential inundation area [optional], stream centerline [optional], model cross-sections [optional], river station/river mile [optional], water surface elevation contours [optional], U.S. National Grid (USNG) zones [provided], USNG 100,000 meter grid ID [provided].	HIGH	HIGH	HIGH
			<b>R53</b> - These map layers, defined below, should be acquired from sources outside the ISF: levee centerlines [provided], leveed area [provided], active streamgages [provided], flood forecast locations [provided], base map layers [provided], radar [provided] and other flood warning services [provided], georeferenced flood impact statement points [provided], and flood warning polygon [provided].	HIGH	HIGH	HIGH
			<b>5.1.4 Data and Reports</b>			
			<b>R54</b> - Users should have the capability to export flood inundation maps and related reports as well as their supporting data, based on FOUO or public designation.	MEDIUM	MEDIUM	LOW
			<b>R55</b> - Supporting data, that should be available for download, includes the hydraulic models used to produce flood inundation maps and data layers managed by the ISF.	MEDIUM	MEDIUM	LOW
			<b>R56</b> - The complete project data, including layer metadata and project report or project report metadata, should be made available for download via the services and applications.	MEDIUM	MEDIUM	HIGH
			<b>R57</b> - Basemap layers and layers served from other sources should not be made available for download.	MEDIUM	MEDIUM	HIGH
			<b>R58</b> - In addition to flood inundation maps, the ISF should support the ability to generate consistent FIM technical reports available for electronic viewing and printing.	LOW	MEDIUM	LOW
			<b>R59</b> - Reports should be made available for download through all services and applications, including via URL hyperlink requests that reference map library ID numbers.	MEDIUM	MEDIUM	HIGH
			<b>R60</b> - Reports should also include a unique IWRSS FIM report identification number for citation and tracking purposes and based on information in the ISF. An example summary report, presented as a flood inundation map information page is shown in Figure 5.4 and in Appendix F.	MEDIUM	MEDIUM	LOW
			<b>R61</b> - The map information page/summary report should be a concise 1-page summary of a more detailed project report. Appendix F summarizes recommended project report content. The advantages of this strategy are:	MEDIUM	HIGH	MEDIUM
			<b>R62</b> - Other types of standard reports could be made available for generation using the ISF and may take the form of complete reports linked to agency publication repositories, short topical reports dealing with a specific technical area such as a hydraulic model description or GIS techniques, brief bulleted fact-sheets, and location-based topical reports, such as one describing flood inundation impacts for a landowner's particular area of interest or a description of loss estimation data and results for a selected community.	MEDIUM	MEDIUM	LOW
			<b>5.2 Collaborative FIM Project Scoping Requirements</b>			
			<b>R63</b> - Recognizing local partner issues and needs are greatly varied, IWRSS partners should follow a uniform scoping procedure when undertaking projects that involved multi-agency, state and local or private sector collaboration. The intent is to ensure IWRSS requirements, standards and methods are adhered to, so that consistent and credible inundation maps are generated and broadly available through national services.	HIGH	HIGH	HIGH
			<b>R64</b> - Past, current and future flood inundation mapping projects should be registered within a consolidated list that could be made broadly available through the ISF data registry. This is to ensure that IWRSS member agencies and stakeholders are aware of existing, ongoing and planned projects. Documentation and tracking of existing, proposed and ongoing IWRSS FIM projects would promote efficient and effective planning and coordination of FIM product development. For example, with successful early communication two neighboring projects could be combined for a cost savings or new tools could be developed to display a unique flooding situation in time for the map release.	HIGH	MEDIUM	HIGH
			<b>R65</b> - The listed project information should include, but not be limited to, the spatial extent, the vertical height (stage) extent, the streamgage or streamgages included, the technical team, the local stakeholders, the intended resolution of the maps, and any optional mapping features that will be developed.	HIGH	MEDIUM	MEDIUM

			REQ# REQUIREMENT	NWS	USACE	USGS
			Collaborative project scoping and project development tools should be produced and made available to all IWRSS mapping partners. These tools could be delivered as printed or web-based documents and checklists designed to guide IWRSS mapping partners through the project development and scoping process and should describe agency specific coordination and data gathering activities. Examples of such documents include the FIMI Toolbox (U.S. Geological Survey) and the NOAA FIM Project Development Template (NWS), and the			
			<b>R66</b> - NOAA Partnered Guidelines (NOAA).	HIGH	MEDIUM	LOW
			<b>R67</b> - A uniform scoping procedure should encourage local stakeholder interaction and engagement in the map development process.	HIGH	HIGH	MEDIUM
			<b>R68</b> - Local stakeholder interactions and engagement should be documented in the QA/QC checklist.	HIGH	MEDIUM	MEDIUM
			<b>R69</b> - IWRSS mapping partners may choose to document the optional coordination tasks within the optional checklists.	HIGH	MEDIUM	LOW
			<b>R70</b> - The optional checklists may be submitted with the project data, in order to expedite the review and approval process. Examples of such coordination and data gathering tasks include, but are not limited to, the following activities:	HIGH	MEDIUM	LOW
			<b>5.3 Hydraulic Modeling Requirements</b>			
			<b>R71</b> - The hydraulic modeling software used for the analysis should be well documented, well established, and widely accepted in the hydraulic engineering community.	HIGH	HIGH	HIGH
			<b>R72</b> - The development of geometric data used in the hydraulic model, model version, geometric parameters selected, flow and boundary conditions used, and modeling decisions should be well supported through documentation that is submitted with the completed maps. Further discussion of hydraulic modeling to support flood inundation mapping is provided in Appendix H.	HIGH	HIGH	HIGH
			<b>5.4 Georeferenced Flood Impact Statement Requirements</b>			
			<b>R73</b> - Georeferenced flood impact statements should be delivered through OGC compliant web services and maintained by NWS.	MEDIUM	LOW	MEDIUM
			<b>R74</b> - Existing NWS flood impact statements should include new fields to allow for georeferencing and provide warning/response information to the public. This should help communicate flood impacts, infrastructure concerns, such as highway bridges, and tie all the impacts to flood maps, where available. Using this system to communicate flood impacts, bridges and levees can be represented differently at different stages. An example of general flood impacts for a community is shown on the Appendix F maps and in tabular format in Appendix I.	MEDIUM	LOW	LOW
			<b>R75</b> - Required flood impact attributes include: latitude/longitude (center of bridge, levee centerpoint, address of building, etc.), critical stage(s) and elevation(s), associated USGS/other streamgage, impact category tag (bridge, levee, road, etc.), Flood Impact statement (warning/response).	MEDIUM	LOW	MEDIUM
			<b>R76</b> - Optional flood impact attributes include: Weather Forecast Office and River Forecast Center responsible (tracked, not displayed) and stakeholder agency contact (tracked, not displayed).	MEDIUM	LOW	LOW
			<b>R77</b> - The latitude/longitude information should represent the geographic center of the impact area.	MEDIUM	LOW	MEDIUM
			<b>5.5 Bridge Requirements</b>			
			<b>R78</b> - Georeferenced flood impact statements at bridges will be standardized for every bridge registered as an impact point. A three tiered system will be developed to illustrate that the bridge is clear of floodwaters, the bridge is at risk, and the bridge is unsafe. Bridge impact statement examples are illustrated in Figure 5.5.	MEDIUM	LOW	MEDIUM
			<b>R79</b> - When possible, within the scope and constraints of a project, it is suggested that, in addition to populating bridge flood impact statement points as described in Section 5.4, bridge decks should be clipped from the inundated area polygons and/or depth grids once the hydraulic model indicates that water obstructs the opening beneath the low chord of the bridge. This step is necessary because elevation models typically do not incorporate bridge decking elevations or low-chord elevations, rather they depict the "bare earth" channel or surface elevation below the bridge.	MEDIUM	LOW	LOW
			<b>R80</b> - IWRSS mapping partners should describe the benefits of bridge clipping and recommend bridge clipping as a best practice to the local stakeholders as a part of the uniform scoping procedure.	MEDIUM	LOW	LOW
			<b>5.6 Levee Requirements</b>			
			<b>R81</b> - Levee centerlines should be available for display in online and map sheet products.	HIGH	MEDIUM	MEDIUM
			<b>R82</b> - The entire spectrum of levee systems, which may range from a federally constructed/maintained levee system to an agricultural levee system, accredited or non-accredited, certified or not certified should be treated equally as hydraulic features.	HIGH	MEDIUM	HIGH
			<b>R83</b> - Levee centerlines should be acquired and displayed from the National Levee Database (NLD) and should not be redundantly stored in the ISF. The NLD levee centerline to be displayed is an aggregate of the horizontal alignment of all levees, floodwalls, and closure structures throughout a study extent.	HIGH	HIGH	HIGH
			<b>R84</b> - If a levee within the FIM project scope does not exist in the NLD, it is the responsibility of the project to submit the necessary data to the NLD for proper display in FIM end products. Information on how to submit data to the NLD is available from the NLD Help Desk, contact information is provided at nld.usace.army.mil.	HIGH	MEDIUM	MEDIUM
			<b>R85</b> - The NLD data submission process should be included within the uniform scoping procedure and documented in the QA/QC checklist.	HIGH	MEDIUM	HIGH
			<b>R86</b> - If a map distinguishes inundation in leveed areas from inundation in non-leveed areas, the inundation polygons should be displayed in a separate layer as the potential flood extent in leveed areas.	HIGH	HIGH	HIGH
			<b>R87</b> - Care must be taken to ensure that for maps developed at stages above the effective elevation of the levee, areas behind levees are not shown as "flood extent in leveed areas" but rather as inundation in a non-leveed area.	HIGH	HIGH	HIGH
			<b>R88</b> - There should be three main layers that depict flooding around levees, as defined below: levee centerline, leveed area and leveed area flood extent.	HIGH	MEDIUM	MEDIUM

			REQ# REQUIREMENT	NWS	USACE	USGS
			R89 - Where available, the leveed area flood extent should show inundation conditions on the landward side of the levee (Figure 5.6). They can be controlled in a disconnected fashion from the reach map in a manner that allows individual leveed areas to be connected and adjusted in coordination with an event-based inundation simulation.	HIGH	MEDIUM	MEDIUM
			R90 - The default setting for an event-based map displaying levee information should show no flooding behind the levee system unless the levee is confirmed overtopped or breached.	HIGH	MEDIUM	HIGH
			R91 - Once flooding occurs, or is forecast to occur behind a levee (overtopping or breach), the landward levee profile of a stream reach map library should be activated and displayed according to the event forecast information.	HIGH	MEDIUM	HIGH
			<b>5.7 Data Requirements</b>			
			<b>5.7.1 Elevation Data</b>			
			R92 - The best available topographic data referenced to the North American Vertical Datum of 1988 (NAVD88) should be used for the development of geometric data for hydraulic model inputs and the generation of flood inundation map products from hydraulic model results.	HIGH	HIGH	HIGH
			R93 - Further, the vertical accuracy of the terrain model used for analysis should be appropriate for the intended use of the underlying river hydraulics model and the topography of the study area.	HIGH	HIGH	HIGH
			R94 - The horizontal and vertical data accuracy of the elevation data should be clearly documented according to Federal Geographic Data Committee (FGDC) standards (Federal Geographic Data Committee, 1998).	HIGH	HIGH	HIGH
			<b>5.7.2 Projections and Datums</b>			
			R95 - All flood mapping products, models and reports should be submitted to the IWRSS FIM system according to a documented and common measurement system, geodetic datum and projection.	HIGH	MEDIUM	HIGH
			R96 - All mapping products should use a common vertical datum, the North American Vertical Datum of 1988 (NAVD88).	HIGH	HIGH	HIGH
			R97 - All mapping products should use a common horizontal datum, the North American Datum of 1983 (NAD83).	HIGH	HIGH	HIGH
			R98 - All mapping projects should be submitted with a defined projection that is appropriate for the study. Albers Equal Area Conic USGS is recommended as a suitable model projection projects within the continental U.S.	HIGH	HIGH	HIGH
			R99 - All flood inundation map services hosted by the ISF should use a common projection for map data and mapping services; recommended is the World Geodetic System (WGS) 1984 Web Mercator (Auxiliary Sphere) projection.	MEDIUM	HIGH	HIGH
			<b>5.7.3 Project Documentation and Metadata</b>			
			R100 - When a flood map is submitted to the IWRSS ISF, a minimum standard for project documentation should be met as identified in Appendix G. Projects should be encouraged to submit as much documentation as necessary to conduct a proper peer review and ensure scientific reproducibility of the effort.	HIGH	HIGH	HIGH
			R101 - All spatial data submitted should include FGDC compliant metadata in addition to the project documentation (Federal Geographic Data Committee).	HIGH	MEDIUM	HIGH
			R102 - Common ISF metadata elements need to be standardized specific to IWRSS services, specifying required minimums for the data submission process.	HIGH	MEDIUM	LOW
			<b>5.7.4 Loss Estimation Reports</b>			
			R103 - If implemented within flood inundation mapping services the supplied loss estimation data should include estimates of population at risk, loss of life and structure and content damage (residential, commercial, industrial).	MEDIUM	LOW	MEDIUM
			R104 - Damage to agricultural areas and general indirect economic impacts to all locations may also be considered within loss estimates.	MEDIUM	LOW	LOW
			R105 - It is suggested that these broad loss estimation reporting categories be defined to allow population at risk estimates to be reportable from several loss-estimation models, such as FEMA's Hazus software or USACE's Hydrologic Engineering Center Flood Impact Analysis (HEC-FIA) software.	MEDIUM	LOW	MEDIUM
			R106 - Regardless of the loss estimation method chosen, it must be citable and reproducible and the methods and tools used should be provided along with the results.	MEDIUM	MEDIUM	HIGH
			R107 - If displayed on maps, consequences information should only be displayed at aggregated (county, etc.) levels.	MEDIUM	MEDIUM	HIGH
			<b>5.7.5 Data Submission</b>			
			R108 - When agencies and partners complete studies the project data submissions will need to include the following information in order for the minimum ISF capabilities to be available: digital elevation model location for review and/or retrieval, hydraulic model location for review and/or retrieval, location of cross-sections or mesh used to create the model for review and/or retrieval, inundation mapping layers required/optional per Section 5.1, documentation and metadata, optional loss estimation information, QA/QC checklist documentation, and certification by agency proponent that product has been reviewed.	HIGH	MEDIUM	HIGH
			R109 - When agencies and partners complete studies the project data submissions will need to include the following information in order for the fully implemented ISF capabilities to be available: digital elevation model, hydraulic model, cross-sections or mesh used to create model, inundation mapping layers required/optional per section 5.1, documentation and metadata, optional loss estimation information, QA/QC checklist documentation, and certification by agency proponent that product has been reviewed.	MEDIUM	MEDIUM	HIGH
			R110 - The final data parameters in the ISF should be determined by a far-reaching survey of existing studies and cooperators to ensure a balance between completeness and usability.	HIGH	MEDIUM	LOW
			R111 - Further effort is needed to evaluate the full range of data that could be included to the IWRSS ISF and develop a comprehensive list of data elements.	HIGH	MEDIUM	MEDIUM
			R112 - Detailed requirements should be developed for populating pertinent FGDC metadata tags. These requirements may restate existing FGDC requirements for metadata tags or may introduce IWRSS specific requirements on how to populate specific elements of the metadata.	HIGH	MEDIUM	LOW



		REQ#	REQUIREMENT	NWS	USACE	USGS
		R113 -	A set of detailed examples of completed metadata should be developed for each database element and made available alongside the QA/QC checklist and other tools.	HIGH	HIGH	MEDIUM
<b>5.8 Map Requirements</b>						
		<b>5.8.1 Basemap Layers</b>				
		R114 -	Common vendor-provided basemap services should be used for exported maps and for applications. Some basemap layers must include licensure that allow for publication of maps to map sheet formats and printing for public distribution.	MEDIUM	HIGH	HIGH
		R115 -	The current scope of the IWRSS FIM system does not include development or maintenance of a unique basemap or of any map annotation beyond what is displayed on the basemaps. Stakeholders and customers needing these capabilities can utilize IWRSS FIM map services and other desktop or online systems to meet their specific needs for basemaps or additional feature labeling.	MEDIUM	HIGH	HIGH
		R116 -	The range of basemaps available should, at a minimum, include topographic, aerial/imagery, and road/street map services.	MEDIUM	HIGH	HIGH
		<b>5.8.2 Flood Depth</b>				
		R117 -	Depths should be symbolized consistently within all map libraries and end products using a range of blue shades with transparency as defined in Appendix F.	HIGH	HIGH	HIGH
		R118 -	Depths to be mapped should be defined by the study provider, because appropriate depth ranges must be based on considerations of map purpose and usability as well as underlying elevation data and model accuracy considerations.	HIGH	HIGH	HIGH
		R119 -	Depth ranges should be consistently represented in all products within a map library, both exported versions and those presented in applications.	HIGH	HIGH	HIGH
		<b>5.8.3 Conveying Uncertainty</b>				
		R120 -	Uncertainty should be displayed on maps via the potential inundation area feature as defined in Appendix F.	MEDIUM	HIGH	MEDIUM
		R121 -	The potential inundation layer should be available as an option, and not as part of the standard presentation of an inundation map.	MEDIUM	HIGH	MEDIUM
		R122 -	Documentation must be captured regarding the sources of uncertainty used to define the area (terrain, model, forecast, and other considerations). The intent is to convey an area of uncertainty bounding the "best guess" extent of inundation. This feature can be displayed with the depth layer, but there is no intent to visually depict depth uncertainty, other than via the depth ranges provided in depth queries.	MEDIUM	MEDIUM	MEDIUM
		<b>5.8.4 Exportable and Printable Maps</b>				
		R123 -	The cartographically-controlled maps should be produced through the ISF in PDF format.	MEDIUM	MEDIUM	HIGH
		R124 -	A national tiling scheme based on existing USGS 7.5 minute quadrangles should be used for the controlled map sheets.	MEDIUM	HIGH	HIGH
		R125 -	The tiling scheme for controlled maps should at minimum provide for printing and exporting at fixed scales from a largest scale of 1:7,920 to a smallest scale of 1:126,720 with each scale increment being two times the scale of the previous map.	MEDIUM	HIGH	HIGH
		R126 -	North should always be the top of the map for printed maps.	MEDIUM	HIGH	HIGH
		R127 -	When the user requests a map the PDF returned by the ISF should be a file that includes as page 1 a map information page followed by one or more map sheets meeting the user request.	MEDIUM	MEDIUM	HIGH
		R128 -	The map information page is also recommended to be provided with maps requested through the ad hoc printing function.	MEDIUM	MEDIUM	MEDIUM
		R129 -	The map information page should provide map title, purpose and use, disclaimer, data sources, map notes and legend. An example is provided as Figure 5.4 and in Appendix F.	MEDIUM	HIGH	HIGH
		R130 -	The controlled map sheet(s) should include the map area, title block, Universal Transverse Mercator (UTM)/USNG reference tics, USNG grid zone and 100,000 meter grid ID designation, scale statement and join sheet labels.	MEDIUM	HIGH	HIGH
		R131 -	Join sheet labels of controlled maps should serve as hyperlinks to adjoining sheets.	MEDIUM	MEDIUM	MEDIUM
		R132 -	The map title block should display the same title as presented on the map information page, the unique map sheet identifier and the IWRSS logo.	MEDIUM	MEDIUM	HIGH
		R133 -	The map area should present the basemap service selected by the user, the flood inundation map layers that are on and visible in the interactive map, the map tile boundary, and labels showing adjoining map sheet numbers.	MEDIUM	MEDIUM	MEDIUM
		R134 -	Printed and exported maps should be uniquely identified by the bounding box defined by their USNG 1,000 meter identifiers per the following examples: 1:31,680 scale map - 15SUD59713238; 1:15,840 scale map - 15SUD60653638.	MEDIUM	HIGH	HIGH
		R135 -	These unique USNG identifiers will serve as map sheet numbers. A benefit of this approach is that all maps at all scales nationwide are uniquely identified.	HIGH	HIGH	HIGH
		R136 -	In combination, the map library ID and map sheet number should serve as the IWRSS ID for any map sheet.	MEDIUM	HIGH	HIGH
		R137 -	Geographic reference tics should be displayed on map sheets; UTM 1,000 meter tics are required for USNG referencing, and latitude/longitude tics are optional.	MEDIUM	HIGH	HIGH
		R138 -	Map sheets should present all information needed to uniquely identify locations based on the USNG: USNG Grid Zone, e.g. 15S; 100,000 meter grid unique identification numbers, e.g. YC, BH; and 1,000 meter tics.	MEDIUM	HIGH	HIGH
		<b>5.8.5 Mapping Scales and Standards</b>				
		R139 -	Scale bars in both feet/miles and meters/kilometers and ratio scales (e.g. 1:15,840) should be provided for all online map applications and map sheets. Engineering scales (e.g. 1" = 10,000') should not be used for flood inundation map products.	HIGH	HIGH	MEDIUM
		R140 -	The unit of vertical measurement for map scales should be U.S. survey feet.	HIGH	MEDIUM	MEDIUM
		R141 -	The unit of horizontal measurement for map products should be scale dependent, and may vary between either U.S. survey feet or miles.	HIGH	MEDIUM	HIGH
		R142 -	Scales should be consistently represented in all versions of maps, both exported versions and those presented in applications.	HIGH	HIGH	HIGH
		<b>5.8.6 Map Purpose</b>				

