NOAA PARTNERED GUIDELINES

FOR THE

DEVELOPMENT OF ADVANCED HYDROLOGIC PREDICTION SERVICE FLOOD INUNDATION MAPPING

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Acronyms

AHPS	Advanced Hydrologic Prediction Service
CNMS	Coordinated Needs Management Strategy
CSC	Coastal Services Center
CTP	Cooperating Technical Partner
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FGDC	Federal Geographic Data Committee
FIM	Flood Inundation Mapping
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GCS	Geographic Coordinate System
GIS	Geographic Information System
H&H	Hydrology and Hydraulics
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center Riverine Analysis System
HUC	Hydrologic Unit Code
HWM	High Water Mark
LiDAR	Light Detection and Ranging
NAD	North American Datum
NADCON	North American Datum Conversion
NAVD	North American Vertical Datum
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration

NWS	National Weather Service
RFC	River Forecasting Center
SFHA	Special Flood Hazard Area
TIN	Triangulated Irregular Network
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VDATUM	Vertical Datum Transformation
VERTCON	North American Vertical Datum Conversion
WFO	Weather Forecast Office
WSEL	Water Surface Elevation

NOAA Partnered Guidelines for the Development of Advanced Hydrologic Prediction Service Flood Inundation Mapping

Introduction

Inundation mapping corresponding to National Weather Service (NWS) flood categories conveys flood severity and risk, based on the potential impact to property and public safety rather than on the probability of occurrence. Such maps are provided at select NWS Advanced Hydraulics Prediction Service (AHPS) forecast locations, with the aim to assist local partners – such as emergency mangers and public officials – in assessing their overall flood risk.

1. National Weather Service Advanced Hydrologic Prediction System Inundation Mapping Program

The National Flood Insurance Program (NFIP) of the Federal Emergency Management Agency (FEMA) measures flood risk based on the probability of occurrence for particular floods. Probability of occurrence is measured as the annual chance of exceedance. The 1-percent-annual-chance flood (i.e., 100 yr flood) is used as the standard for regulatory and flood insurance purposes. This reference is commonly used in floodplain management and floodplain mitigation.

Due to local conditions and varying situations (e.g. topography, infrastructure developments, storm types, etc.), flood impacts do occur at levels less severe but more frequent than the 1-percent-annual-chance event. Significant impacts may occur commensurate to the event's level of occurrence and emergency response may be warranted. In addition, the extent and severity of flooding varies at different locations. Thus, it is desirable for entities in the public and private sector to know which areas near the river are at high, medium and low risk from flooding.

The National Oceanic Atmospheric Administration (NOAA) National Weather Service (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 potentially save lives. NWS coordinates with the United States Geological Survey and local cooperators in this effort. In addition, the NWS works with many water resource authorities such as the U.S. Army Corps of Engineers and Bureau of Reclamation to improve river and water forecasting. Because there is a need to better understand the impacts of flooding and communicate the risks thereof, the National Weather Service is partnering with many lead agencies to create these Guidelines. Its intent is to assist local communities and water authorities better communicate future flood risks across the United States through the development and implementation of web-based Flood Inundation Map libraries. Since surveys by Claes Fornell International Group and David Ford Consulting Engineers have indicated that communities are familiar with the NWS flood severity categories and knowledgeable about NOAA's Advanced Hydrologic Prediction Services (AHPS), NOAA NWS will partner with communities and water authorities to implement Flood Inundation Map Libraries onto AHPS. The Flood Inundation Map Libraries, combined with USGS river observations and NWS forecasts, enhance the communication of flood risk and provide decision makers the information they need to mitigate the impacts of flooding.

1.1. Program Description

Inundation mapping of NWS flood categories conveys flood severity and risk based on the potential impact to property and public safety. The severity of flooding at a given river stage can differ along a particular river reach as a result of varying channel characteristics, local topography, and the location of structures and roads relative to the floodplain.

In contrast, Flood Insurance Rate Maps (FIRMs) developed and used by FEMA's NFIP convey flood severity based on the probability of occurrence of particular floods. Probability of occurrence is measured as the annual chance of exceedance. The 1-percent-annual-chance flood is used as the standard for regulatory and flood insurance purposes and is also widely used in floodplain management and mitigation.