		REQ#	REQUIREMENT	NWS	USACE	USGS
			For each map presented, a narrative describing the map purpose should be made available, on the map or map information page for map sheets, via a menu option in online interactive maps and via either attribute or metadata from map services. Example purpose statements are provided in Appendix F.			
		R143 -		HIGH	HIGH	HIGH
		<b>5.8.7 Dates</b>				
		R144 -	All dates should be presented in format DDMMYYYY, for example, 01MAY2005.	HIGH	HIGH	MEDIUM
		R145 -	Dates should be consistently represented in all versions of maps, both exported versions and those presented in applications.	HIGH	HIGH	HIGH
		R146 -	Times when appropriate should be 24-hour and reference time zone, e.g. 1200 EST.	HIGH	HIGH	MEDIUM
		R147 -	The study date should always be presented in the map title. The study date is the publication date of the map.	HIGH	HIGH	HIGH
		R148 -	The forecast date should be presented in the map title for all event-based maps that predict flooding at a future time based on a forecast river stage profile.	HIGH	HIGH	HIGH
		<b>5.8.8 Map Titles</b>				
		R149 -	Map titles should have a summary title and detailed sub-title component consistent with the following examples. Information included in the [brackets] is specific to each map generated.	HIGH	HIGH	HIGH
		R150 -	Map titles should be consistently represented in all versions of maps, both exported versions and those presented in applications.	HIGH	HIGH	HIGH
		<b>5.9 Application Requirements</b>				
		<b>5.9.1 Geocoding</b>				
		R151 -	Standard geocoding functions should be available that at minimum allow for geocoding by street address, latitude/longitude and USNG coordinates.	MEDIUM	MEDIUM	MEDIUM
		<b>5.9.2 Depth Layers and Queries</b>				
		R152 -	Depths should be reported in U.S. feet.	HIGH	MEDIUM	HIGH
		R153 -	Depth data, while highly desired, may not be available and is not required for all studies.	HIGH	MEDIUM	HIGH
		R154 -	A depth layer should be available for display in all methods of delivery if the data are available.	HIGH	MEDIUM	HIGH
		R155 -	If depth data are available, the applications should allow the user to query the depth grid and request depth at a selected location.	HIGH	MEDIUM	MEDIUM
		R156 -	The query feature should report the depth grid value and should also provide an accuracy range rounded to the nearest 0.1 ft.	HIGH	MEDIUM	HIGH
		R157 -	Disclaimers or accuracy statements for depth maps and depth queries should display the accuracy of the result; the statement should state that the accuracy of results are limited by the quantified accuracy of the terrain dataset and the uncertainties inherent in the hydraulic model and river forecast.	HIGH	MEDIUM	MEDIUM
		<b>5.9.3 Exporting Maps</b>				
		R158 -	Exported maps should be requested via online interactive maps via common point and area selection functions.	MEDIUM	MEDIUM	HIGH
		R159 -	Exported maps should also be accessible via URL hyperlink requests that include latitude/longitude, USNG coordinate, USNG bounding box and/or unique map library identification numbers.	MEDIUM	MEDIUM	MEDIUM
		R160 -	The URL-based requests for exporting maps should serve as the alternative map access for Americans with Disabilities Act Section 508 compliance of the Rehabilitation Act requirements for access to maps.	MEDIUM	MEDIUM	MEDIUM
		<b>5.9.4 Clearly Identifying Event-Based Maps</b>				
		R161 -	There shall be one federal event-based map for a reach of river during a flood event. During a significant flood event, it will be important to ensure that the best available map representing the forecast conditions, should it exist, be clearly identified to assist users in a flood-warning situation.	HIGH	MEDIUM	HIGH
		R162 -	The event-based map should always be the prominent mapping feature that is displayed through the multiple delivery formats described in Section 5.1.	HIGH	MEDIUM	HIGH
		R163 -	Stream reach maps and historical flood documentation maps will be made available to the public stakeholders at all times, in addition to the one federal event-based map that is designated for a reach of river.	HIGH	MEDIUM	MEDIUM
		R164 -	A mechanism to quickly display the event-based map for active flood events, and provide a level of visibility that gives the event map primary focus, should be considered. It should be different from the standard workflow for selecting layers from map libraries, as it would keep users from having to manually select the most appropriate map layer(s) representing an ongoing flood event from all those that exist in available map libraries. An event-based map could be identified from an event-based map library created based on a recent forecast, or an existing stream reach map library inundation layer most near to the current stage or forecasted flood stage. The most current and best-available map scenario should be presented to the user.	HIGH	MEDIUM	HIGH
		R165 -	Further effort is needed to determine, within the concept of operations, the process and responsibility for identifying event-based maps from existing map libraries or for ordering real time modeling and mapping procedures to be undertaken to produce event-based maps.	HIGH	MEDIUM	MEDIUM
		<b>5.9.5 Displaying Multiple Flood Extent Layers</b>				
		R166 -	The multiple delivery formats described in Section 5.1 should be capable of delivering and displaying multiple flood extent layers simultaneously from a single map library.	MEDIUM	MEDIUM	MEDIUM
		R167 -	The multiple delivery formats described in Section 5.1 should be capable of delivering and simultaneously displaying flood extents from more than one map library.	MEDIUM	MEDIUM	MEDIUM
		R168 -	When multiple flood extents are displayed on one map, they should be symbolized in a manner to ensure they are clear and distinct, possibly as lines rather than filled polygons with differing line weights, line styles and colors.	MEDIUM	HIGH	MEDIUM
		<b>5.9.6 Displaying Historical Flood Documentation Maps</b>				
		R169 -	The historical crest record at the streamgage should be displayed at each mapping location.	HIGH	HIGH	HIGH

			REQ# REQUIREMENT	NWS	USACE	USGS
			Each historical crest record should be linked to the best available map, using the following selection procedure: (1) If a historical flood documentation study was conducted for the chosen event, the appropriate map should be displayed along with the accompanying link to the full study; (2) If an event-based map was created for the chosen event, then the event-based map should be displayed with all the timestamp information shown; (3) If a map out of the stream reach map library is determined to be relevant and representative of the historical crest, the appropriate stream reach map library should be displayed; and (4) If an appropriate map cannot be identified, then no historical flood map will be displayed for the crest record.			
			<b>R170 -</b>	HIGH	HIGH	HIGH
			<b>5.10 Training Requirements</b>			
			Mapping partners involved in the production of flood inundation maps will need training on the following topics: (1) requirements which must be met before flood inundation maps are to be disseminated, (2) scoping procedures, (3) QA/QC checklist, (4) project documentation (metadata, data registry), and (5) reporting standards.			
			<b>R171 -</b>	MEDIUM	HIGH	MEDIUM
			Mapping partners involved in the production of flood inundation maps will need training to understand how to effectively use the data registry to identify existing projects, available datasets, and report access. Data registry user training should include the following topics: (1) the registry's data fields, (2) the registry's features, and (3) the registry's access to available data sets.			
			<b>R172 -</b>	MEDIUM	HIGH	MEDIUM
			Stakeholders that will be accessing and using the uniform mapping services to make flood risk management decisions, require training on the following topics: (1) interpretation of uniform flood mapping products, (2) interpretation of customized flood mapping products and (3) data access through the four delivery formats.			
			<b>R173 -</b>	MEDIUM	HIGH	MEDIUM

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## Appendix B: Stakeholder Use Case Summaries

This section provides a summary of common flood emergency management phases and user activities considered to be within the scope of the envisioned NFIMS. These stakeholder use cases identify actions that could be enhanced by a robust flood inundation mapping services capability. The emergency management process for flooding is divided into the four phases of the flood risk management life-cycle, which has been previously adopted by the USACE as a conceptual tool for flood risk management and planning. These four phases have a defined theme and structured activities or actions that complement the theme. The four phases include: preparedness, response, recovery and mitigation. The flood risk management life-cycle and summary level description of activities are depicted in Figure B.1.



**Figure B.1. Flood Risk Management Life-Cycle (USACE, 2012).**

The following use case summaries describe the types of information that should be provided to meet the needs of stakeholders in each of the four phases of the flood risk management life-cycle. It must be understood that in most, if not all of these examples, the flood inundation map is only one component of what the stakeholder needs to make decisions. Much of the decision making occurs at a local level, and requires the fusion of highly-detailed local information with less detailed, regional information about flood risk and flood events. There is no intent for the scope of the envisioned NFIMS to fully meet the information requirements of stakeholders for all

emergency preparedness, response, recovery and mitigation activities. Rather the document intends to identify how this NFIMS may be able to enhance decision-making activities.

## **B.1 Preparation/Training Phase**

The preparation/training phase includes planning, training and preparations completed before the flood threat occurs. Depending on the type(s) of stream and river system(s) involved, time available to coordinate and activate emergency response in advance of flood waters can vary from weeks for a snowmelt driven event to days or to hours for a high-intensity rainfall driven event. During this phase, the public stakeholders decide if and when to take action, in response to the forecasts, warnings and response information provided by the emergency management authorities. In addition, event preparedness activities are initiated between federal, state and local agencies on reservoir regulation plans, reservoir releases, possible levee system overtops or breaches, planned levee system breaches, floodway operations, and flood-fighting activities. These activities are conducted at many jurisdictional levels including authorities from the federal, state and local government jurisdictions.

Internal multi-agency preparation activities may begin before public warnings are issued. Agency coordination ensures the best available and consistent information can be provided to the affected stakeholders and effective event planning can occur, resulting in organized and effective actions in the response phase. Flood risk management systems, levees, floodwalls and levee closure structures are prepared, tested and may be armored or enhanced. Reservoir release plans are developed, and flood fighting and sandbagging operations are planned and staged. Emergency Operations Centers (EOC) may be established, Emergency Action Plans (EAP) are reviewed and training may occur to rehearse for the event response. Flood mapping can assist all of these activities by providing a tool for planning, visualizing potential flood impact scenarios, and evaluating risk.

Public engagement during the preparation/training phase begins with flood warning dissemination. Warning products are broadcast through multiple sources including NWS watches or warnings, local media broadcasts, mobile Commercial Mobile Alert System messaging Systems (CMAS), public officials, social media and web pages. Flood inundation maps can assist with the process of training the public to respond to an imminent event by allowing them to visualize the flood consequences in advance of the event. Heightened public awareness as a result of maps displaying forecasted events should make citizens more responsive to official direction and also accelerate individual responses to threats to property. As with EAPs and evacuation plans, flood inundation maps are an important tool for flood risk outreach and awareness because most citizens readily comprehend the information conveyed by the graphic presentation of simple maps. Once information on pending flood threats is issued to the public, all affected stakeholders begin closely monitoring, coordinating, and participating in decision support activities for forecasted flood threats.

Flood maps provide the local media, who serve as a main conduit for distributing critical disaster information, with a powerful visual communication tool. Recent flood experiences in the U.S. show that if flood mapping is available, its dissemination at this time is more informative to the media and the general public than a river stage forecast alone. Flood inundation mapping, if reasonably accurate, allows local emergency management officials to more quickly and confidently implement evacuation plans and other actions to save life and property.

## **B.2 Event Response Phase**

The event response phase includes actions that are taken from the initial impact of the disaster and continue throughout the duration of the flood event. These actions include saving lives and preventing further property damage. Emergency coordination and response occurs immediately prior to and during a flood event. The event response phase is triggered by a local assessment of current conditions and of future conditions, through the evaluation of flood forecasts and warnings. In contrast to the preparation/training phase, any preparation of flood inundation maps in the event response phase are extremely time critical and should reflect as much as possible near-term conditions. For most flood events, it will be necessary to evaluate existing flood map libraries to river observations and forecasts to identify the map that most closely depicts the pending flood event and present that information as the initial “pending event map”. Whether or not event-based flood inundation mapping can or should be conducted as part of event response will depend upon the time to crest, the current state of hydraulic models and flood mapping systems for the at-risk area, resources available, accuracy of existing flood maps, and projected consequences and risk.

At the time emergency response is activated along a reach of river it is important to identify two items to the user: (1) that an emergency exists, and (2) the available map that should be used for the pending event. Reducing all available content to a single map or series of maps ensures all emergency management officials and responders at all levels of jurisdiction are working from the same map. For the same reason, it is important that all flood maps in all locations be presented in the same format. The best available mapping information should be presented as a flood extent warning area, the boundaries of which should be adjusted to account for inaccuracies inherent in the models as well as event uncertainties. If map confidence is depicted as anything other than a single area of flood extent the presentation should be simple, easy to interpret, integrated within the single flood map, and presented in a manner that highlights the maximum predicted flood extent.

Stakeholder response during the event response phase is a continuous, looping cycle of monitoring, assessment, and response to the flood threat. The public is made aware of the flood threat and is continuously motivated by emergency managers and public officials to take appropriate mitigation actions in response to the flood threat. Flood inundation maps can help the public better understand and relate to the impending flood threat. Emergency managers at the local, state and federal level are the primary leaders of the flood response. Emergency managers close roads, staff and manage a command center, and activate first responders. Community infrastructure managers and flood fighters continue to construct flood defenses and begin flood monitoring of community infrastructure. Flood mapping connected to streamgage stage forecasts can assist with the identification of bridges, roads, infrastructure and areas that may be impacted and identify the timing of the impacts. The emergency management staff need to know what will be impacted and when the impacts will occur, so the resources needed to respond can be staged and coordinated. Throughout the response phase, first responders evacuate the at risk public to shelters and may be involved in flood fighting operations within the community. Flood mapping can assist first responders in identifying at risk populations, and identify the most effective and safe transportation routes for accessing or evacuating the impacted areas.

It is essential that flood maps are made available to the team of emergency managers and first responders in a robust, consistent, and highly reliable form that is capable of being used in the field, and on mobile computing devices such as smartphones and tablets. Because internet-based technology may not be reliable during a disaster, the maps must be made available in an

electronic form that can be used offline and viewed or printed by the end-user. In addition, the flood mapping data must be made available to these emergency management users in both a form to download and as highly reliable OGC standard geospatial web services, so that the users may view the data within the context of their own GIS systems. Providing the ability to access the flood inundation map service via multiple software platforms should maximize dissemination and allow for the information to be presented in a manner most appropriate to the user for the event and purpose, such as a basic map presented by local media or as part of a more detailed evacuation order issued by state or local emergency management.

Flood fighters begin the tactical positioning and construction of flood fighting defenses to begin their response to the hydrologic forecast. Levee infrastructure managers and levee districts begin flood fighting activities and the operation/maintenance of flood fighting defenses. Flood impacts and flood protection system performance is monitored and reported to flood fighting teams. Corrective actions may be necessary to repair or enhance the flood protection systems in response to a changing flood threat. Flood mapping can provide assistance with understanding the impacts behind flood infrastructure, and the consequences of the failure of the flood protection infrastructure.

The IWRSS team and federal agencies are highly involved during this period. USACE may project levee freeboard and or overtopping, may coordinate daily flood fighting activities with a liaison team, maintains river gaging systems and plans reservoir releases to minimize flood impacts. NWS coordinates the development of river forecasts and disseminates flood forecasts and warnings through the Emergency Alert System. USGS maintains critical streamgauge networks, measures streamflow at gaged and ungaged locations where additional data are needed, and extends rating curves for emergency operations. All federal partner agencies can benefit from flood mapping for individual and joint agency missions.

## **B.3 Recovery Phase**

The recovery phase begins with actions taken after the initial impact, including those directed toward normalcy. Flood damage assessments, cleanup and debris removal begin almost immediately after the event impact begins to decrease. Flood inundation mapping can assist recovery by delineating the impacted area, predicting when road and bridge access may be restored, and serve as an initial tool for quantifying the severity of impacts. The severity of flood impacts are driven by the actual inundation depth, stream velocities experienced during the flood, and the duration of inundation (wetting). Flood mapping that identifies depth and velocity instantaneously and over a selected period of time can assist with the classification of the severity of flood impacts and assist in getting flood disaster relief funds to the affected communities faster.

Recovery phase activities are driven by financial aid, social services, and other recovery resources. Aid may be distributed to the impacted areas, immediately after the event, in the form of establishing shelters, providing social services, assisting with cleanup, providing food, labor, other needed supplies, or assist in getting flood disaster relief funds to the affected areas. Financial aid is distributed to homeowners, business, state and local agencies later in the recovery period, and serves to speed the recovery process. The FEMA National Flood Insurance Program (NFIP) issues payments for those homeowners and businesses that are holders of flood insurances policies. FEMA may issue disaster declarations, which will lead to the transfer of federal funding from FEMA to the state hazard mitigation agency. Private insurance companies reimburse expenses as a result of policy claims for storm-related damage,



and need to evaluate which structures were damaged by flooding and other storm-related events. The amount of money distributed by FEMA is dependent on the damage recorded during the event. Flood mapping can help speed the distribution of funding by providing a tool for conducting a generalized damage assessment and for planning detailed damage assessment.

Infrastructure is repaired in the recovery phase, as the event subsides. Utilities, which may include water, sewer, power, natural gas, may require restoration. Public infrastructure, including roads, bridges, community buildings, traffic signals or public spaces may need repair or restoration. Private Citizens and businesses will need to repair or rebuild homes and businesses. USACE, levee districts, or local communities may repair or rebuild levees that were damaged or destroyed during a flood event. Flood inundation mapping can assist with the repair of public and private infrastructure, by providing a tool to identify damaged areas. Inundation mapping data can help communities identify which locations and components of public infrastructure may be the most damaged, allowing the communities to inspect damage, organize a recovery plan, prioritize repairs, and develop plans for more resilient structures.

Recovery activities, conducted by IWRSS partners, may include documentation of high water marks, hydraulic model refinement, and hydraulic model recalibration. Flood maps prepared before an event would be compared to the actual event to confirm reliability of the mapping products. USACE may be involved in extensive efforts to rebuild or rehabilitate levee systems. NOAA may have to recalibrate hydrologic forecast models to better match newly recorded record events. USGS may repair gaging infrastructure, extend rating curves to incorporate new data from a flood of record, and use the new peak flow observations to refine flood frequency estimates. Flood inundation maps, within the affected areas, would need to be updated based on changes to levee systems or other flood protection infrastructure. Model calibration and rating curve changes also may result in flood map updates.

## **B.4 Mitigation Phase**

The mitigation phase of the flood response life-cycle includes activities to prevent a disaster, reduce its chance of happening, or reduce its damaging effects. In contrast to the previous phases of the flood response life-cycle, preparation of flood inundation maps in the mitigation phase is not highly time-critical and the parameters used to define flood events are not based on current or near-term conditions. Viewing multiple formats and types of flood inundation maps is acceptable, although a common presentation format is preferable.

During the mitigation phase the focus is on planning for future flood events. Flood inundation maps used during this phase are either of past (historic) or potential events deemed appropriate for planning purposes. Flood maps for Emergency Action Plans typically show the predicted extent of flooding from predetermined events whose parameters are defined for planning purposes. A range of predetermined events can be evaluated and provided as a map library to support more specific and tailored emergency planning. At the local level such maps are used to prepare evacuation plans, possibly including evaluation maps that identify evacuation routes from potentially flooded areas, identify appropriate locations for command and control, and evacuation and relief centers. Evacuation maps and flood inundation maps are different products with different purposes.

Public outreach and engagement during the mitigation stage is a critical activity. The public must be made aware of their flood risk, and must be engaged in activities to assist with the

mitigation of individual flood risk. Flood mapping can help the public identify the degree of structural mitigation actions that may be required. Structural mitigation actions at the individual household level may be expensive and cost prohibitive. The purchase of a flood insurance policy may be a more cost effective non-structural method for the public to mitigate flood risk.