Comparison of NWS flood maps and NFIP FIRMs and Flood Insurance Studies (FISs) shows differences between NWS flood categories and the 1-percent-annual-chance flood: NWS flood maps provide relevant and detailed information to its local partners – such as emergency managers and key decision makers –, many of whom contend with flooding more frequent than the 1-percent annual chance flood. Impact flooding, as defined by NWS flood categories, often begins before the 1 percent-annual-chance elevation is reached. By assigning flood categories based on severity of impending risk, the NWS issues the appropriate (minor, moderate, and major) flood warnings to the local officials in charge of minimizing damage and implementing evacuations.

1.2. NWS Mapping Partnerships

The NWS, in collaboration with the Coastal Services Center (CSC) of NOAA, initiated a pilot project to use NWS Form E-19 data to map the areal extent of various flood categories in a product known as NWS Flood Severity Inundation Maps. The successful partnership with CSC began with a static-form prototype in eastern North Carolina and later transformed into an interactive AHPS website; its coverage would eventually include the four Gulf States (Alabama, Mississippi, Louisiana, and Texas) affected by Hurricanes Katrina and Rita. As of May 25, 2011, there are 57 inundation map products served interactively on the AHPS Web site (http://water.weather.gov/ahps/inundation.php).

Inundation maps are jointly developed with partners other than the CSC, including universities and local, state and federal government entities. They provide the necessary resources for NWS to manage, guide, and/or develop products for AHPS implementation.

This is demonstrated by the success of the NWS Southern Region's West Gulf River Forecast Center (WGRFC) and the Weather Forecast Offices (WFOs) of Austin/San Antonio and Houston, Texas, who are partnering with the San Antonio River Authority and the Lower Colorado River Authority. This partnership – a model for future partnerships – has produced inundation maps for several AHPS forecast locations in Texas. It has worked in the following manner:

> The local agency or authority provides the data and hydraulic models from a FEMA FIS to create additional inundation maps for the Flood Categories and various river intervals below the 1-percent-annual-chance flood. WGRFC then produces the additional maps, coordinates the preliminary review, and provides the NWS AHPS contractor with the necessary flood inundation shapefiles and flood depth data for integration into the AHPS Web pages.

Since the creation of the first AHPS Flood Mapping products, NWS and CSC have introduced quality assurance measures and quality checks into the process. To maintain consistency and verify map accuracy, the NWS and CSC developed a flood mapping process with quality assurance measures. These guidelines constitute the body of this document.

1.3. Partner Requirements

While there are no formal requirements necessary to partner with the National Weather Service in the development of inundation mapping, it is recommended that the partner exhibit certain capabilities needed to successfully perform the modeling and mapping components of the inundation map libraries. These capabilities include:

- Experience in water resources engineering and modeling
- Experience in GIS-based data management and mapping
- Familiarity with FEMA's National Flood Insurance Program

Partners may hire subcontractors, AE firms, or consultants as necessary to perform the work. Partner registration as professional engineers (PE), geospatial professionals (GISP), or certified floodplain managers (CFM) is not required, but is a plus. For more information on partner requirements, please contact the NWS FIM Services Leader.

1.4. Purpose of Document

This document provides guidelines for the construction of a Flood Inundation Map library. This document is written to a technical audience. Its purpose is to provide officials a framework to develop a Flood Inundation Map library that is consistent with current NWS practices and is easily accessible to its constituents. Since maps are the output, other parties such as emergency managers, local planners, community advisors, or government officials are encouraged to become acquainted with these guidelines.

The guidelines have specifics regarding the usage of NWS forecast locations for flood mapping, the development of water depth grids, and the graphic representation of such products; for this reason, this document is different from other resources. Specifically, the key outputs of the Flood Inundation Map Library will be a series of gridded water depths for areas surrounding a river gage and the spatial extent of these floodwaters. Individual grid layers will correspond to discrete river levels at the gage – the same levels used by the NWS to provide forecasts. Because the ensemble of grids can be mapped geospatially to a forecast location, the collection of maps will be referred to in this document as a "Map Library."

There are four important aspects that are critical to development of web-based map libraries. These include acquiring map data, modeling the water surface, mapping the inundation areas, and representing any complementary productions graphically. The Guidelines discuss the importance of each aspect and provide specific recommendations on the acceptable tolerance and limits of the data, modeling, mapping, and dissemination.

1.5. AHPS Inundation Mapping Program Process

The inundation mapping process is composed of four phases: the planning phase, the map production phase, the AHPS implementation phase, and the map maintenance phase. Each of these steps is outlined in this document. In the planning phase, mapping partners are tasked with site selection. The map production phase is centered on the hydraulic and hydrologic modeling. The implementation phase will include the assembly of information for subsequent review and verification of mapping results by NWS GIS QC teams and the local NWS or EMS. Finally, the maintenance phase ensures that all materials displayed on the AHPS website are up to date, especially after a significant flooding event.

2. Phase 1 – Planning

The initial, or planning, phase of the NWS flood inundation mapping process includes:

1. Pre-selection of candidate AHPS Forecast Gage Locations.
2. Evaluation of data resources for candidate inundation mapping sites.
3. Screening of candidate locations for Phase 2 developments.
4. The identification and coordination of the process roles between FEMA, mapping partners, and the NWS across the four phases.

All AHPS forecast locations should include: accurate topographic data with sufficient vertical accuracy; and engineering data derived from an effective FIS, detailed study (labeled as Zone AE or Zone A1-30). The initial phase for inundation mapping projects is to develop a database of available data for all AHPS forecast locations. The list of AHPS forecast locations was reviewed and prioritized based on flooding impacts, suitability for inundation mapping, and available accurate data.

In other projects, individual forecast point locations are based on the level of flood risk on the neighboring community. For such locations, the need for enhanced visualization of these impacts is more important than the availability of data and topography. An example of a candidate selection requirement is attached in Appendix A.

The planning phase also includes evaluating resources, such as existing topographic, engineering and base data.

NWS is working with regional partners who are conducting ongoing flood studies to develop other AHPS static flood inundation maps. Because data will be acquired as part of the overall flood study, there should be less difficulty in assembling the required data and less need to resolve conflicts and inconsistencies in the data.

2.1. Project Planning

A national analysis that includes all the AHPS forecast locations is available online by the NWS: http://water.weather.gov/ahps/. Using these locations, the partner can select a location for inundation mapping and begin the planning phase.

The planning phase should include the following:

1. Define the length of reaches mapped and obtain partner feedback.
2. Select the modeling approach.
3. Evaluate the rating suitability.
4. Establish a project timeline.
5. Review of GIS base data.

The required topographic, engineering, and base map data and orthophotographic imagery can be acquired from a variety of sources. It is important to consider the most recent aerial imagery and most accurate datasets when developing the inundation mapping.

Acceptable topographic data formats include DEMs and LiDAR; it may be obtained through the local community, a regency agency, or a statewide data clearinghouse.

Engineering support data is used to develop the hydraulic model, which then generates the inundation mapping boundaries. Mapping base data include transportation features, FEMA special flood hazard areas and hydraulic structures. Aerial orthophotographic imagery is the final component; along with the topographic data, it is used to verify and adjust the stream centerline. This is of critical importance when delineating the inundation area.

2.1.1. Review Flood History and Flood Categories

AHPS forecasting locations are used because of the information – necessary for developing various inundation stages – supplied by its respective gage. Each also contains a series of markers, known as Flood Categories, that describe at what stage certain action or flooding occurs. For example, the Yakima River near Parker, OR includes four Flood Categories: the lowest, known as the Action Stage, occurs when the water level is at 9.4'; in contrast, Major Flood Stage occurs at 14' and is usually pre-empted by evacuation.

2.1.2. Review Available Data

The mapping partner should review Section 3.1 to determine what data will be needed to develop the inundation mapping library.

2.2. Review Project Checklist

The project checklist was developed in coordination with USGS and does not include other technical considerations, which are normally part of a FEMA detail flood study, such as Technical Data Notebook and Data Sheet requirements. The checklist was designed to suggest the minimum required tasks, specific actions, and stakeholder coordination. It neither replaces nor reduces the level of professional judgment, attention to project details, and due-diligence required to complete the project. The checklist was written in support of the guidelines. The project team leaders have the responsibility to seek permission from the stakeholders when they deviate from any requirements as listed in the checklist or the guidelines, in particular the appropriate map scale, map resolution, topographic standards, and data accuracies. The checklist is provided in Appendix B.