Because of the National Flood Insurance Program, the public has become widely aware of FEMA's 1-percent annual exceedance probability (AEP) flood mapping products. Additional flood mapping products that are related to FEMA's 1-percent AEP maps can help the public realize that a flood risk exists, even outside of a 1-percent AEP flood zone, where insurance purchases would be required for mortgaged properties. The National Flood Insurance Program is the primary means of offsetting the costs of flood damages in the United States. Flood Insurance Studies are performed to determine flood prone areas eligible for flood insurance. These studies evaluate 1-percent AEP and 0.2-percent AEP events and result in flood inundation maps for those frequency-based events. Local community planning and zoning activities utilize FEMA Digital Flood Insurance Rate Maps (DFIRMS) and other frequency-based flood inundation maps as inputs for identifying flood prone areas and are tools for local governments to encourage appropriate land uses. DFIRMS, like stream reach and event inundation maps, should be updated when urbanization or other anthropogenic or natural factors sufficiently impact the hydrology and associated flood risk in a given floodplain.

Communities and infrastructure managers must develop actionable response plans to prepare for disasters. Emergency action plans (EAPs) are created during the mitigation phase and are the initial information available to guide the preparedness, training, and response phases. EAPs define sequences of key response activities, roles and responsibilities and key points of contact critical for responding to an emergency event. EAPs have varying levels of detail, but tend to become more specific at the more local levels. An EAP for the owner or operator of a facility designed to mitigate flooding, such as a dam or a levee for example, would focus only on aspects specific to the facility. State EAPs, among other things, would define the separation of responsibilities among state and local emergency authorities. Community EAPs would provide the greatest detail and the local information readily usable by residents of the flood zone. Flood inundation maps are a valuable component of all types of flood EAPs and, like the EAPs themselves, will vary in both purpose and level of necessary detail.

In general, flood inundation maps only need to show predicted extent of flooding on a common base map for the information to be useful for emergency preparedness activities. Other useful information, when available, includes flood depth, floodwater velocity, flood duration, and flood crest arrival time. Estimates of consequences are useful for conveying the magnitude of impacts; communication of estimated population at risk and damage to buildings and infrastructure can make pending flood risks immediately tangible. Flood crest arrival time information is also extremely useful information. This is commonly presented as date and time of damage-inducing river stages and of the peak. For EAPs of a dam or levee, flood arrival time would be defined as time for flood water to arrive at a location following overtopping or failure of the structure. All flood map information presented should clearly document the flood scenario evaluated in the mapping. The scenario could range from something simple, such as evaluated river stage for areas in close proximity to a streamage, to complex such as larger reaches where more dynamic events are presented. For planning purposes, it is also useful to know the frequency of the mapped event.

Mitigation strategies include developing projects to reduce the likelihood of flooding, such as dams, levees and projects to increase channel capacity; efforts to offset the damages incurred by flooding; and efforts to encourage appropriate uses of flood prone areas. Risk mitigation

projects go through many phases. The first phase is reconnaissance study, which would typically use existing flood inundation map. Following phases include feasibility studies to determine the range of project options, their costs, and subsequent benefits if constructed in terms of reduced economic damage. Subsequent phases of planning and design are meant to ensure that the constructed solution provides the maximum benefits per unit cost, is based on sound engineering principles, and is environmentally suitable. These studies produce calibrated hydraulic models and frequency-based flood inundation maps that could be used for additional purposes.

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# Appendix C:

## Current Agency Flood Inundation Mapping Operations

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### C.1 NOAA National Weather Service

The NOAA National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy as cited in the National Weather Bureau Organic Act of 1890 (U.S. Senate, 1890). NWS forecast data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. The NWS is the designated federal agency mandated to forecast the Nation's rivers and provide warnings to communities, all in an effort to minimize flood impacts and save lives as cited in the Inland Flood Forecasting and Warning System Act of 2002 (U.S. Senate, 2002). NWS coordinates with the United States Geological Survey, the U.S. Army Corp of Engineers, the Federal Emergency Management Agency, the Bureau of Reclamation and local cooperators in this effort. Hydrologic forecasts and warnings are issued in the form of single-value river forecasts, 90-day probabilistic outlooks, short-term flood outlook, advisory, watch, warning products, and static flood forecast inundation maps.

The NWS has undertaken an expanded effort to provide information on the spatial extent and depth of flood waters in the vicinity of NWS river forecast locations in the form of static flood forecast inundation maps, as cited in the *NWS Directive 10-901, Sec 3.4* ([NWS, 2011](#)). A NWS flood forecast inundation map provides an estimate of the areal extent of flood waters and depth of flooding for a specified area relative to a real-time flood forecast per the *NWS Directive 10-950* ([NWS, 2012](#)). There are a variety of mapping techniques and approaches that may be utilized to estimate the extent and depth of the flooding. The technical approach is determined by the complexity of topography, hydrology, bathymetry, hydrography, hydraulics, and geospatial analyses identified in the *NOAA Partnered Guidelines, Sept 2011* ([NOAA, 2011](#)).

The key NWS public product of the [Advanced Hydrologic Prediction Service](#) (AHPS) is the web-based flood forecast inundation mapping interface which allows users to display maps for various levels of flooding including observed and forecast stages, user-selected stages, and established flood categories ([NWS FIM, 2013](#)). The maps can be used to show if roadways, streets, buildings, airports, and other structures are likely to be impacted by floodwaters. Combined with USGS river observations and NWS forecasts, these flood forecast inundation maps enhance the communication of flood risk and provide users additional information for mitigating the impacts of flooding and building more resilient communities.

Since the development of flood forecast inundation maps involves significant financial resources, human capital, data requirements, and data analysis, NWS works with partners who can contribute financial resources and technical mapping expertise towards the development of flood forecast inundation maps for new areas. Offices at all levels of the NWS contribute to the process. For each river location or group of locations for which maps will be developed, a project team is formed consisting of Weather Forecast Office, River Forecast Center, and regional headquarters personnel and the technical mapping partner. These teams develop flood forecast inundation maps and map libraries to uniform standards published in the NOAA

*Partnered Guidelines* ([2011](#)) and the NWS flood forecast inundation map *Project Development Template v1.2* ([NWS](#)).

The AHPS flood forecast inundation map projects are constrained by the following issues: (1) availability of outside project funding, (2) identification of a technical mapping partner to develop the flood forecast inundation map project, (3) presence of or need for an AHPS flood forecast point at a proposed flood forecast inundation map location, (4) available topographic data and hydraulic modeling that meets NWS requirements, (5) NWS staff resource availability to participate in the project, and (6) a location and reach of river suitable for static flood forecast inundation map development.

## **C.2 U.S. Geological Survey**

In relation to water resources and natural hazards, the mission of the U.S. Geological Survey (USGS) is to collect and disseminate reliable, impartial, and timely information that is needed to understand the Nation's water resources in order to minimize loss of life and property from natural disasters.

The mission of the USGS for the Mission Area of Natural Hazards, as it relates to Flood Inundation Mapping, is to develop and apply hazard science to help protect the safety, security, and economic well-being of the Nation. A sustainable society requires a responsive government to reduce the loss of life and disruption caused by natural hazards. The USGS role is to make and effectively communicate reliable statements about hazard characteristics such as frequency, magnitude, extent, speed of onset, consequences, and where possible the time of future hazardous events, derived from a growing understanding of the physical processes responsible for the hazards.

Scientific analysis and research are critical as the Nation strives to be more resilient to hazardous events and natural disasters. The natural processes leading to events that are potentially hazardous to human society are ongoing and only hazardous when their effects exceed the range that is expected or planned for. As the agency with the perspective of geologic time, the USGS is uniquely positioned to extend the collective experience of society to include events over that much greater time scale. The science also provides information that decision makers need to determine what risk is acceptable and what risk reduction activities are feasible.

Hazard science comprises several interlocking components: observations, fundamental understanding, assessments, forecasts, warnings, and crisis and disaster response. The components are linked and overlapping; progress within one component supports and contributes to progress in other components. The USGS Hazards Mission Science Strategy identifies goals and strategic actions that will lead to more accurate, higher resolution, and timely hazard assessments and warnings of natural hazards based on sound fundamental understanding and supported by robust observations. Effective hazard assessments and warnings will have an increased impact on hazard planning, preparedness, and response decisions and will result in reduced hazard vulnerability.

The USGS develops assessments of natural hazards, vulnerability and risk to inform decisions that can mitigate adverse consequences. Assessments are a practical tool for decision makers to increase risk-wise behavior and a primary way that the USGS can communicate hazard science. Assessments can address natural hazards, vulnerability, and risk.

Flood Inundation Mapping services meet the core responsibilities of USGS Natural Hazard assessment responsibilities. In order to fulfill its mission and statutory responsibilities, the USGS must continue to: (1) Create hazard assessments used to support decision making, based on fundamental understanding of natural hazards, (2) Evaluate the assessments using observations made at national and regional scales and over long time periods to capture significant and infrequent events, (3) Develop new assessment tools to improve the scientific foundation of assessments as new understanding evolves, and (4) Inform the public about natural hazards to promote risk-wise behavior by publishing assessments and providing assessment tools using USGS scientific information ([Holmes Jr, et al., 2012](#)).

The Science Strategy of the USGS for the Mission Area of Water discusses Flood Inundation Science and Mapping as a Priority Action for the USGS over the next ten years (2012-2022). This Priority Action includes developments in static and dynamic mapping and developing a core science team from the USGS and other federal and partner agencies to address the tools and methods to help educate the nation about local flood risk. The Water Mission Area and Natural Hazards Mission Area directly overlap with their goal of promoting flood-inundation map library development and sciences ([Evenson et al., 2012](#)).

The USGS develops flood-inundation map libraries through our Water Science Centers which are partly funded by the USGS Cooperative Water Program. The WSCs collaborate with local partners to choose the appropriate project reaches and develop the maps relevant to the community flood risk and needs. Typically, these projects are focused on a reach with a USGS streamgage that is used as a NWS flood forecast point. Real-time data are used to bring context to the map during a flood event. Each map produced has an accompanying USGS report (Scientific Investigations Map Series or Scientific Investigations Report Series) that details the model, base elevation data and methods used. Additionally, the map libraries can have other supporting information, such as, HAZUS flood loss reports for the reach at each flood stage and/or real-time webcams near the USGS gage to confirm flooding conditions. All of these tools are made available to the users together in the *USGS Flood Inundation Mapper* ([U.S. Geological Survey](#)).

USGS flood-inundation map projects are constrained by the following issues: (1) projects are largely funded through the USGS Cooperative Water Program requiring that a local or state partner fund at least half of the expense of the project; (2) the presence and funding of a USGS streamgage for the map location; (3) available topographic data and hydraulic modeling that meets USGS requirements; (4) the development of a publishable USGS report to document the development and limitations of the map; and, (5) the availability of USGS staff to participate in the project.

### **C.3 U.S. Army Corps of Engineers**

The U.S. Army Corps of Engineers (USACE) has been acting in the public interest to address flood problems since the mid-1800's. Since the enactment of the *Flood Control Act of 1917*, the USACE has played a significant federal role in managing flood risk nationwide ([U.S. Congress, 1917](#)). However, the USACE mission and its implementation have evolved over time, moving from flood control to flood damage reduction and, most recently, to flood risk management. USACE formulates projects, designs, builds, operates and maintains a diverse portfolio of flood risk management infrastructure throughout the United States consisting of dams and reservoirs, levees and channel improvement projects. The USACE (Corps) Water Management System (CWMS) is used to support real-time operations of USACE flood risk management infrastructure, including development of flood inundation mapping.

The *Water Resources Development Act of 1996* tasked the National Academy of Sciences (NAS) to evaluate the impact of risk-based analysis on project formulation, and to determine the scientific validity of applying risk-based analysis in flood damage reduction studies (NAS, 2000). Since 1996, design and analysis of all USACE projects must be informed by flood risk management principles. Flood risk management is the process of identifying, evaluating, selecting, implementing and monitoring actions taken to reduce and manage flood risk ([USACE, 2006](#)). USACE flood risk management projects are planned, designed, constructed, and operated to protect people and property from adverse impacts of floodwater in a manner that will "contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements" (U.S. Water Resources Council (WRC), 1983). The USACE employs flood risk management procedures to all levels of planning studies and other USACE studies including, but not limited to, levee evaluation, permitting applications, and operation of reservoirs and other water control facilities.

As part of the Dam Safety, Levee Safety and Critical Infrastructure Protection and Resilience Programs, the USACE develops flood inundation maps for a broad range of project scenarios, including overtop and breach scenarios. These maps are used within emergency action plans as well as to inform program investment priorities. These products are developed by the USACE Modeling, Mapping and Consequences (MMC) center of expertise.

The USACE Water Management System (CWMS) is used to support real-time operations of USACE flood risk management infrastructure, including development of flood inundation mapping. The CWMS has been developed for the purpose of providing a single, integrated package of data management and near-term modeling tools to meet the needs of water control managers within the USACE. Using an integrated suite of USACE Hydrologic Engineering Center (HEC) modeling applications, CWMS retrieves precipitation, river stage, gate settings and other data from field sensors, and validates, transforms and stores those measurements in a database. The measurements are used for calibration and adjustment of hydrologic and hydraulic models to reflect current conditions. Once the models have been adjusted to reflect current hydro-meteorological conditions within a watershed, they can be executed to produce forecasts of hydrologic conditions, including flood inundation maps that will assist water managers in evaluating the effects of their operating decisions in the near future. Many USACE District Offices routinely produce flood inundation maps for internal use through CWMS via H&H modeling applications.

USACE works in close coordination with other federal, state and local agencies to ensure flood inundation mapping is available for emergency planning, response and mitigation activities. As documented in Engineer Circular (EC) 1165-2-215, USACE standard policy is to mark flood inundation maps "For Official Use Only" (FOUO) in accordance with Army regulations and manuals (USACE). Examples of stakeholders with which FOUO static (non-editable) information is routinely shared include federal agencies such as the Department of Homeland Security (DHS) and the Federal Emergency Management Agency (FEMA), adjacent and potentially impacted dam and levee owners, and state and local authorities who provide emergency services and/or notification. USACE intent is to assist local authorities in their mission of protecting public health, safety and welfare, while limiting the extent to which information could be used to threaten a project's security. Supporting (editable) data is only provided upon request and only through close coordination to assure appropriate use within model constraints.

EC 1165-2-215 allows USACE commands to release non-editable (static) inundation map data to the public when deemed necessary for public safety in extreme events, provided that all



FOUO information is removed (USACE). During an emergency such as a flood or potential flood event, H&H modeling is done in partnership with the NWS by District offices or the MMC to support real time flood fighting efforts. USACE Divisions have the authority to release data developed to support real time flood inundation mapping to the public in support of flood fighting activities as well as making the public aware of potential consequences. Divisions may delegate the authority to their District Offices. If the flooding event is of national significance, Headquarters USACE may host the flood inundation data as a web service to the public to communicate the extent of flooding condition.

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# Appendix D:

## Flood Inundation Mapping Requirements for the System Interoperability and Data Synchronization Requirements Team

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The following requirements were identified through the IWRSS FIM scoping process and provided in 4.3.3 of the IDS Requirements Document to complement the data-centric requirements put forward to the IDS design team. These requirements ensure consistent FIM services through access and exchange of information used for flood inundation mapping. This section states the data centric functional requirements for FIM by addressing the FIM “information exchange” requirements. Solution for IDS must include these data in terms of format, transfer, protocol and metadata standards. The IDS design team is encouraged to review the full FIM scoping and Requirements report.

FIM requires access on the same data sets made available through IDS requirements defined in the above section for:

- **Hydro-Meteorological Forcing Data and Model States**
  - Real-time Data to assist in Decision Support, such as radar, precipitation, satellite imagery which are overlayed on top of a Flood Inundation Map
  - Interactions between Continuous Modeling and Hydraulic Modeling for FIM Event-based Maps
  - River forecast, including Flood Warning Polygons, to assist FIM to determine spatial and temporal resolution for FIM.
- **Streamflow Observational Data and Ratings**
  - Ratings used to convert flow to stage at FIM location
  - Ratings, included for the purpose of modeling river elevation intervals at FIM location
  - Stream Gage Datum, to cross reference the stage and elevation of the Water Surface Profiles at the Gage
  - Streamflow Observations to inform approximate stream reach map from FIM libraries
  - Flood Categories for the generation of FIM Layers specific to known stakeholder criteria used in Decision Making.
- **Water Management**
  - Reservoir and Dam Safety Status, which could be overlayed onto Flood Inundation Map to provide decision makers an understanding of the flood operations in effect to reduce or alleviate flooding
  - Dam Break EAPs from USACE Map Modeling Consequence Group, includes dam breach inundation map based on modeled conditions
- **Integration and Interoperability**
  - FIM-related data must consider community-adopted model and format standards for geospatial data specified by IDs so that a common Geospatial Fabric or enterprise GIS can virtually exist amongst the IWRSS stakeholders
  - FIM- related data and map outputs need to be exchanged through a well defined intersystem communication, as such IWRSS FIM Requirements have specified

the need for the IWRSS FIM Information Services Framework (ISF) to catalog available FIM-related data for the exchanges.

Specific data for FIM exchange, which have not been explicitly specified in the IDS requirements but should be considered as part of the IDS design, include:

- **Elevation Datasets**
  - Digital Elevation Models
- **Hydrologic and Hydraulic Models**
  - Structure
  - Cross Sections
  - Stream Centerline.
  - River Station Miles
  - Water Surface Profiles and Contours
- **Levee Status and Data**
  - National Levee Database
- **Flood Data**
  - Geospatially referenced Flood Impacts
  - Impacted Roadways and Transportation Network,

The data-centric requirement for IDS include:

**R4.1. Description:** The IWRSS Consortium identifies a common digital elevation model (DEM) standard, including current vertical and horizontal datum standards, and metadata standards, for use in hydrologic and hydraulic modeling activities. In particular, the DEM shall be conditioned to the bare earth at a sufficient enough resolution for varying mapping needs; the needs for FIM have been specified to the USGS 3D Elevation Program<sup>1</sup>. All mapping products shall use a common vertical datum, which is currently at North American Vertical Datum of 1988 (NAVD88) and common horizontal datum, currently North American Datum of 1983 (NAD83).

**R4.1. Rationale:** DEMs used in various activities across the IWRSS consortium either be synchronized between multiple DSS where common services are provided, or conform to IWRSS standards so that coupled services can be built around a common understanding of the terrain spatial representation.

**R4.1. Solution-Risk:** Moderate/High

**R4.1. Priority:** High

**R4.2. Description:** Upon completion (final calibration or publication), IWRSS Consortium members should make available the Hydrologic and Hydraulic Models including the representation of structures, cross-sectional information, stream centerline, stream characteristics, and river station miles). The models should include pertinent assumptions made in its development and its validity of its data collection, in terms of timeliness and accuracy. The models should also show the upstream and downstream boundaries.

**R4.2. Rationale:** The sharing of hydrologic and hydraulic models would help offset the cost and time to develop stakeholder-required flood inundation maps. The cost and time are main drivers on why there are limited actionable flood inundation maps. In addition, the modeling parameters would include key data, such as the channel conveyance (structures, cross-section, bed-slope characteristics, stream centerline) and flood flows, which are main considerations for determining the water surface profiles. The boundary

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<sup>1</sup> <http://nationalmap.gov/3DEP/>

conditions are critical to show the extent of the models, so that the proper scaling can be determined for FIM. Most importantly, a consistent centerline will allow FIM mapping development to align with the existing hydrologic and hydraulic models being shared by IDs. The sharing of common river station mile references will allow agencies to quickly identify particular river locations in the model, on the map, or on-sight flood coordination.

**R4.2. Solution-Risk:** Moderate

**R4.2. Priority:** High

**R4.3. Description:** USACE provides full access to NLD to the IWRSS Consortium, which would include the current Levee status and pertinent data.

**R4.3. Rationale:** Proper modeling of the levee and its current status would better inform the proper routing of flood flows through a leveed section of the floodway. Considerations for when the levee is being operated or when flows are being distributed to alternative floodways would allow downstream communities to better realize their appropriate flood risk in terms of what flows are being regulated downstream.

**R4.3. Solution-Risk:** Moderate

**R4.3. Priority:** High

**R4.4. Description:** NWS seamlessly and transparently provides flood data to inform and enhance decision support including the following new fields of geo-referenced data: a) latitude/longitude of center of bridge, levee center-point, address of building, or other critical infrastructure and associated flood impact, b) critical stage and elevation; c) associated USGS/other gage; and d) associated Flood Impact statement describing the warning and response.

**R4.4. Rationale:** Geocoded information allow for enhanced coordination so that areas, services, and infrastructure impacted can be quickly identified and the source notified for improved flood fighting, mitigation, preparation, and resiliency. In addition geocoding by street address, latitude/longitude and U.S. National Grid (USNG) coordinate will allow users of FIM to locate particular features of the map and its associated flood risks. Point-of -contact information with name, email, and phone will allow agencies to rapidly coordinated during, before, and after a flood.

**R4.4. Solution-Risk:** Moderate

**R4.4. Priority:** Moderate

**R4.5. Description:** In accordance to IWRSS FIM Services standards and guidelines, the member agencies provide a base set of map layers with a common layer symbology to IDs for exchange with the member agencies. These map layers inform the spatial extent of flooding and make available flood depths, where appropriate. All spatial data will have Federal Geographic Data Committee (FGDC) compliant metadata. Any data restrictions, use, or disclaimers shall also accompany the maps.

**R4.5. Rationale:** Shared FIM Maps could be routinely shared and exchanged, for immediate use in flood fighting, mitigation, response, and recovery. Sharing this information ensures consistency within application supporting a first-cut of a common operating picture for flood inundation mapping. Although the IWRSS agencies will negotiate the widest use and lesser restrictions, map features may have encumbrances added for restricting it to conditionally uses, such as critically sensitive information For Official Use Only (FOUO), by partnered stakeholders.

**R4.5. Solution-Risk:** Low

**R4.5. Priority:** High

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# **Appendix E:**

## **Concept of Operations and Information Services Framework Description**

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Defining the current and proposed roles, contributions, and interactions of participating agencies through an interagency IWRSS process that will streamline the submission, review, and publication of flood inundation mapping products is the purpose of this section. The collaboration will be across the agencies and may involve multiple programs within those agencies to develop and support products that have the potential to be more than the sum of each partners' efforts. When fully developed, this process will meet individual agency scientific peer review requirements and is agency independent. That independence allows for all cooperators, federal, state, local, and private groups to have access to the same quality assurance process, produce the same reports, and make available final maps in a centralized system with no single agency bearing the responsibility and costs of approval and publication. In addition, this section references the IWRSS Information Services Framework (ISF), which is described in detail in Section 4. The ISF is the core IWRSS system that contains an integrated set of components used for gathering, processing, storing and communicating multiple types of information for improved organizational efficiency.

### **E.1 Current and Proposed Agency Roles**

The following paragraphs describe each agency's role in a collaborative concept of operations, identifies current functions within each agency that are vital to the National Flood Inundation Mapping Services and proposed new partner agency functions that would be integral to the success of the collaboration.

#### **E.1.1 NOAA NWS Operations**

The NOAA National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the purpose of protection of life and property. The traditional hydrologic forecasts and warnings are issued in the form of single-value river forecasts, 90-day probabilistic outlooks, and short-term flood outlook, advisory, watch, and warning products. These products are distributed using a highly-available, OGC compliant web service which allows NWS products to be displayed interactively within other web pages.

The NWS process to develop flood outlook, watch, and warning products requires NWS hydrologists to determine the spatial extent of flooding. IWRSS flood mapping products will enhance current NWS forecast and warning processes by providing additional sources of information that can be used to guide the spatial definition of outlook, advisory, watch, and warning polygons. IWRSS flood inundation event-based maps, and derived products, will better guide the NWS in the process of issuing a more area-specific, event-driven, and impact relevant warnings for targeted reaches of river. NWS flood warning polygons could be published to include a very narrow geographic area, guided by the flood inundation mapping layer, and customized to a specific flood event.

NWS should continue to partner with state, local, and private sector agencies to develop stream reach flood inundation maps that can be published within the IWRSS Information Services Framework (ISF). The current business model for developing the flood inundation maps would

change, and the new model would follow the IWRSS standards and protocol for developing and delivering the flood maps. NWS would contribute staffing resources to conduct outreach to identify new mapping partners to continue the development of flood maps, provide staff to conduct IWRSS flood mapping QC data reviews, and conduct project specific outreach to inform technical mapping partners of the requirements for developing and submitting data to the IWRSS ISF, and to provide education on flood inundation maps and their uses.

A new NWS service should include the operational production of event-based mapping products, following IWRSS guidelines. The NWS should examine opportunities to leverage operational HEC-RAS and other hydrodynamic models which could serve as the basis for the routine production of flood inundation event-based maps. As an example, the North Central River Forecast Center has developed an operational method for producing a HEC-RAS based event-based map for a reach of the Red River of the North, in partnership with the Red River Basin Decision Information Network. A similar event-based map could be produced for a location where a HEC-RAS model is used in NWS operations or any coastal area where NWS has coupled the CHPS forecast system to a coastal or an estuarine hydrodynamic model.

Existing NWS warning products would be further enhanced by embedding known current and forecast conditions for levee systems and flood-control reservoir systems within the NWS forecasts, including XML and RSS feeds. This process is dependent on USACE, USGS and NWS emergency management partners communicating levee failure status to NWS Weather Forecast Offices before, during and after a flood event. Tools should be developed that allow the USACE and NWS to better coordinate the release of flow from reservoir systems. This would involve tightly coupling the reservoir operations models used by USACE to the operational hydrologic model used by NWS to produce forecasts.

Flood impact statement enhancements, identified in section 5, require a change to the format of NWS flood impact statements. Standard NWS flood impact statements could be spatially referenced as described in section 5. This would enable any AHPS data point or forecast point to be tagged for spatial flood impacts. Spatial tagging of flood impacts would not require the development of a flood inundation map. This activity would provide IWRSS stakeholders with the ability to spatially visualize flood impacts at any AHPS location. NWS Hydrology Program Manager assistance would be required to spatially locate flood impacts on the IWRSS maps.

Bridge impacts should be documented by the NWS as a spatial impact as defined in section 5. A standardized method for documentation of flood impacts at bridges could further enhance the communication of flood risk to the public and serve to assist emergency managers with scheduling bridge closures. Bridge impact documentation would require collaboration between the NWS Service Hydrologists and the local community and/or emergency manager to define distinct flood impact levels at bridges. These impact levels would be displayed as an IWRSS service and could be communicated in NWS warning products.

All of these proposed interactive products must be supported and accessible through a highly-available, OGC compliant web service which will allow NWS outlook, advisory, watch, and warning products to be displayed interactively within the IWRSS ISF and other web pages. NWS should provide OGC compliant services for layers described in section 5 and ensure the services meet the ISF standards defined in section 4.

### **E.1.2 USGS Operations**

One of the primary missions of the USGS Water Mission Area is to collect stage and streamflow information from the streams and rivers of the US and deliver those data in a useable form and



timely fashion to assist water managers, emergency responders, recreationists, and the public in making decisions concerning their missions and activities. The USGS currently operates over 8,000 streamgage stations nationwide that are used for these purposes. A large number of the streamgages operated by the USGS are reporting data in real-time; meaning stream or reservoir stage and other hydrologic and meteorological data are transmitted from the streamgages on a one-hour interval and these data, along with computed streamflow, are delivered on the USGS web page. When stream and river levels rise to flood-action stages and higher, these real-time data, along with NWS river forecasts, are linked to available flood inundation map libraries to better portray and describe the consequences of flooding and communicate flood risk.

In addition to providing the streamflow information, the USGS also supplies other streamgage data that are critical in the development and delivery of FIM maps. For each streamgage, a rating curve to relate stage and discharge is developed to provide streamflow information and the rating information is also used in the calibration of the hydraulic models for flood inundation maps. When necessary and appropriate, the USGS extends ratings above the highest measured discharge. Development of hydraulic models associated with flood inundation maps may offer additional opportunities to extend ratings. The surveying completed as a part of the model data-collection effort is generally run using the commonly accepted vertical datum of NAVD88. Elevation data collected for the model development should be used to convert the streamgage datum to NAVD88, if it has not already been converted, so that the reported real-time data elevations and the flood inundation map are using the same datum. During flood operations, the USGS makes additional measurements and provides information to the public and our partner federal agencies to aid in the flood fighting efforts.

Most of the USGS activities that have produced flood inundation maps are cooperative projects with local partners and within the USGS Cooperative Water Program ([U.S. Geological Survey](#)). The Program is designed to bring local water science needs and the need for decision-making tools together with USGS national capabilities, and other USGS resources such as consistent methods, quality assurance, innovative technology, model development, and data management systems. The USGS state-based Water Science Centers develop programs independently and partner with local communities, counties and states to develop flood maps. The project team chooses the study reach, appropriate model and makes other local decisions on a case by case basis as defined by the cooperator's mapping needs. Priority is placed on projects that leverage existing datasets, such as, the USGS streamgage network, the NWS river forecast network, and existing hydraulic and digital elevation models. Maps are developed cooperatively for a variety of reasons, including flood risk communication, environmental mapping, and other local needs.

Throughout the project, the USGS ensures all flood inundation map projects follow USGS Fundamental Science Practices (FSP) ([U.S. Geological Survey](#)). The USGS FSP govern how scientific investigations, research, and activities are planned and conducted ([SM 502.2](#)) and how information products are reviewed and approved for release and dissemination ([SM 502.3](#) and [SM 502.4](#)). The USGS FIM Program has added steps to the minimal requirements of the FSP process to include additional reviews by our cooperators and partners. All USGS FIM projects result in peer-reviewed and Bureau-approved maps and accompanying report. The products are available through the USGS Publications Warehouse and interactively through the USGS Flood Inundation Mapper. Maps may be made available through other outlets based on the local project team's decisions, including partner websites or the NWS AHPS pages.

The USGS will continue supporting the development and use of flood inundation maps by delivering the necessary hydrologic data and through cooperative projects developed by USGS

Water Science Centers with support from the national Cooperative Water Program. These projects will be designed with a dual purpose of supporting local community needs and enhancing the nation's flood inundation mapping science capabilities by tackling complex modeling or data-display issues, documenting the results, and making the results publicly available.

### **E.1.3 USACE Operations**

The USACE (Corps) missions that provide information to support production or directly produce or consume flood inundation maps include water management, dam safety, levee safety, critical infrastructure protection, contingency operations (flood fights), planning studies, ecosystem restoration projects, habitat evaluation projects, hydraulic design studies, flood damage reduction studies, and navigation studies. The Corps will continue to develop flood inundation maps as necessary to achieve its missions.

Flood inundation map dissemination will be governed by EC 1165-2-215 or future documents that supersede it. The goals and capabilities of the IWRSS flood inundation mapping system should be communicated regularly to Corps elements involved with developing flood inundation maps (a) with appropriate encouragement to align with any pertinent IWRSS guidance that does not conflict with internal Corps policy, standards and guidance for flood inundation map production, content, format and dissemination and (b) stating that IWRSS systems are an appropriate mechanism for release of flood inundation mapping intended for release to the general public.

The Corps should also continue supporting flood inundation mapping through cooperative and reimbursable projects such as projects within the Silver Jackets program. When appropriate, via coordination with project cooperators, project scopes should be designed to meet the IWRSS requirements for national flood inundation map services and with the intent to post project results on the IWRSS system.

Because of its combination of significant technical resources, operation of flood risk management infrastructure, responsibility to support levee sponsors during flood events, and experience conducting flood fights, the Corps is uniquely qualified to develop tools, processes and procedures for real-time mapping during flood events and shares with NWS the vision of contributing such products to enhance existing forecasting and emergency warning systems. The Corps should maintain coordination with other IWRSS members to explore options for aligning mission tools and products when possible with IWRSS systems. This may include activities such as:

- Evaluating IWRSS and other federal inundation map guidance during 5-year reviews of Corps inundation map standards and aligning where possible and appropriate.
- Adjusting USACE systems primarily involved with production and dissemination of inundation mapping such as the Corps Water Management System (CWMS) and its component modeling packages, the National Levee Database (NLD) and CorpsMap to integrate with and provide Corps-generated information to NWS and/or IWRSS systems.
- Coordinating with IWRSS members to ensure common understanding of schedules and modeling and mapping products that will be available from the CWMS national implementation.
- Continuing to maintain CWMS modeling components: hydrologic model -HEC-HMS, reservoir model - HEC-ResSim, hydraulic model - HEC-RAS and flood damage model - HEC-FIA for development of state of the art flood inundation models and maps by federal agencies, state and local governments and the private sector.

- Through CWMS and other Corps programs, develop and maintain a searchable library of H&H models available to support the Corps missions listed above as well as the needs of IWRSS members. Whenever possible, ensuring those available models are calibrated to support real-time inundation mapping during significant flood events.

## **E.2 Proposed Joint Collaborative Operations**

New interagency IWRSS functions and processes are proposed that will streamline all of the development, submission, review, publication, data dissemination and display of flood inundation mapping products. This section defines the respective roles, contributions and interactions of participating agencies through an interagency IWRSS process. Joint collaborative operations for flood inundation map (FIM) production require the seamless integration of partner agency data collection activities, FIM production processes, and quality control activities to produce a suite of IWRSS FIM products and services. The IWRSS system serves to enable this function and promote a collaborative map production process.

In consideration of this collaborative process, materials obtained as a result of Federal Emergency Management Agency (FEMA) activities would increase its effectiveness. Access to FEMA model database information such as, study locations, cross sections and water surface profile information would be beneficial. Coordination between FIM studies and DFIRM/RiskMap studies currently under development or planned would benefit the National Flood Inundation Mapping Services and FEMA, both technically and financially.

System interoperability is a key requirement and the enabling technology necessary for the IWRSS joint collaborative operations. The production data must be exchanged through a central location, to be known as the IWRSS Information Services Framework (ISF). Once the map production process has been completed, the completed mapping products and services are hosted by the ISF. The dissemination of IWRSS public products and services, on a nationwide scale, will be highly dependent on an interoperable IWRSS ISF to facilitate data sharing. Flood mapping data products, and the data supporting these products, will be transmitted between agencies by registering a data product with the IWRSS ISF. Once an IWRSS data product is registered with the ISF, the data product would be available to all IWRSS agencies. A good part of the maps and supporting materials should be immediately available to the public. Some data will be sequestered due to its sensitive nature.

The registered data will be extracted through the IWRSS ISF and used by an individual agency for a singular purpose or multiple agencies for collaborative activities. Registration of standardized, consistent and documented data would strengthen the modularity of the IWRSS data products, thereby enabling IWRSS partner agencies to quickly identify existing products, develop new products, or refine existing products from the IWRSS ISF. The ISF, when applied to quality control activities, serves to facilitate the peer review process through the easy sharing of data, tracking of quality control metrics, and certification of approved data. Once data are approved by the proponent agency, the end state of the map production processes is a suite of robust IWRSS flood inundation mapping products and services that are designed for either public or official use only.

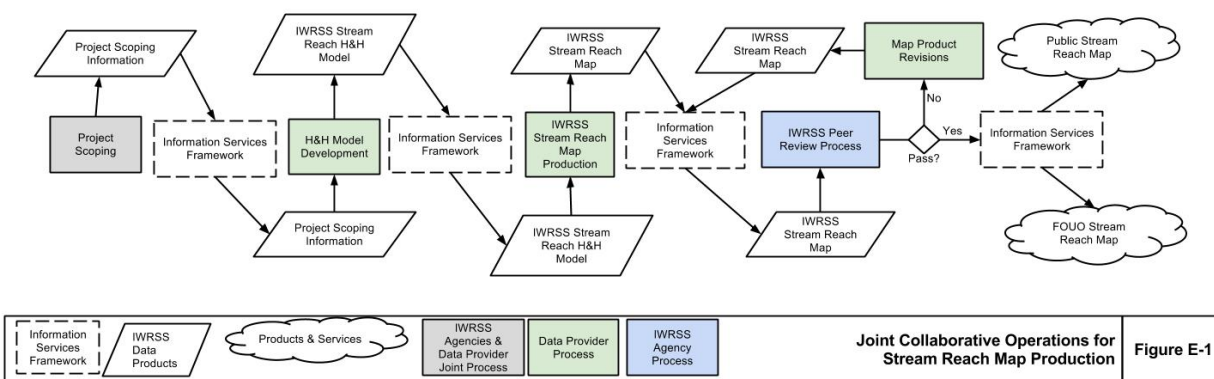
Descriptions and illustrations of the respective roles, contributions and interactions between the participating agencies for three different flood inundation mapping purposes, as enabled by the IWRSS ISF, should be provided. In addition, descriptions of an oversight mechanism, a peer review process, and a quality assurance-quality control process should also be provided.

A repeatable, modular and standardized approach to developing the mapping data products allows for map development tasks to be divided or shared by agencies and other stakeholders. During a flood event, one agency may develop the hydrologic and hydraulic model, a second agency may focus on data collection tasks, while a third agency may take on the task of map production from the model results. This modular approach allows agencies to collaborate jointly to the development of flood inundation maps, without requiring agencies to deviate from their current practices and guiding policies for operations. The IWRSS system may also facilitate the sharing of tasks, whereby two or more agencies could participate in the update of a large or complex hydraulic modeling or mapping project.

Figures E.1, E.2 and E.3 detail the proposed map production process, and the exchange of data between IWRSS agencies and data providers, through the ISF. Participating agency roles and resulting data products are color coded as either IWRSS Agency, data provider or IWRSS Agencies and data providers. IWRSS agencies include all chartered members of IWRSS. Data providers could include any party that has been approved to submit data to IWRSS, including IWRSS agencies, government/non-profit partners or the private sector. Roles presented on the graphics are interchangeable and can be filled by any participating IWRSS agency or data provider with the appropriate capabilities.

### E.2.1 Proposed Stream Reach Map Generation

The proposed process illustrated in Figure E.1, shows the data exchange that occurs throughout a generalized methodology for the production of stream reach maps. There is a logical progression, within the productions process, from scoping of the project, to data collection, to FIM production, to quality control, and finally to dissemination. These production processes are repeatable, modular, and can be standardized to facilitate joint operations between agencies.



**Figure E.1. Joint Collaborative Operations for Stream Reach Map Production.**

#### *Stream Reach Map Production Process:*

- A stream reach map project is jointly scoped by both the IWRSS agencies and data providers.
- The H&H models are developed by the data provider.
- The stream reach map is finalized by the data provider.
- The stream reach map is evaluated in a peer review process conducted by the IWRSS agencies. If the product passes review, it is published as an IWRSS product and service. If the product does not pass review, it is sent back to the data provider for revisions and the map may be granted provisional publication until the final review is accepted.

The proposed process illustrated in Figure E.2, also shows the data exchange that occurs throughout a generalized methodology for the production of event-based maps. It is important to note that a number of steps in the event-based map production process can be completed in advance of an event (scoping, hydrology and hydrologic modeling). Event-based maps differ from stream reach map libraries in that they are usually generated very near the time of the event and are generally not applicable at some time after the event. For most flood events, it should be necessary to evaluate existing flood map libraries to identify the available map that most closely depicts the pending flood event and present that information as the initial “pending event-based map”. The maps could be used to communicate risk as the result of an extraordinary situation, such as an extreme flood event on a major river system with high risk to life and property, a dam breach or a levee breach. Since the event-based map is based on the NWS provided river forecast, the best possible and most timely river forecast is imperative to an effective event-based map display.

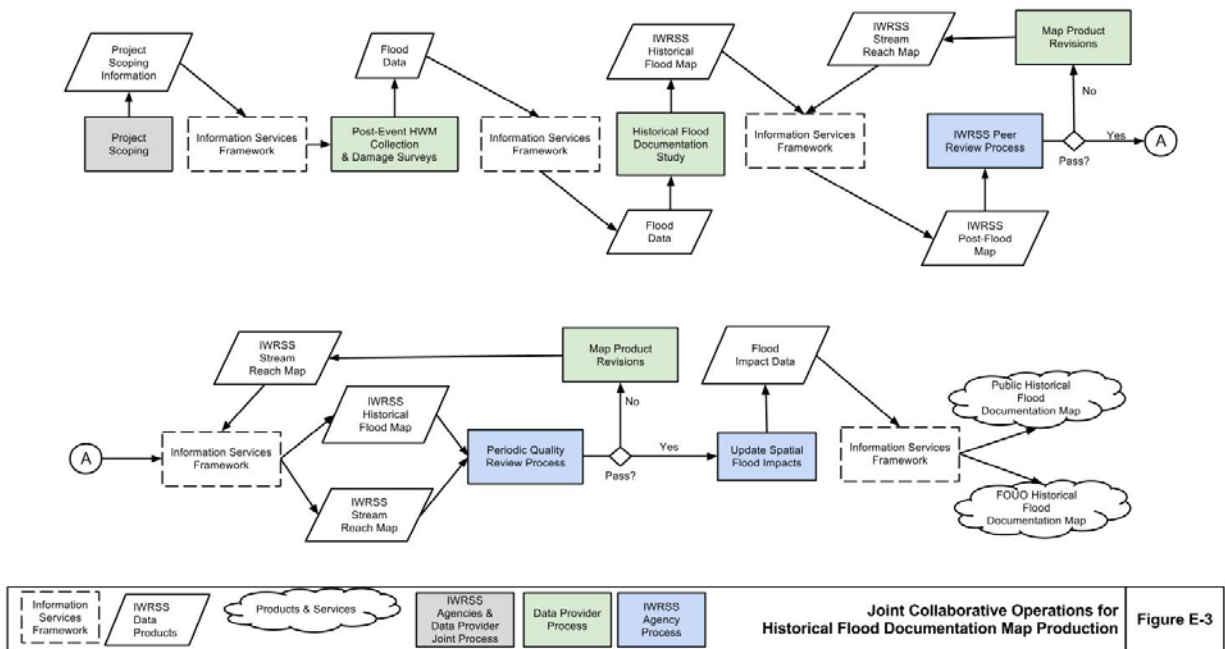


- An event-based map project is jointly scoped by both the IWRSS agencies and data providers.
- The H&H model is developed by the data provider.
- CWMS Reservoir releases are developed by the data provider (USACE).
- Levee Monitoring and freeboard forecasting is developed by the data provider (USACE).
- A river forecast is produced by the data provider (NWS).
- An event-based map is produced by a data provider, which factors in an event specific H&H model, levee status, river forecast and reservoir releases.
- The event-based map is evaluated in a peer review process approved by the IWRSS agencies. If the product passes peer review, it is published as an IWRSS product and service. If the product does not pass review, it is sent back to the data provider for

revisions, and may be considered for provisional review. In some cases, the map should be published on a provisional basis to meet time constraints and organizational needs.

### E.2.3 Proposed Historical Flood Documentation Map Generation

The proposed process illustrated in Figure E.3, also shows the data exchange that occurs throughout a generalized methodology for the production of historical flood documentation maps. These maps generally do not involve any hydraulic modeling and are usually available individually rather than as a part of a map library. The maps can be used to document and archive the inundation extent as a result of an individual storm event of substantial magnitude or for another reason of interest.



**Figure E.3. Joint Collaborative Operations for Historical Flood Documentation Map Production.**

#### *Historical Flood Documentation Map Production Process:*

- A historical flood documentation map is jointly scoped by both the IWRSS agencies and the data providers.
- Post-event High Water Marks (HWM) and damage survey data are collected by the data provider.
- A historical flood documentation study is developed from the flood data by the data provider.
- The historical flood documentation map is evaluated in a peer review process conducted by the IWRSS agencies. If the product does not pass review, it is sent back to the data provider for revisions, and may be considered for provisional review. In some cases the map should be published on a provisional basis to meet time constraints and organizational needs.
- The historical flood documentation maps can then be used to conduct a periodic quality review process on the stream reach maps. The review is conducted by the IWRSS agencies. If the stream reach maps pass the periodic quality review process, it remains a published IWRSS product. If the stream reach map does not pass the periodic review



process, then it is removed from publication as an IWRSS product. Stream reach mapping that is removed must be revised and resubmitted to the review process.

- Once a stream reach map has been updated, the spatial flood impact data are revised by NWS.

## **E.2.4 Proposed IWRSS FIM Governance**

The team proposes that an IWRSS FIM Steering Committee should be established that should oversee and manage the entire National Flood Inundation Mapping Services. This includes the establishment and management of an IWRSS report series and the review, maintenance, and revision of standards for a flood inundation map. The steering committee should include technical and management expertise and be representative of the IWRSS membership.

An IWRSS FIM Liaison Office, that includes an IWRSS FIM Data Steward, should be established to act as a point of contact for IWRSS FIM issues and questions. This office would oversee the day-to-day activities of managing the Information Services Framework (ISF) and guiding projects through the creation, submission and review processes. Additionally, the IWRSS FIM Liaison Office would connect FIM Project Managers with appropriate technical resources within the IWRSS FIM community. For example, to provide local contacts to assist in scoping and coordinating projects or to connect a project to an expert for complex hydraulic modeling support. The IWRSS FIM Liaison Office would appoint and manage the membership of the IWRSS FIM Technical Review Committee and the Peer Review Panel.

The IWRSS FIM Technical Review Committee should provide feedback on complex maps, which may include new methods, large studies, new authors, atypical calibration etc. The Technical Review Committee should also coordinate which maps need updating and assist the Steering Committee with reviewing new methods, standards, and other related technical items.

The IWRSS FIM Peer Review Panel would be managed by the IWRSS FIM Technical Review Committee and have a large membership of qualified and certified reviewers across all the member agencies. The membership would be responsible for conducting data and product reviews and ensuring that the current technical standards are upheld.

In order to design and successfully implement the National Flood Inundation Mapping Services, at least four working integrated limited-term subcommittees are recommended to be established to further develop the standards for Flood Inundation Mapping. These subcommittees have been referenced throughout the document and are summarized here.

IWRSS FIM QA/QC Subcommittee – Example tasks: develop a QA/QC\_checklist; outline a FIM process from scoping to peer-review and publication,

IWRSS FIM Information Services Framework Subcommittee– Example tasks: identify physical location, server type, and community operations mechanism; identify types of data eligible for submission; recommend data storage and archiving method,

IWRSS FIM Map Viewer Subcommittee – determine mapper needs; recommend viewer location and accessibility; and review map and report characteristics,

IWRSS FIM Loss Estimation Subcommittee – evaluate and recommend loss estimation methods, and the loss estimation data calculation; data storage and dissemination methods.

### **E.2.5 Proposed IWRSS FIM Peer Review Process**

The proposed IWRSS FIM Liaison Office should be responsible for the quality and integrity of the flood inundation maps. A rigorous peer-review and reporting process should help uphold those standards. The USGS Fundamental Science Practices have been used as a model for the IWRSS peer review processes outlined here. As implemented, it should also be designed to meet USACE policy for review of civil works products as defined in EC 1165-2-214. In short, there should be two peer reviews required of every map submission. One of the reviews should include a member of the IWRSS FIM Peer Review Panel; the other review (most commonly an internal review) should be completed before submission.

In order to facilitate IWRSS oversight of the maps and provide a second peer-review, an IWRSS FIM Peer Review Panel and peer review map viewer should be created. The IWRSS FIM Peer Review Panel should be composed of numerous qualified peer reviewers from the IWRSS member agencies. The peer reviews should be facilitated by a submission and tracking system that is based on the public viewer.

The Peer Review Map Viewer should:

- Have all the same features and functionality as the public map viewer, but is secured with a login
- Act as the working area for peer reviewers to complete a review, mark problem areas on maps, and route maps through the process (either back to the author for revisions or forward for approval and publication)
- Allow reviewers to participate and thoroughly review the quality of the spatial data without requiring any GIS skills or licenses
- Have an IWRSS FIM Review Dashboard where the duties are assigned for reviewers and approvers and for authors to check the status of reviews.

The preliminary data would be submitted via the ISF, electronically announced, and made available for review by internal technical and customer reviewers (stakeholders, cooperators, local communities, state HMO etc.); only final draft data are reviewed by an IWRSS FIM Peer Review Panel. Incoming final draft libraries produced by IWRSS member agencies are assigned a reviewer in a different agency and non-federal maps are assigned among the federal agencies on a rotating basis. The assigned IWRSS FIM Peer Review Panel member can either send the map back to the submitter for revisions and/or clarifications or may approve the map for preliminary submission to the map viewer.

Once a map is approved by two peer reviewers (one review before submission and one IWRSS FIM Peer Review Panel member), the package would be transmitted to the submitting agency's publications approval process, if necessary. Following approval by the submitting agency, the IWRSS FIM Peer Review Panel approves the map for final publication and assigns an IWRSS report number to the submitted documentation materials. Any developed reservoir, hydrology, hydraulic, and consequence models, as well as, input and output datasets from standard models used in the process of developing a flood inundation map should be archived and made available for distribution.

Further proposed operational guidelines of the IWRSS FIM approval process would include:

- IWRSS member agencies agree that standard maps meeting agreed-upon technical guidelines are approved by consensus when approved by an IWRSS FIM Peer Review Panel member.



- All member agencies must unanimously approve a non-standard map (new hydrologic, hydraulic or geospatial modeling methods) before it can be published as a final product on the public mapper. An additional step should be required through the IWRSS FIM Steering Committee or other agreed upon method of the IWRSS FIM Peer Review Panel. All maps, including those that have been developed with non-standard methods, are accepted as provisional products and may be published to the public map viewer as provisional products.
- If a particular submitting agency or group is not meeting its technical review obligations as determined by the remaining federal agency members, their ability to submit new products can be suspended by the Steering Committee until they demonstrate the ability to meet the technical standards and obligations.
- For a submitted map with USGS authors, a USGS Bureau Approving Official (BAO) should review the final report package to make sure it meets the USGS Fundamental Science Practices (FSP) guidelines before it is released to the map viewer. Prior to the BAO review and approval, a USGS Supervisory/Center Director level review, which in some cases may be delegated to the USGS FIM program lead, should be conducted to ensure that the peer reviews are substantive, without conflict of interest, and that the FIM product meets all IWRSS guidelines.

During critical flood fight situations it is in the interest of all IWRSS member agencies and all FIM stakeholders that a single, authoritative event-based map should be provided. The provisional peer review process should be embraced in order to produce timely forecasts. Especially during critical flood fight situations, it is critical that the review is expedited to meet the demands of the real-time modeling and map production process. An expedited review may be improved by having robust, long-practiced hydrology and hydraulic models applied for specific flood event-based maps. Event-based maps are the most complex and most time-constrained products envisioned within this document.

### **E.2.6 Proposed IWRSS FIM Periodic Quality Review Process**

The periodic quality review process should conform to a minimum standard of one review per every 10 years. Periodic quality reviews may also be initiated on a more frequent basis at the request of a local stakeholder, at the request of an IWRSS partner, upon the acquisition of detailed verification data from major flood events, or as a result of known topographic, infrastructure, or river channel changes as a result of anthropogenic or natural events. The IWRSS FIM Technical Review Committee should assess the need for periodic reviews and manage the review process. Reviews should be conducted by the IWRSS FIM Peer Review Panel or a delegate on a rotating basis, using standards established by the peer review process.

Feedback and the availability of recent flood documentation should be used to evaluate the need to review outside of the standard 10-year review cycle. Interim quality reviews can be triggered through a feedback loop from a mechanism established on the IWRSS FIM Map Viewer. Feedback should be reviewed periodically by the IWRSS FIM Technical Review Committee. Reviews should be conducted if any of the following verification data become available over a substantial part of the mapped reach:

- Flood documentation study is completed by the USGS,
- Collection of high water marks for a major event by any IWRSS partner,
- Collection of the high water record by other means that may include flood documentation by aerial photography or other remote sensing methods,

- Any other condition or data set determined to qualify by the IWRSS FIM Technical Review Committee.

All IWRSS periodic map reviews should be documented within the Information Services Framework (ISF). Upon identification of degraded mapping product, the map may be temporarily or permanently removed from the IWRSS FIM Map Viewer. In the event that the mapping accuracy is degraded, but removal is not warranted, selected mapping features be restricted or disabled and a public notice should be clearly posted.

Any map change initiated by the IWRSS FIM Technical Review Committee should be communicated to the public and the local stakeholders. Notification of the map change could be through the display of a note highlighting the change on the IWRSS FIM Map Viewer. The local stakeholders should be notified directly and be part of the update process. In addition, each FIM map should include the dates of production and the most recent review and revision, if applicable.

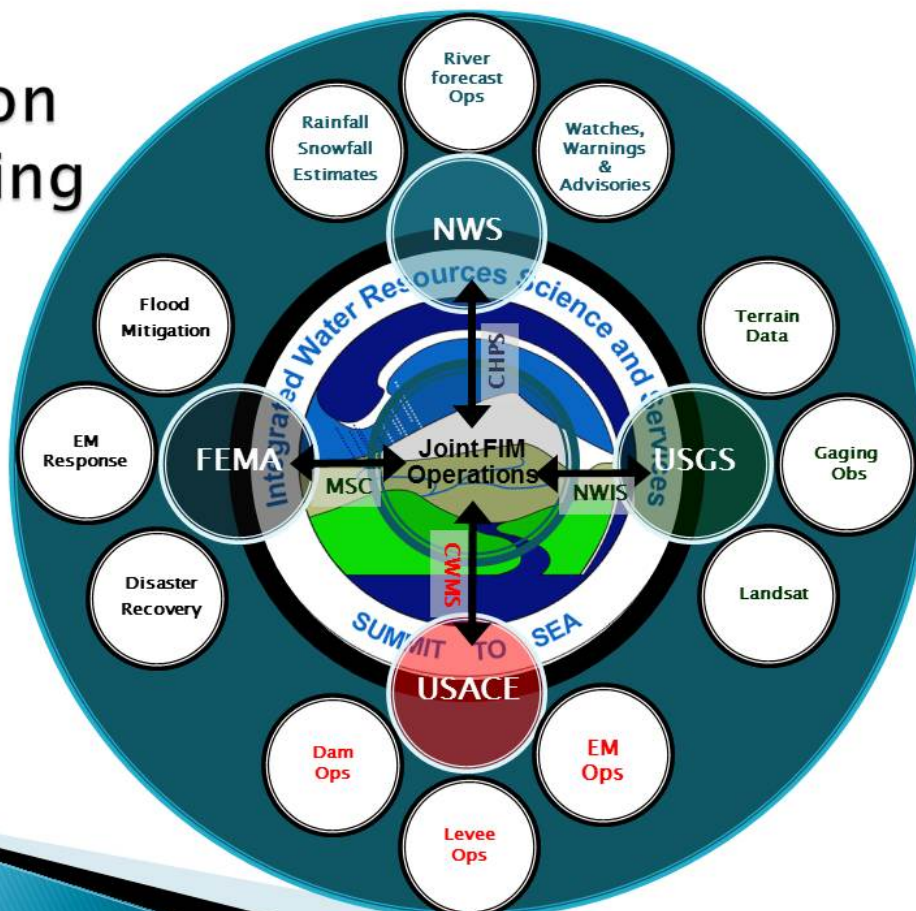
## **E.3 Common Operating Picture Overview**

The IWRSS member agencies envision building a highly collaborative and integrative modeling environment and Information Services Framework (ISF). Coupling Flood Inundation Mapping (FIM) with the ISF would promote the establishment of a common operating picture for improving modeling and data synthesis, and provide a platform to support the production of a new, comprehensive, seamless, and consistent suite of high-resolution water resources information. Presently, the agencies' existing enterprise FIM solutions (consisting of decision support systems, models, data, products and services) largely operate independently of one another. A common operating picture would enhance coordination, support map production, and allow dissemination of flood risks and unified mapping products.

### **E.3.1 Common Operating Picture and Supporting Framework**

IWRSS should consider establishing a common operating picture which considers how mission critical agency functional areas can come together to produce the flood maps. Figure E.4 provides a suggestion of the interconnectivity required to produce the flood maps. The interconnections to support the common operating picture are held together by the ISF, which includes a mutual modeling environment to access and share information for producing the IWRSS maps for stream reach maps, event-based maps, and/or historical flood documentation maps.

# Common Operating Picture



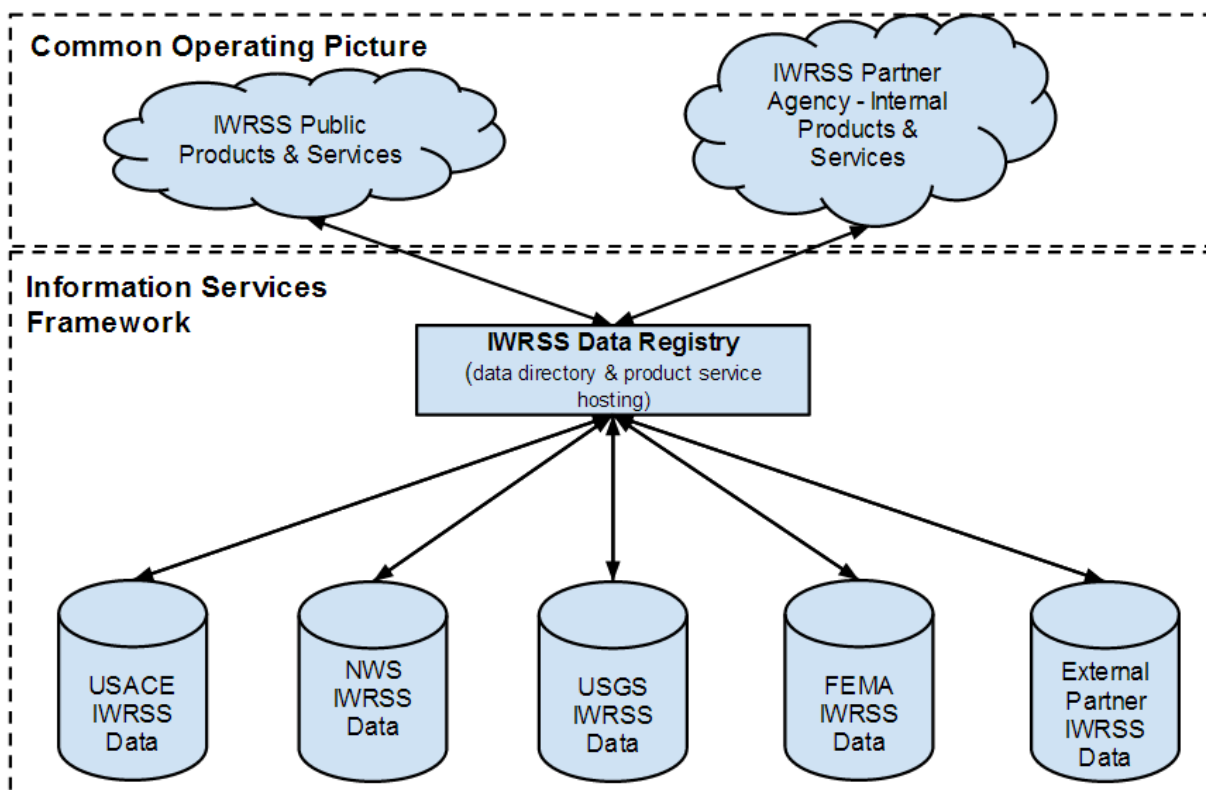
**Figure E.4. Overview of the IWRSS Common Operating Picture.**

Within the framework, member agencies will need flexibility to interoperate, share data model inputs, store data model outputs, and enhance existing data which have been used in recent and historical FIM efforts. Data sharing agreements will should consider database privileges and security aspects and need to be pre-negotiated to allow seamless virtual access to the IWRSS framework and product access to FIM stakeholders.

The information and data for FIM needs to be readily available to the IWRSS member agencies with a specified latency to be determined by an ad hoc IWRSS FIM team. The proposed system should inform the user if IWRSS latency requirements are not met so that corrective actions or remedies can be taken by IWRSS members. This and other latency requirements, such as the minimum required latency to display the standard flood map product, should be examined by the ad hoc team through coordination with anticipated stakeholders and other users of IWRSS FIM.

IWRSS should establish the ISF to support the Common Operating Picture for FIM. To maintain agency fundamental practices, the data, model parameters, and workflow that went into the model are to be independently saved in accordance with the common standards, independently stored with common attributes, but made known to the ISF through the IWRSS data registry. The proposed data registry should be managed by the ISF. To enable the flow and exchange of information, governance of the inputs and outputs of the mutual models also should be an ISF function.

To function effectively, the common operating picture would benefit from a common database that includes: (1) a data registry for the flood mapping products, (2) identification of the owner of each product, (3) the corresponding metadata, and (4) the data location (to which IWRSS would direct the user). The data should be provided by the respective IWRSS agencies via OGC Compliant Web Services, the electronic display of the flood maps, and the printable maps. In addition, the database should be accessed through the Federal Geoplatform on [data.gov](https://data.gov) to provide the IWRSS consortium and new stakeholders the ability to discover the various FIM services and products. Figure E.5 displays a diagram of the interaction between the data registry, the IWRSS agencies, and individual agency data sources.



**Figure E.5. Overview of the IWRSS System and FIM Data Requirements.**

### **E.3.2 The Information Services Framework (ISF)**

The proposed ISF would have an important responsibility for the data processing and handling of the information systems. The information systems contain an integrated set of components used for gathering, processing, storing and communicating multiple types of information for improved organizational efficiency. The ISF should support the common operating picture by facilitating the dissemination of shared sets of flood maps, as well as providing the framework for the member agencies to perform mutual modeling, produce, co-produce, and assimilate flood inundation maps into respective critical mission areas. Flood risk information, developed using available demographic and infrastructure data and the disseminated maps, should be dispersed to its member agencies, partnered stakeholders, and the users to enable flood preparedness, flood fighting, and flood mitigation through the ISF. The information should be available to the user through commonly available IWRSS portal(s) and in a flexible data format designed to be usable by the respective stakeholder and their own applications. The seamless

availability of flood maps allows stakeholders and users to add more value, such as flood loss estimation, to the flood maps.

The ISF could provide the IWRSS agencies a fundamental structure or common operating picture in which interagency decision support systems, data, models, and workflows are interoperable, seamless and transparent. Its function is to enable the efficient and effective generation and provision of comprehensive water resources products and services, including flood inundation maps. The ISF could support mutual modeling efforts by making known the modeling inputs, modeled outputs, and any operationally critical mutual modeling parameters for flood inundation mapping. It could also support the data management, workflow, tracking, servicing, and administering the seamless and transparent production of flood inundation maps across agency boundaries. In addition, the ISF could support the collaborative actions serving the workflow, described in this document, to check and review the draft flood inundation maps before they are made publicly available.

In order for this framework to deliver access and seamless sharing of the modeling workflow and data, the IWRSS data registry should include the data structure of the modeling components. The ISF should register, provide version control, and store all data required for map production. Sharing procedures and protocols should be jointly agreed upon to allow access to the respectively stored datasets, checking-in and checking-out of the mutual modeling workflows, and responsibilities for maintenance, availability, and governance of the information.

The ISF could manage the processes for the IWRSS agencies and stakeholders to check-in new, revised, or enhanced data and models into the IWRSS data registry, checkout the data and models through a common interface, and share this information for the production of flood inundation maps. The ISF could be designed to foster this communication, facilitate the exchange, and govern the version control of all hydrologic, hydraulic and terrain models required for the map production process. The ISF could be constructed to recognize the diverse datasets, data formats, and modeling workflows for the various types of flood maps, namely (1) stream reach maps; (2) event-based maps, and (3) historical flood documentation maps.

The ISF should be operationally supported, routinely maintained, and securely administered by a designated IWRSS entity. To maintain the ISF in support of the Common Operating Picture, there should be a recommended maintenance plan for the associated framework, individual data repositories, and its associated components. The design team should specify a support system to provide operational support and maintenance to the ISF. A two-tier support model should be provided for continuity of operations and to respond to system outages and to provide technical support to IWRSS agencies. Tier 1 support should function to log support issues, provide basic troubleshooting, and should be available 24x7. Tier 2 support could provide advanced support services and should be available during normal business hours. During instances where event-based maps are being generated within a real-time mutual modeling environment, the Tier 2 business hours should be extended to a 24x7 day support. The proposed system should meet a minimum requirement for availability (e.g. 99.999%) that should be defined by the design team. The design team should evaluate the practices of existing operational systems, such as NWS AHPS, USACE CWMS and USGS NWIS, and evaluate the requirements and expectations of the stakeholders for product availability and system backups.

### **E.3.3 System Interoperability and Data Synchronization**

Interoperability allows the various system components and the member agencies and stakeholders to work in sync. The ISF should enable this interoperability for producing and sharing flood maps with a supporting synchronized data set. Data interoperability will be

required to make available important map layers showing the potential flood impacts to critical infrastructure. IWRSS member and stakeholders should follow common flood mapping standards and develop products with common attributes in order for interoperability to occur. The synchronized data will require a formulated process of establishing consistency among the data from the source to the target data storage and return.

To support the interoperability and the exchange of data and models, the framework should consider the user's request, semantically translate the request by the ISF, and systematically serve the requested data, model, or flood mapping products to the user or the respective application requesting the service. Data and models to support the generation of flood mapping should be available and discoverable by member agencies through the ISF. This framework supports the specific geospatial data used in the mapping by providing linkages to the sources via the internet through web mapping services. The ISF should interact with the respective member agencies web services, which are required to be available 24x7, redundantly backed up, and viewable in the highest defined resolutions for the flood map at the pre-specified accuracy.

The framework should serve as the common link and point users to the common map display. The implementation of OGC compliant geospatial services and a common viewer would support stakeholders' interactions and requests for the mapping development over the internet. Any services that are added to the framework's OGC compliant geospatial services should be approved by the agency POCs on behalf of the corporate board before the IWRSS custodian makes the info shareable and grants rights to IWRSS member agencies or member groups.

Any data tagged For Official Use Only (FOUO) should be secured by the ISF so that only the authorized IWRSS partner agencies are allowed access to the products and data services. The data requirements team should determine the appropriate security and access protocols. This data should not be transmittable or downloadable outside the domain of the pre-designated IWRSS member agencies.

There should be a designated viewer specifically for the IWRSS Member Agencies that is internal and NOT available to the public to display sensitive information which has been tagged with security restrictions or FOUO. This viewer should be available to the member agencies during routine and emergency situations.

### **E.3.4 Documentation Requirements for the Common Operating Picture and Supporting Framework**

A designated official by the IWRSS FIM Steering Committee would be responsible, to maintain, distribute, and update user support documentation to assist the user with an understanding of how to use and interact with the data being provided through the ISF. The document should show the functions and how the information could be used to produce flood inundation maps by following the workflow, the mapping procedures, and technical standards. Continual feedback should be collected to maintain this framework and foster the Common Operating Picture for modeling and mapping. Outreach and education materials must be developed to increase awareness of the National Flood Inundation Mapping Services.

# **Appendix F:**

## **Flood Inundation Map Examples and Graphics Specifications**

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This appendix presents an example map notes page and a series of example maps depicting the FIM map layers as described in Section 5. The examples are followed by graphics specifications necessary to re-create the map layer symbols within FIM maps, applications and data services.



# St. John River Estimated Inundation, River Stage 28.60 Feet at St. John Gage (ID 0101400), Map Library ID 123456

## STUDY AREA

The town of Fort Kent, Maine, is a small urban community with an estimated population of 4,300 (Maine Register, 2009). Fort Kent has experienced severe flooding numerous times, most notably in 1974, 1979, and 2008. The majority of flood damages have occurred in Fort Kent at the confluence of the St. John and Fish Rivers.

## PURPOSE AND SCOPE

The purpose of this document is to describe the development of a series of flood-inundation maps for the St. John and Fish Rivers near Fort Kent, Maine, and to make these maps available to emergency workers and the public on the USGS Flood Inundation Mapping Science Web site available at [http://water.usgs.gov/osw/flood\\_inundation/](http://water.usgs.gov/osw/flood_inundation/).

## UNCERTAINTY AND USE LIMITATIONS

Although the flood-inundation maps represent the boundaries of inundated areas with a distinct line, some uncertainty is associated with these maps. The flood boundaries shown were estimated based on gage heights at selected USGS streamgages. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, assuming unobstructed flow and using discharges and hydrologic conditions anticipated at the USGS streamgage(s). The hydraulic model reflects the land-cover characteristics of any bridge, dam, levee, or other hydraulic structure existing in 2010. Unique meteorological factors (timing and distribution of precipitation) may cause actual discharges along the modeled reach to vary from assumed conditions during a flood and lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded due to unanticipated backwater from major tributaries along the main stem or from localized debris or ice jams.

## MAP SOURCES

Detailed source data for this map series can be found on page 14 (citation page) of the "Flood-Inundation Maps for the St. John and Fish Rivers in Fort Kent, Maine - Pamphlet to Accompany Scientific Investigations Map 3157 (April 2013)" at: <http://pubs.usgs.gov/sim/3157/downloads/pfd/>

-Background Source Data Provided by:  
Service Layer Credits: Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

-USACE AGC National Inventory of Dams (NID): USACE Dams, and Non-USACE Dams:  
[http://National\\_Levee\\_Database/whereismylevee.gov](http://National_Levee_Database/whereismylevee.gov)

-USGS Flood Impact Points:  
<http://pubs.usgs.gov/sim/3157/downloads/FIP>



## HYDROLOGIC AND STEADY FLOW DATA

The study area hydrologic network consists of two streamgages, both with more than 80 years of recording information. Gage height is measured continuously at the two sites from which continuous records of streamflow are computed. All water-surface elevations are referenced to gage datum and to NAVD 88.

## HYDRAULIC MODEL CALIBRATION AND PERFORMANCE

The hydraulic model was calibrated to the gage height-discharge relations at the St. John and Fish River streamgages in Fort Kent and high-water marks from the flood in 2008 (Lombard, 2010). Differences between measured and simulated gage heights for models calibrated to high-water marks were less than 0.2 ft except at the mouth of the Fish River.

## WATER SURFACE PROFILE

Profiles were developed for nine gage heights at 1-ft intervals between 20.6 ft and 28.6 ft as referenced to a local gage datum at streamgage 01014000, corresponding to elevations of between 505 and 513 ft NAVD88. In addition, profiles were developed for seven gage heights at 1-ft intervals between 8.3 ft and 14.3 ft as referenced to a local gage datum at station 01013500—corresponding to elevations of between 519 and 525 ft NAVD 88.

## PRODUCT ACCURACY

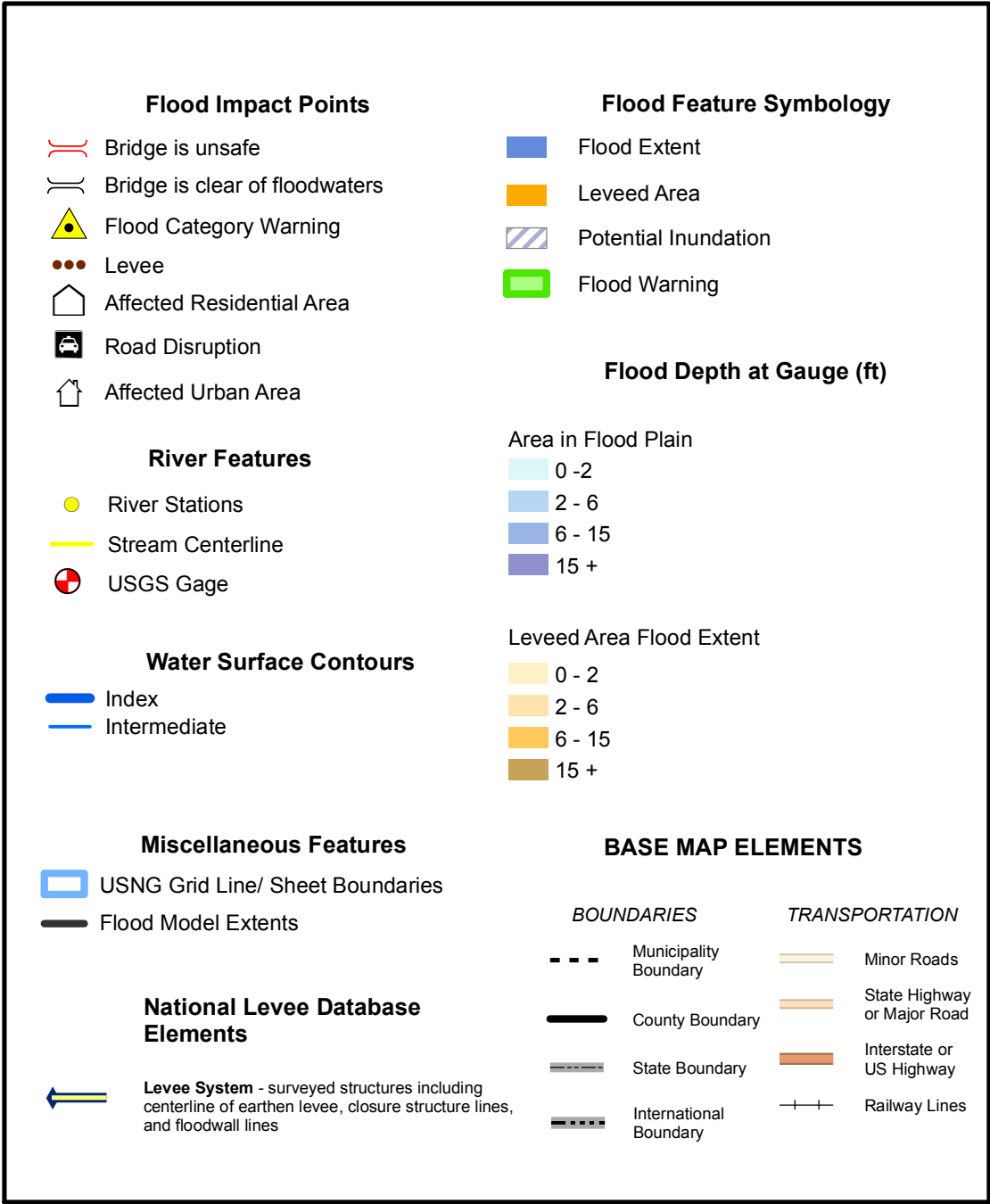
These maps were created in a GIS by combining the water-surface profiles and digital elevation model data. The digital elevation model data were collected and processed to meet 3.3-ft (root-mean-squared error) horizontal accuracy and a vertical accuracy of 0.6 ft.

## READING USNG LOCATIONS

The primary coordinate system displayed in these maps is the U.S. National Grid (USNG). A USNG location is composed of the world Grid Zone Designation (GZD), the two letter 100,000m grid ID, and the grid coordinate. To read USNG locations from these maps, locate the GZD and grid ID values at the bottom of each sheet. Then use the two-digit UTM principal digits displayed on the map. Ignore the small UTM superscript numbers that are provided for reference purposes. USNG coordinate strings can be 4, 6, 8, or 10 digits long; having coordinate precision of 1,000m, 100m, 10m or 1m. The left half of the coordinate string is the easting value and the right half is the northing value. The first two easting and northing digits should be the principal UTM digits as displayed on the map. Additional digits refine the accuracy of the coordinate pair. Additional resources pertaining to the USNG can be found at <http://www.fgdc.gov/usng/index.html>

## DISCLAIMER

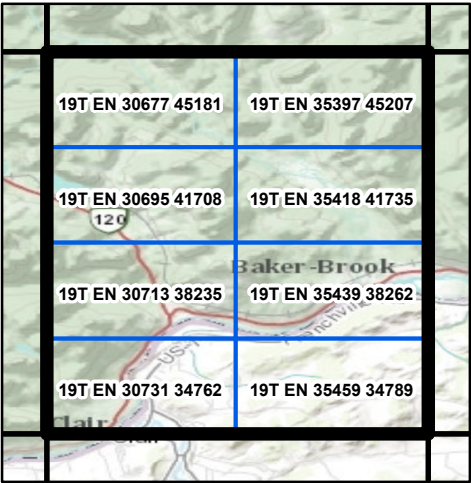
Inundated areas shown should not be used for navigation, regulatory, permitting, or other legal purposes. The IWRSS provides these maps as a quick reference and emergency planning tool but assumes no legal liability or responsibility for any direct, indirect, incidental, consequential, special, or exemplary damages or lost profit resulting from the use or misuse of this information.



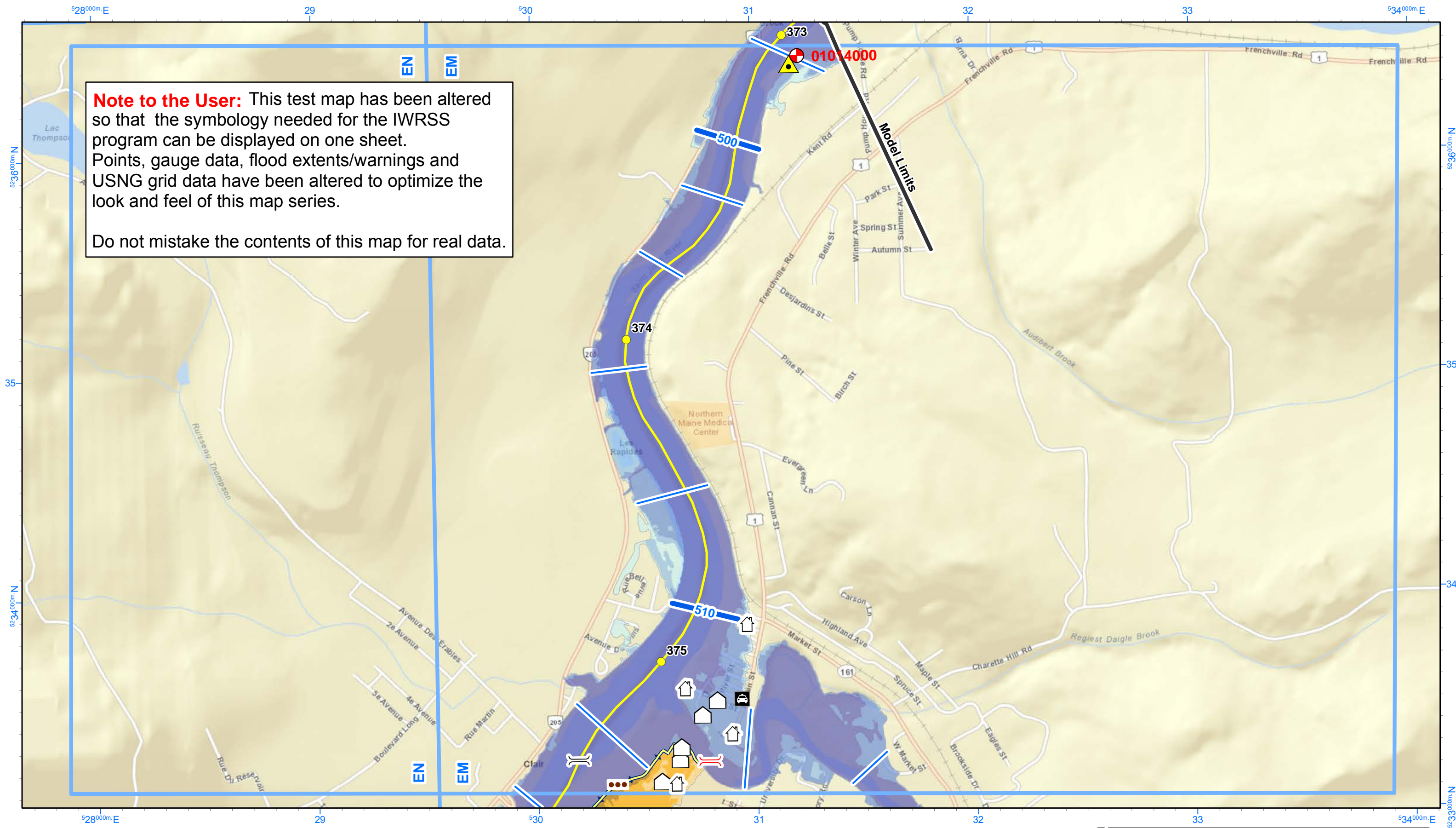
The Flood Inundation Map Series tiling scheme is based on the United States National Grid (USNG) coordinate system. Each tile is represented by an alpha-numeric coordinate string that is unique world wide. The length of the coordinate string corresponds proportionately to the map scale.

The reference map on the right contains eight coordinate strings. Each string represents a map tile that is constructed at 1:15,840 scale.

For more information on IWRSS flood inundation scales, tiling schemes and content refer to: <http://pubs.IWRSS.INFO/featuredproducts.gov>

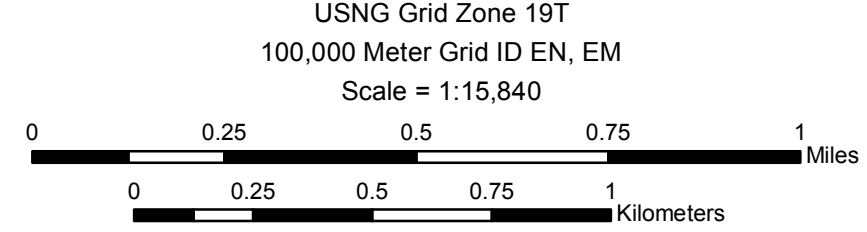
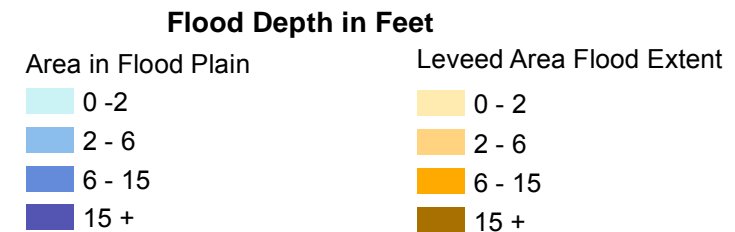






**Note to the User:** This test map has been altered so that the symbology needed for the IWRSS program can be displayed on one sheet. Points, gauge data, flood extents/warnings and USNG grid data have been altered to optimize the look and feel of this map series.

Do not mistake the contents of this map for real data.



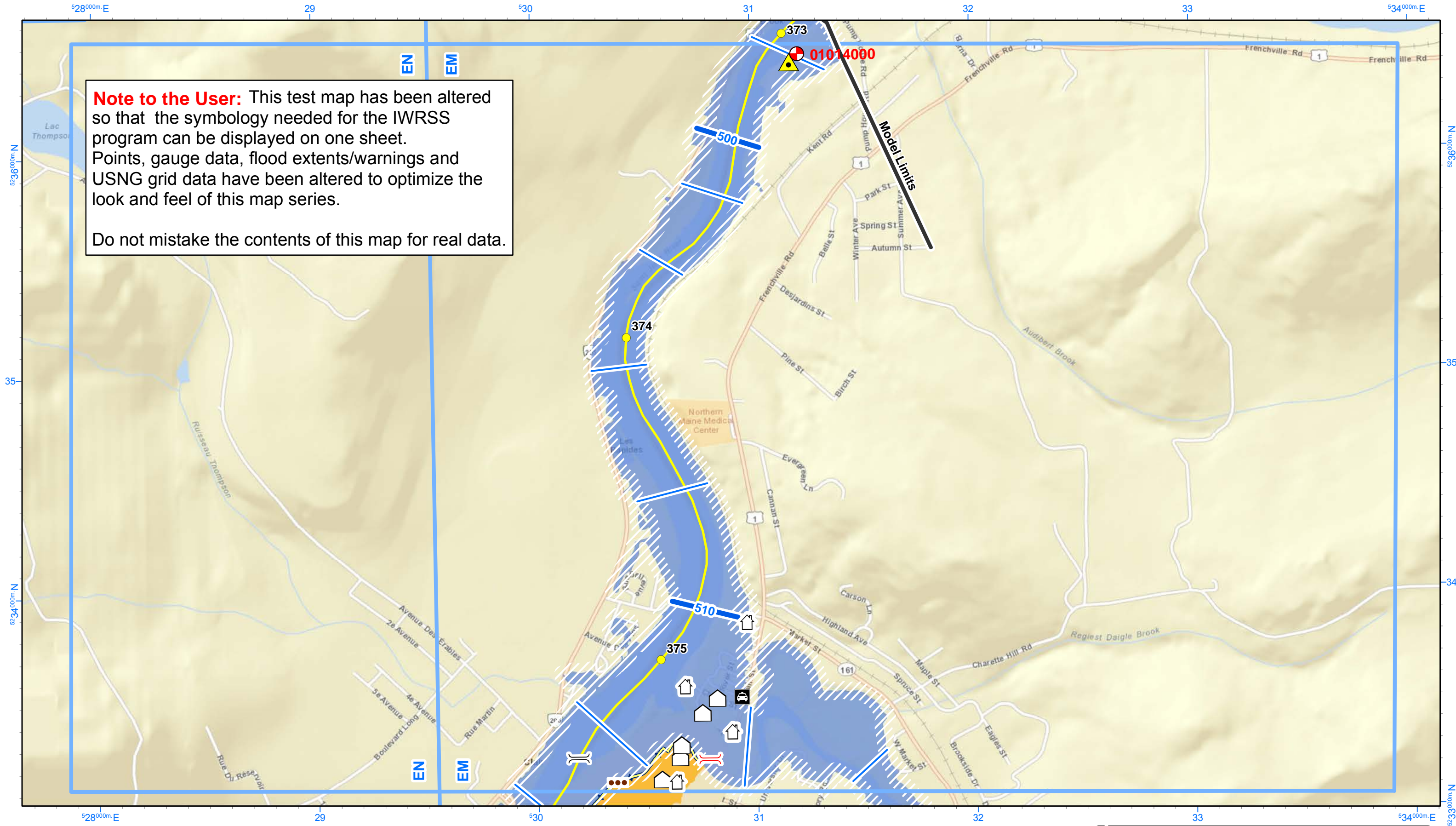
IWRSS

At St. John Gage (01014000)  
**Saint John River Estimated Inundation**  
**River Stage 28.60 Feet**  
Map Library ID: 123456  
Map ID: 19TEN2833336

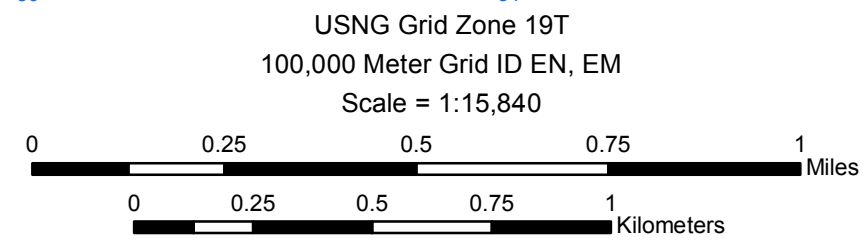
01APR2013







- Flood Extent
- Leveed Area
- Potential Inundation



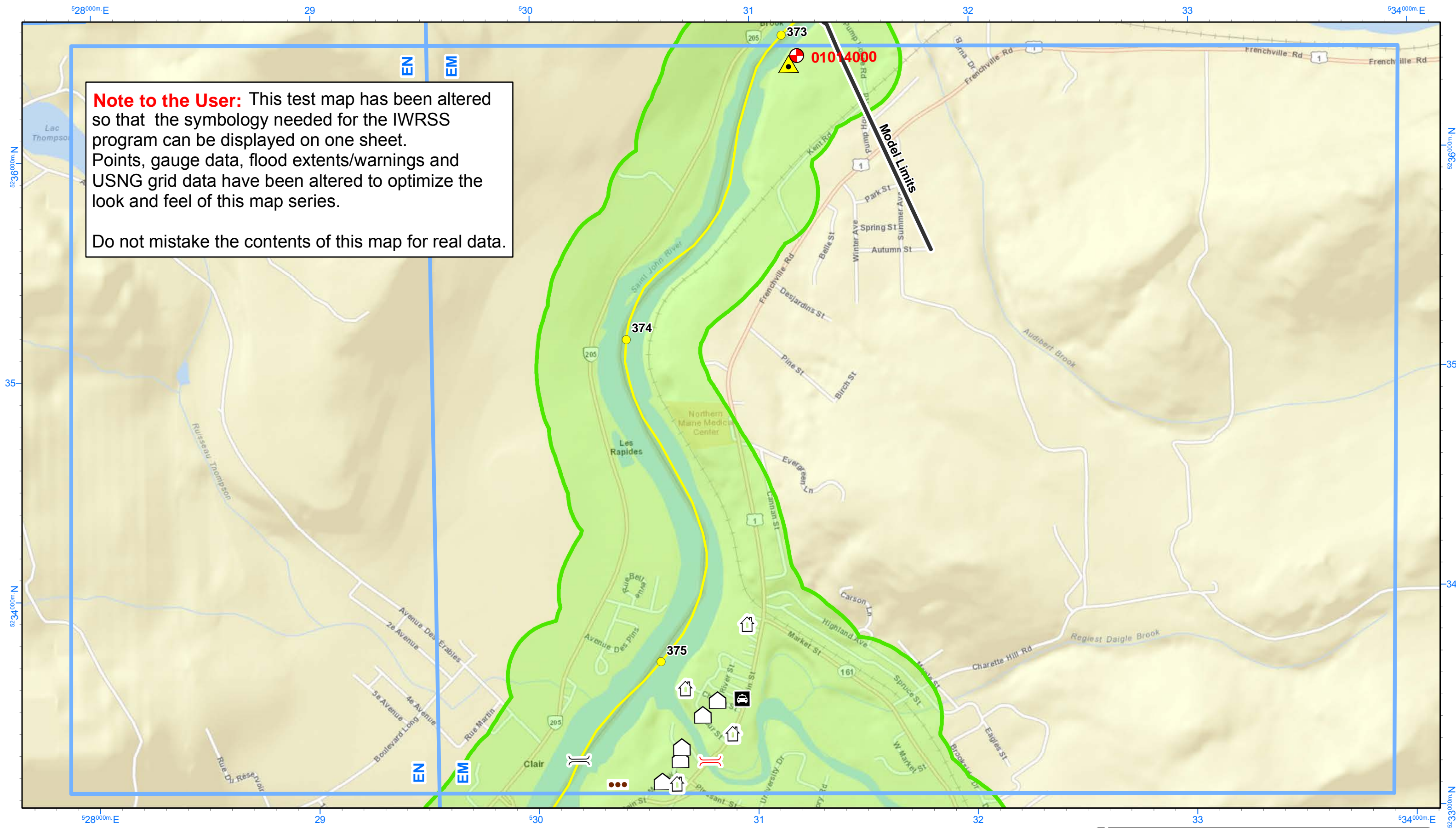
**IWRSS**

At St. John Gage (01014000) 01APR2013

**Saint John River Estimated Inundation**  
**River Stage 28.60 Feet**

Map Library ID: 123456 Map ID: 19TEN2833336






**Note to the User:** This test map has been altered so that the symbology needed for the IWRSS program can be displayed on one sheet. Points, gauge data, flood extents/warnings and USNG grid data have been altered to optimize the look and feel of this map series.

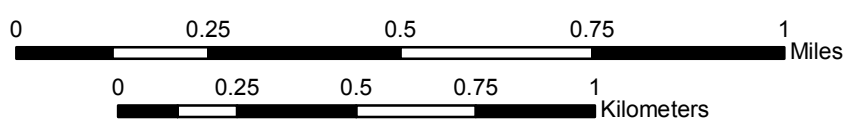
Do not mistake the contents of this map for real data.



F-5

 Flood Warning

USNG Grid Zone 19T  
100,000 Meter Grid ID EN, EM  
Scale = 1:15,840



**IWRSS**

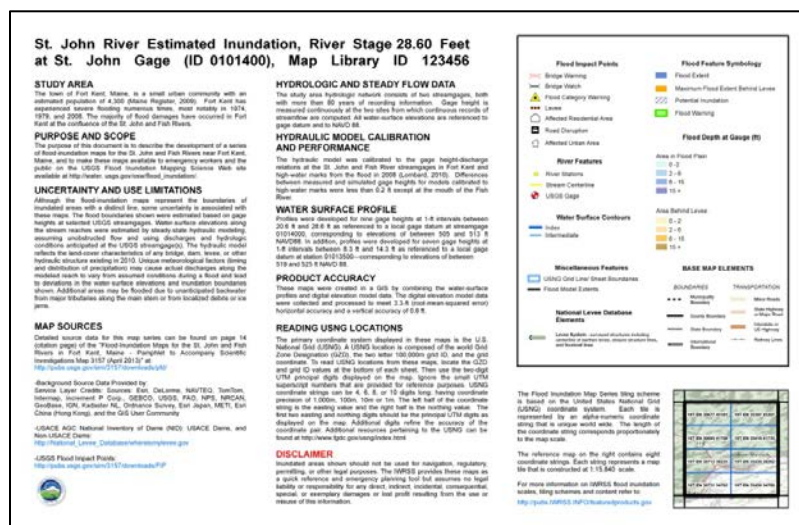
At St. John Gage (01014000)  
**Saint John River Flood Warning**  
Map Library ID: 123456

01APR2013  
Map ID: 19TEN2833336

## Map Notes Page

The Map Notes page template contains notes to users section and legend for the Flood Depth, Flood Inundation Stages, and Flood Warning Sheets. This page displays information about:

- The purpose and use of the maps
- Data definitions and sources
- Disclaimer
- Brief tutorial into reading USNG locations
- Provides the legend



### Figure 1. Map Notes Page Example

Map Notes page is made up of 3 columns, legend, and the USNG reference map. The page is setup as an 11" by 17" sheet.

Text	Font	Size	Style	Color	Halo	Notes
Title	Arial	22 pt	Bold	Red Fill	N/A	
Sub Titles	Arial	14 pt	Bold	Black	N/A	Capitalize
Text	Arial	10 pt		Black	N/A	
URL	Arial	10 pt		Cretan Blue		

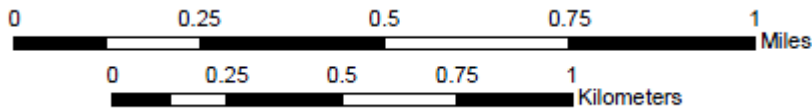
### Table 1. Map Notes Editable Text

## Detailed Pages

All sheets are 11" by 17".

### Scale Bar and North Arrow

While not technically editable text, the scale bars and north arrow are dynamic and will change with the scale and rotation of the map frame as you change study areas.



**Figure 2. Scale Bars**

The sheets are derived by splitting either the north or south half of a USGS 7.5 minute topographic quadrangle evenly into four parts. The sheets are designed for display at 1:15,840, or 1 inch = 1/4 mile. The font used on the scale bars should be set to a size of 8.



**Figure 3. Sheet Index North Arrow**

The north arrow is the ESRI 5 North Arrow displayed at a size of 95. This arrow will rotate depending on the projection and rotation of the main data frame. Make sure that the angle of the north arrow agrees with the changes made to the data frame prior to printing.

### Background Data

The background data used for these sheets are services available through ESRI's ArcGIS Online. The services are available from [services.arcgisonline.com](http://services.arcgisonline.com).

The symbology used in the main data frame and in the locator map is discussed in the map symbology section of this document.

### Data Frame Border

The border of the map data frame displays the coordinate ticks associated with the UTM and USNG coordinate systems. The ticks closest to each corner should display using the complete notation while those interior to the edge of the map will display in a shorter fashion. The coordinate ticks should be set in the template and as long as the coordinate system is set to the appropriate UTM zone, the ticks will display correctly.

710000m.E

Figure 4. Coordinate Tic

## Title Block

The title block contains information about the study area being mapped.

<b>IWRSS</b>	At Example Gage (00000000)		00MON2000
	<b>Study Area Estimated Inundation</b> <b>River Stage 00.00 Feet</b>		
	Map Library ID: 123456		Map ID: 00TEN0000000

Figure 5. Example Title Block

Text	Font	Size	Style	Color	Edited By
Title	Arial	12 pt	Bold	Black	Manual
River Stage	Arial	12 pt	Bold	Black	Manual
At Gage (Top Left)	Arial	8 pt	Regular	Black	Manual
Date	Arial	8 pt	Regular	Black	Manual
Map Library ID	Arial	8 pt	Regular	Black	Manual
Map ID	Arial	8 pt	Regular	Black	Manual

Table 2. Title Block Editable Text

## USNG Information

The block of text in the lower center portion of the map sheet contains information about the location of the sheet in reference to the US National Grid. The USNG Grid Zone and 100,000 meter Grid ID are required along with the coordinates on the map collar to derive USNG coordinate locations from the map.

USNG Grid Zone ##T
100,000 Meter Grid ID EN, EM
Scale = 1:15,840

Figure 6. USNG Information Block

Text	Font	Size	Style	Color
USNG_GZD	Arial	10 pt	Regular	Black
GridID	Arial	10 pt	Regular	Black

Table 3. USNG Information Editable Text

## Map Symbolology

### Flood Impact Points



Bridge is unsafe

Type: Character Marker Symbol  
Font: ESRI Environmental & Icons  
Subset: Latin-1 Supplement  
Description: Bridge  
Unicode: 250  
Size: 25  
Color (RGB): 255, 0, 0; Mars Red  
Mask: Halo; Size-2.0; Color-Arctic White



Bridge is clear of floodwaters

Type: Character Marker Symbol  
Font: ESRI Environmental & Icons  
Subset: Latin-1 Supplement  
Description: Bridge  
Unicode: 250  
Size: 25  
Color (RGB): 0, 0, 0; Black  
Mask: Halo; Size-2.0; Color-Arctic White



Flood Category Warning

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Default Marker	ESRI Default Marker
Subset:	Basic Latin	Basic Latin
Description:	Triangle with middle circle	Solid Triangle
Unicode:	48	35
Size:	25	25
Color (RGB):	0, 0, 0; Black	255, 255, 0; Solar Yellow
Mask:	None	None



Levee

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI US MUTCD 3	ESRI US MUTCD 3
Subset:	Latin-1 Supplement	Latin-1 Supplement
Description:	Three circles	Solid Rectangle
Unicode:	182	181
Size:	25	25
Color (RGB):	155, 38, 0; Cherrywood Brown	255, 255, 255; White
Mask:	None	None



## Affected Residential Area

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Hazardous Materials	ESRI Hazardous Materials
Subset:	Latin-1 Supplement	Latin-1 Supplement
Description:	House Outline	Solid House Shape
Unicode:	179	178
Size:	18	18
Color (RGB):	0, 0, 0; Black	255, 255, 255; White
Mask:	None	None



## Affected Urban Area

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Cartography	ESRI Cartography
Subset:	Latin-1 Supplement	Latin-1 Supplement
Description:	House Outline	Solid House Shape
Unicode:	214	215
Size:	18	18
Color (RGB):	0, 0, 0; Black	255, 255, 255; White
Mask:	Halo; Size-2.0; Color-Arctic White	None



## Road Disruption

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Public 1	ESRI Public 1
Subset:	Basic Latin	Basic Latin
Description:	Car	Solid Square
Unicode:	96	74
Size:	18	18
Color (RGB):	0, 0, 0; Black	255, 255, 255; White
Mask:	None	None

## River Features

### ● River Stations

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Default Marker	ESRI Default Marker
Subset:	Basic Latin	Basic Latin
Description:	Circle Outline	Solid Circle
Unicode:	40	33
Size:	10	10
Color (RGB):	0, 0, 0; Black	255, 255, 0; Solar Yellow
Mask:	None	None





### Label

Label Expression:	[Value]	Text Background:	-
Font:	Arial	Fill Color (RGB):	-
Size:	10	Line Color (RGB):	-
Style:	Bold	Line Style:	-
Color (RGB) :	0, 0, 0; Black	Line Width:	-
X, Y Offset:	0, 0	Leader Line:	-
Angle:	0	Mask:	1pt; 255, 255, 255; Arctic White
V. Alignment:	Bottom	Placement:	Prefer Top Right
H. Alignment:	Center		



### USGS Gage

	Layer 1 (Top)	Layer 2 (Middle)
Type:	Character Marker Symbol	Character Marker Symbol
Font:	ESRI Enviro Hazard Analysis	ESRI Enviro Hazard Analysis
Subset:	Latin-1 Supplement	Latin-1 Supplement
Description:	Circle Outline	Circle with cutouts
Unicode:	167	60
Size:	12	12
Color (RGB):	0, 0, 0; Black	255, 0, 0; Mars Red
Mask:	None	None
	Layer 3 (Bottom)	
Type:	Character Marker Symbol	
Font:	ESRI Enviro Hazard Analysis	
Subset:	Latin-1 Supplement	
Description:	Solid Circle	
Unicode:	38	
Size:	12	
Color (RGB):	255, 255, 255; White	
Mask:	None	



### Label

Label Expression:	[NAME]	Text Background:	-
Font:	Arial	Fill Color (RGB):	-
Size:	12	Line Color (RGB):	-
Style:	Bold	Line Style:	-
Color (RGB) :	255, 0, 0; Mars Red	Line Width:	-
X, Y Offset:	0, 0	Leader Line:	-
Angle:	0	Mask:	2pt; 255, 255, 255; Arctic White
V. Alignment:	Bottom	Placement:	Prefer Right
H. Alignment:	Center		

## Stream Centerline

Layer 1  
 Type: Simple Line Symbol  
 Color (RGB): 255, 255, 0; Solar Yellow  
 Style: Solid  
 Width: 2

## Water Surface Contours



Index

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Simple Line Symbol	Simple Line Symbol
Color (RGB):	0, 92, 230; Lapis Lazuli	255, 255, 255; White
Style:	Solid	Solid
Width:	4	8



Label

Label Expression:	[Value]	Text Background:	-
Font:	Arial	Fill Color (RGB):	-
Size:	10	Line Color (RGB):	-
Style:	Bold	Line Style:	-
Color (RGB) :	0, 112, 255; Cretan Blue	Line Width:	-
X, Y Offset:	0, 0	Leader Line:	-
Angle:	0	Mask:	-
V. Alignment:	Bottom	Placement:	Horizontal
H. Alignment:	Center	Position:	On the Line



Intermediate

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Simple Line Symbol	Simple Line Symbol
Color (RGB):	0, 112, 255; Cretan Blue	255, 255, 255; White
Style:	Solid	Solid
Width:	1.5	5

## Miscellaneous Features



USNG Grid Line / Sheet Boundaries

Type: Simple Fill Symbol  
 Fill Color: No Fill  
Outline  
 Type: Simple Line Symbol  
 Color (RGB): 115, 178, 255; Yogo Blue  
 Style: Solid  
 Width: 3



Label

Label Expression:	[Sheet Name]	Text Background:	-
Font:	Arial	Fill Color (RGB):	-
Size:	12	Line Color (RGB):	-
Style:	Bold	Line Style:	-
Color (RGB) :	0, 112, 255; Cretan Blue	Line Width:	-
X, Y Offset:	0, 0	Leader Line:	-
Angle:	0	Mask:	2pt; 255, 255, 255; Arctic White
V. Alignment:	Bottom	Placement:	Vertical
H. Alignment:	Left		

## Flood Model Extents

	Layer 1 (Top)	Layer 2 (Bottom)
Type:	Simple Line Symbol	Simple Line Symbol
Color (RGB):	0, 0, 0; Black	255, 255, 255; White
Style:	Solid	Solid
Width:	3	7
Label		
Label Expression:	[EOM]	Text Background: -
Font:	Arial	Fill Color (RGB): -
Size:	10	Line Color (RGB): -
Style:	Bold	Line Style: -
Color (RGB) :	0, 0, 0; Black	Line Width: -
X, Y Offset:	0, 0	Leader Line: -
Angle:	0	Mask: 1pt; 255, 255, 255; Arctic White
V. Alignment:	Bottom	Placement: Parallel
H. Alignment:	Center	Position: Above


## National Levee Database Elements




Levee System

	Layer 1 (Top)	Layer 2 (Middle)	Layer 3 (Bottom)
Type:	Cartographic Line Symbol	Marker Line Symbol	Cartographic Line Symbol
Font:	N/A	N/A	N/A
Subset:	N/A	N/A	N/A
Description:	Solid Line	Diamond – Repeating Pattern	Solid Line
Unicode:	N/A	N/A	N/A
Size:	1.4	10	2.85
Color (RGB):	255, 255, 115; Autunite Yellow	0, 38, 115; Dark Navy	0, 38, 115; Dark Navy
Mask:	None	None	None


Flood Feature Symbolology

 Flood Extent – Transparent 25%


Type:	Simple Fill Symbol	
Fill Color:	100, 139, 217	
Outline:		Layer 1
Type:		No Line
Color (RGB):	-	
Style:	-	
Width:	-	

 Leveed Area – Transparent 30%

Type:	Simple Fill Symbol	
Fill Color:	255, 170, 0 Electron Gold	
Outline:		Layer 1
Type:		No Line
Color (RGB):	-	
Style:	-	
Width:	-	

 Potential Inundation

Type:	Line Fill Symbol	
Transparency:	0%	
		Layer 1 (Top)
Fill Line Type:	Simple Line Symbol	
Color (RGB):	255, 255, 255; White	
Style	Solid	
Width	1.5	
Outline Line Type:	None	
Color (RGB):	-	
Style:	-	
Width:	-	
Line Fill Angle:	45	
Line Fill Offset:	0	
Line Fill Separation:	5	

 Flood Warning

Layer 1 Outline







Transparency:	0%
Type:	Simple Fill Symbol
Outline Color:	85, 255, 0 Quetzal Green
Outline Width:	3.0

Layer 2 Fill

Transparency:	75%
Type:	Simple Fill Symbol
Fill Color:	85, 255, 0 Medium Apple

## Flood Depth

### Area in Flood Plain – Outline

	Type:	Simple Fill Symbol	
	Fill Color:	No Fill	
	<u>Outline</u>		
	Type:	Simple Line Symbol	
	Color (RGB):	178, 178, 178; 30% Grey	
	Style:	Solid	
	Width:	0.5	
0-2 Feet – Transparent 35%			
	Type:	Simple Fill Symbol	
	Fill Color:	203, 242, 245	
	Outline:		Layer 1
	Type:		No Line
	Color (RGB):	-	-
	Style:	-	-
	Width:	-	-
2-6 Feet – Transparent 35%			
	Type:	Simple Fill Symbol	
	Fill Color:	140, 190, 237	
	Outline:		Layer 1
	Type:		No Line
	Color (RGB):	-	-
	Style:	-	-
	Width:	-	-
6-15 Feet – Transparent 35%			
	Type:	Simple Fill Symbol	
	Fill Color:	100, 139, 217	
	Outline:		Layer 1
	Type:		No Line
	Color (RGB):	-	-
	Style:	-	-
	Width:	-	-
15 + – Transparent 35%			
	Type:	Simple Fill Symbol	
	Fill Color:	84, 84, 179	
	Outline:		Layer 1
	Type:		No Line
	Color (RGB):	-	-
	Style:	-	-
	Width:	-	-

## Leveed Area Flood Extent– Outline

Type: Simple Fill Symbol  
Fill Color: No Fill  
Outline  
Type: Simple Line Symbol  
Color (RGB): 178, 178, 178; 30% Grey  
Style: Solid  
Width: 0.5



0-2 Feet – Transparent 35%

Type: Simple Fill Symbol  
Fill Color: 255, 235, 175 Topaz Sand  
Outline: Layer 1  
Type: No Line  
Color (RGB): -  
Style: -  
Width: -



2-6 Feet – Transparent 35%

Type: Simple Fill Symbol  
Fill Color: 255, 211, 127 Mango  
Outline: Layer 1  
Type: No Line  
Color (RGB): -  
Style: -  
Width: -



6-15 Feet – Transparent 35%

Type: Simple Fill Symbol  
Fill Color: 255, 170, 0 Electron Gold  
Outline: Layer 1  
Type: No Line  
Color (RGB): -  
Style: -  
Width: -



15 + – Transparent 35%

Type: Simple Fill Symbol  
Fill Color: 168, 112, 0 Raw Umber  
Outline: Layer 1  
Type: No Line  
Color (RGB): -  
Style: -

# Appendix G:

## Flood Inundation Map Documentation

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In order to facilitate IWRSS oversight of the quality of the maps, all submissions shall be accompanied by documentation. The documentation shall include the following citations, and shall meet the minimum documentation requirements for each citation.

### **Purpose and Scope**

A general description of the purpose of the study shall be provided, which shall include a description of the type of study completed: map library, event map, historical map or dam break EAP map. A general description of the scope of the study shall be provided.

### **Disclaimer, uncertainties, use limitations, and accuracy assessment for maps**

The disclaimer shall incorporate the default IWRSS disclaimer and the default IWRSS use limitations. Any applicable project specific use limitations shall be incorporated into the documentation. For Official Use Only (FOUO) data shall be clearly identified, and the conditions for which FOUO data may be released to the public shall be disclaimed.

A generalized accuracy assessment of the mapping products shall be developed based upon the horizontal and vertical mapping error and any additional project specific information. Standardized IWRSS guidance shall be provided on how mapping products, classified by categorical horizontal and vertical accuracy, may be applied by users. The accuracy assessment shall include a list of streamgage(s) that may be considered to be connected to the map and used for event mapping, and disclose the elevations that depart from a measured rating curve at the specified streamgage(s).

### **Study area description, including flood risk analysis of impacts to life and property**

A generalized study area description shall be included which includes a description of the geographic location of the study, a description of the study river reach, the streamgage(s) that are tied to the study, the elevations mapped by the study, a list of communities included within the study reach, the flood history and significant flood impacts within the study reach.

### **Elevation data source, datum and nominal accuracy**

A description of the quality of the streamgage vertical datum shall be provided for any streamgage(s) that are associated with the mapping products. The description shall include the following items: the date of the last streamgage elevation survey, source of the streamgage survey, survey technique, survey datum, methods used to convert the survey datum and nominal accuracy of the survey.

A description of the quality of the terrain model source(s) shall be provided. The description shall include: a description of the data source, acquisition date, publication date, vertical/horizontal nominal accuracy, native horizontal datum/projection, native vertical datum, format (raster or TIN), DEM cell size (if applicable).

A description of the quality of survey information used to develop the hydraulic and/or terrain model geometry shall be provided. The description shall include the following items: a description of the data source, survey acquisition date, vertical/horizontal nominal accuracy, native horizontal datum/projection, and native vertical datum.

A description of the quality of other information, such as as-built plans, used to develop the hydraulic and/or terrain model geometry shall be provided. The description shall include the following items: a description of the data source, acquisition date, publication date, vertical/horizontal nominal accuracy, native horizontal datum/projection, native vertical datum and format.

#### **Hydrologic modeling, methods (model and version), accuracy assessment, and calibration procedures**

A description of the hydrologic model (if applicable) shall include a discussion of the model version, model technique, and scale. The source of the model geometry, and any updates to the source geometry shall be described. Major assumptions made during the modeling analysis shall be described. Model calibration and validation techniques, assumptions and results shall be described. An error analysis shall be published and based upon on the best available data. A description of the hydrologic analysis shall include a discussion of the flows loaded into the hydraulic model, a discussion of the location and assumptions made at the flow load points, an analysis of the local flow contributions within the study area extent, and the evaluation of backwater influences on the study extent.

#### **Hydraulic modeling, methods (model and version), calibration procedures and validation results**

A description of the hydraulic model shall be provided, which will include the version of the model, the model dimension (1D or 2D), and the mode of operation (steady or unsteady flow). The source of the model geometry, and any updates to the source geometry shall be described. The assumptions and justification for selection of a one- or two dimensional analysis and a steady or unsteady mode of operation shall be described. Major assumptions made during the modeling analysis, including boundary conditions, and modeling approaches for levees or other storage areas (if applicable) shall be described. For flood libraries or events maps connecting inundation data to forecast points, a rating curve analysis shall be developed to compare the model results to the operational rating curve. Hydraulic model calibration and validation techniques, assumptions and results shall be described. An error analysis shall be published and based upon on the best available high-water mark observations and available streamgage data.

#### **Water-surface profile development process and mapping methods**

A description of the GIS techniques used to convert the hydraulic model profiles into inundation polygons and optional depth grids shall be included. A description of terrain model post-processing shall be provided.

#### **Coordinate system & projection & horizontal datum**

Documentation shall be provide to demonstrate that all mapping data have been submitted in a standard IWRSS geographic coordinate system (NAD83 based system). The projection shall be identified, and the NAD83 horizontal datum shall be disclaimed.

#### **List of data/products developed and delivered**

A list of the standard IWRSS product deliverables and optional IWRSS deliverables shall be included.

#### **List of references cited**

A list of references cited throughout the documentation shall be published in standard format.



# Appendix H:

## Terrain and Hydraulic Modeling Description

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### H.1 Terrain Data

The best available topographic data referenced to the North American Vertical Datum of 1988 (NAVD88) should be used for the development of geometric data for hydraulic model inputs and the generation of flood inundation map products from hydraulic model results. Ideally, a high-accuracy terrain model derived from detailed ground surface and bathymetric information will be used for model generation and analysis. However, the best data available geometric data (terrain or surveyed cross sections) from multiple data sources may be used to develop a hydraulic model. Regardless of the data sources used, detailed information documenting the data source, method of processing, and resultant accuracy of the terrain data should be delivered with the model and mapping products and provided to data users. Key information to be published with the map products are sources (if applicable) and accuracy of: elevation data, vertical datum and accuracy, horizontal datum and accuracy, spatial reference system, acquisition date, and output file format.

Further, the vertical accuracy of the terrain model used for analysis must be appropriate for the intended use of the underlying river hydraulics model and the topography of the study area. For instance, detailed channel information becomes more important with smaller rivers that have less floodplain areas. In addition, higher resolution data are of greater importance for rivers with little relief, when compared with high-relief areas. The horizontal and vertical data accuracy of the elevation data should be clearly documented according to FGDC standards ([Federal Geographic Data Committee, 1998](#)).

This requirements document does not define how the terrain data are gathered as technological advances in surveying and remote sensing are not the focus of this effort; however, the terrain models should include linear features that affect the movement of water in the floodplain. Levees, floodwalls, roads, riverbanks and other high ground should be included in development of the terrain model and be properly represented in the corresponding river hydraulics model. *USGS lidar base specifications* currently serve as the minimum standard if new lidar are collected ([Heidemann, 2012](#)).

Sources for elevation data used in model generation may include individually surveyed cross sections or data from existing models which do not match the topographic data used for inundation mapping. To the extent possible, these differences should be resolved and then the best available data should be used for the model development and mapping. Although it is acceptable to combine data from different sources, it is preferred that a single digital terrain model, created from an integrated digital terrain model consisting of both terrestrial and bathymetric elevation data having the same vertical datum and units of measure. The terrain model should represent the bare earth without elevation deviations due to vegetation cover and man-made structures such as building and bridges. It is recommended that the vertical difference between each successive map water surface elevation interval is no less than half the contour interval of the supporting elevation model.

### H.2 Hydraulic Modeling

Hydraulic modeling is used to define the relationship between channel and overbank flow, and water surface elevation. In the FIM process, hydraulic models are developed to compute water

surface elevations for user-defined streamflows. The method used is based on the purpose of the hydraulic model. The most common hydraulic modeling alternatives for FIM are one-dimensional steady-flow, one-dimensional unsteady-flow, and two-dimensional unsteady-flow modeling. Coastal inundation mapping (which is outside the scope of this document) requires at least 2-D hydrodynamic modeling to accurately capture the combined tidal, surge and riverine influences. Regardless of the modeling alternative selected, the hydraulic model must represent the geometry of the land surface and all hydraulic structures that impact flow. Hydraulic models are most accurate when calibrated with and validated by historic flow events.

When deciding between the appropriateness of steady-flow versus unsteady-flow hydraulic modeling, the question of whether hydrologic routing methods are accurate enough to produce flow rates along the river system must be considered. If they are not suitable, then a steady-flow hydraulics model is required. One-dimensional steady-flow modeling is appropriate in rivers having gradually varied flow, where the floodplain is well defined. If there is significant storage in the system that would attenuate flows, unsteady-flow modeling should be used. Unsteady-flow modeling also is necessary when the flow hydrograph is very dynamic in time (rapidly rising and falling hydrographs) such as: (1) dam breach flows and flash floods, (2) in levee overtopping and breaching scenarios, (3) where flows reverse, and (4) in extremely flat river systems where gravity is not the only significant driving force of flow. Two-dimensional models are most appropriate where the floodplain is defined by flat terrain and direction of flow cannot be easily determined. Candidate scenarios for two-dimensional modeling include: (1) alluvial fans, (2) highly braided streams, (3) very wide, flat floodplains where water will take multiple paths, (4) bays and estuaries, and (5) applications where detailed velocity information is important.

While there is a theoretical basis for model selection, there also are many practical considerations. Rivers and floodplains in which the dominant direction of flow follows the general river flow path can be modeled appropriately for depth and water surface elevations. However, around bends in the river and in coastal areas where lateral forces impact the water surface, results may not be accurate. River systems described by numerous and complex hydraulic structures such as bridges, weirs, dams, levees, and pump stations require a model capable of simulating the impacts of such structures. It is generally not practical to simulate large river systems with long simulation times (long forecast window) using two-dimensional modeling. Further, if detailed terrain data are not available, the benefits of using a two-dimensional model will not be realized.

The hydraulic modeling software used for the analysis should be well documented, well established, and widely accepted in the hydraulic engineering community. The development and use of geometric data used in the hydraulic model, model version, geometric parameters selected, flow and boundary conditions used, and modeling decisions should be well supported through documentation that is submitted with the completed maps.

# **Appendix I: Example of Spatially Referenced Flood Impacts**

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Table I-1. Example of spatially referenced Flood Impact statements

Latitude	Longitude	Stage	USGS Gage	Elevation	Category	Impact	NWS Person Responsible	Cooperator Responsible
47.251	-68.5988	29.7	01014000	514.32	Levee	DIKE ALONG SAINT JOHN RIVER IS OVERTOPPED FLOODING DOWNTOWN FORT KENT FROM JAMES STREET TO MARKET STREET.	Jane Doe	John Doe, Ft Kent Public Works
47.2493	-68.6039	27.7	01014000	512.32	Bridge Warning	NEAR RECORD FLOODING. WATER REACHES LEVEL OF THE INTERNATIONAL BRIDGE DECK SUPPORTS. EVACUATIONS MANDATORY.	Jane Doe	John Doe, Ft Kent Public Works
47.251	-68.5988	27.7	01014000	512.32	Levee	DIKE AND LEVEE SYSTEM AT FULL CAPACITY. EVACUATIONS MANDATORY. MANY HOMES FLOODED ON MEADOW LANE AND BLOCKHOUSE ROAD.	Jane Doe	John Doe, Ft Kent Public Works
47.252	-68.595	27.7	01014000	512.32	Residential	EVACUATIONS MANDATORY. FLOODING OF LOWER EAST MAIN STREET INUNDATING SEVERAL STRUCTURES IN THE CENTER OF TOWN.	Jane Doe	John Doe, Ft Kent Public Works
47.253	-68.5918	27.7	01014000	512.32	Urban	EVACUATIONS MANDATORY. WATER FLOWING OVER FISH RIVER BRIDGE. EVACUATIONS MANDATORY.	Jane Doe	John Doe, Ft Kent Public Works
47.2519	-68.5932	27.7	01014000	512.32	Bridge Warning	WIDESPREAD FLOODING OF LOWER EAST MAIN STREET INUNDATING SEVERAL STRUCTURES IN THE CENTER OF TOWN. EVACUATIONS PROBABLE.	Jane Doe	John Doe, Ft Kent Public Works
47.253	-68.5918	26.7	01014000	511.32	Urban	WATER FLOWING OVER THE TOP OF THE FISH RIVER BRIDGE. EVACUATIONS PROBABLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2519	-68.5932	26.7	01014000	511.32	Bridge Warning	SAINT JOHN RIVER REACHES THE BOTTOM OF THE INTERNATIONAL BRIDGE, BRIDGE CLOSED. EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2493	-68.6039	25.7	01014000	510.32	Bridge Warning	FISH RIVER REACHES THE BOTTOM OF THE MAIN STREET (FISH RIVER) BRIDGE, BRIDGE CLOSED. EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2519	-68.5932	25.7	01014000	510.32	Bridge Warning	HOMES THREATENED ON MEADOW LANE, EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2511	-68.5961	25.7	01014000	510.32	Residential		Jane Doe	John Doe, Ft Kent Public Works

47.2525	-68.5949	25.7	01014000	510.32	Residential	HOMES THREATENED ON BLOCKHOUSE ROAD, EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2538	-68.5936	25.7	01014000	510.32	Residential	HOMES THREATENED ON DUFOUR STREET, EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2544	-68.5927	25.7	01014000	510.32	Residential	HOMES THREATENED ON CHURCH STREET, EVACUATIONS POSSIBLE.	Jane Doe	John Doe, Ft Kent Public Works
47.2472	-68.5776	24.7	01014000	509.32	Road	FLOODING IN LOW SPOTS AND BROOK CROSSINGS ALONG STATE ROUTE 161 ABOVE FORT KENT.	Jane Doe	John Doe, Ft Kent Public Works
47.2493	-68.6039	24.7	01014000	509.32	Bridge Watch	WATER REACHES TOP OF BRIDGE PIERS ON INTERNATIONAL BRIDGE.	Jane Doe	John Doe, Ft Kent Public Works
47.251	-68.5952	22.7	01014000	507.32	Urban	QUIGLEY FLATS (QUIGLEY BUILDING SUPPLY LUMBER YARD) AND THE BLOCK HOUSE PARK BEGIN TO FLOOD.	Jane Doe	John Doe, Ft Kent Public Works
47.2549	-68.5946	22.7	01014000	507.32	Urban	AN ELDERLY HOUSING PROJECT ON NORMANGUY DRIVE IS EVACUATED.	Jane Doe	John Doe, Ft Kent Public Works
47.2575	-68.5908	19.7	01014000	504.32	Urban	BETWEEN 20 AND 22 FEET BASEMENT FLOODING BEGINS AT THE B+M APARTMENTS ON EAST MAIN STREET.	Jane Doe	John Doe, Ft Kent Public Works
		17.7	01014000	502.32	Urban	BETWEEN 18 AND 19 FEET WATER COULD BEGIN TO GET INTO THE BASEMENTS OF SOME HOUSES ALONG THE RIVER IF PUMPS FAIL.	Jane Doe	John Doe, Ft Kent Public Works
		15.7	01014000	500.32	Rural	BETWEEN 16 AND 18 FEET MINOR LOWLAND FLOODING OCCURS.	Jane Doe	John Doe, Ft Kent Public Works
47.2833								John Doe, Ft Kent Public Works
3	-68.58528	26.5	01014000	511.12	Flood Category	Major Flood Stage	Jane Doe	John Doe, Ft Kent Public Works
47.2833								John Doe, Ft Kent Public Works
3	-68.58528	24.5	01014000	509.12	Flood Category	Moderate Flood Stage	Jane Doe	John Doe, Ft Kent Public Works
47.2833								John Doe, Ft Kent Public Works
3	-68.58528	22.5	01014000	507.12	Flood Category	Flood Stage	Jane Doe	John Doe, Ft Kent Public Works
47.2833								John Doe, Ft Kent Public Works
3	-68.58528	20.5	01014000	505.12	Flood Category	Action Stage	Jane Doe	John Doe, Ft Kent Public Works

[http://water.usgs.gov/me/nwis/uv/?site\\_no=01014000](http://water.usgs.gov/me/nwis/uv/?site_no=01014000)

<http://water.weather.gov/ahps2/hydrograph.php?wfo=car&gage=ftkm1>