2.3. Project Teams and Expectations

There are several ad-hoc teams which are formed to guide the project, under the supervision and support of the NWS Regional Coordinator, NWS regional senior staff member, and the NWS FIM Services Leader. These teams are involved in a) FIM coordination, b) site selection, and c) review of the hydraulic model, GIS layers, and AHPS deliverables. The team membership consists of federal, state, local, and private partners, who have local hydrologic knowledge of the site characteristics, understanding of the availability and accuracy of existing data, abilities to provide input on site suitability, and capabilities to perform a quality review of the various components in the project. The various teams and their contributions to the Flood Inundation Mapping project are shown in the roadmap (Appendix C). The specific tasks which are to be completed are also shown.

The roadmap could be used in conjunction with the checklist (Appendix B). For example, the site review team is to complete checklist items 1A and 1B before the proposal is submitted for funding. To ensure this is complete, signatures are collected to acknowledge this important metric. This step is also critical to ensure key details that may increase the study cost are identified.

2.4. Define Study Area

2.4.1. Reach Length

The area of study along the reach is known as the *target reach.* Its length is a function of hydraulic data and should be limited to where flow is still reflected by the rating curve of the nearest gage. In cases where the hydraulic model does not fully extend the upper and lower bounds of the target reach, the model may be extended or the target reach may be trimmed. When model extensions are required, additional data collection requirements such as survey or terrain should be considered. Under such scenarios professional judgment should be exercised prudently.

Hydraulic models – used for inundation mapping – facilitate the expansion of the target reach beyond the location of the gage. Though an absolute definition for the target reach is not prescribed, its scope is generally limited to *one* or *two miles* upstream and downstream of the gage. This is to ensure that the drainage area at the gage and near the limits remain the same, so that when the hydraulic model is run (under each discharge for each corresponding target stage), the resulting elevations will be valid. However, in cases where the drainage area differs significantly across the target reach, additional discharge information might be required.

2.4.2. Water Surface Profile Intervals

Map interval selection is critical for the successful delineation at all the critical stages between the flood stage and the maximum stage. Since flood inundation maps will be developed for the range of flows prior to the onset of flooding to the flood of record, an inundation map interval should be selected such that: (a) All desired incremental changes in river stage are mapped; and (b) The change in areal extent of flooding per unit increases per increase in river stage at the forecast point or USGS gage.

In addition, tolerance limits, generally 0.5 ft or 1.0 ft, that are used by hydraulic models to assess calibration results can sometimes be used as guides for establishing a minimum map interval limit. The minimum stage interval between maps within a library should not be less than what is justified by supporting data and the modeling technology selected for the particular flood study. For example, the map interval and grid density should not provide higher resolution than the underlying topographic data. Before the inundation mapping task is initiated at a forecast point, the mapping partner should engage with NWS and other stakeholders to make an informed decision about an appropriate map interval.

2.5. Develop Statement of Work

The NWS will work with the local mapping partner and its subcontractors (as necessary), to develop a statement of work that will guide the production of inundation mapping at a river forecast point. The statement of work will vary in terms of scope and cost for each project, but in general will discuss the types of methods to be applied at each river forecast point, the duration of the project, the costs to be incurred, and the deliverables that shall be submitted upon project completion.

A template statement of work is provided in Appendix A. For more information, please contact the NWS FIM Services Leader.

3. Phase 2 - Inundation Mapping Production

Phase 2 of the NWS inundation mapping process includes implementing the hydrologic, hydraulic, and geospatial analyses required to develop inundation mapping products. In general, the hydrologic analyses include determination of the peak discharges that result in the desired water surface elevations. The hydraulic analyses include the computation of the water surface profiles. Finally, the geospatial analyses include the conversion of one-dimensional water surface profiles to a two-dimensional inundation area.

3.1. Geospatial Data

3.1.1. Required Base Map Datasets

This section discusses the map elements or deliverables that will be required on the base map to properly convey flood-related information. They include submitting hydraulic data (depth grids, cross sections and streamlines), special flood risk areas from effective Flood Insurance Studies (1% and 0.02% annual chance), transportation features, orthophotography, and the study area extent. Map elements not mentioned may be incorporated; however, the developer should use caution and not risk flooding the map with unnecessary information.

All relevant base map datasets should be incorporated into a single geospatial file (shapefile or feature class) for digital submission. All feature classes should have up-to-date metadata adhering to Federal Geographic Data Committee (FGDC) metadata standards.

Additional details on each required deliverable is provided in Appendix D.

3.1.2. Geopolitical Data.

The NWS recommends for project work that the Partner refer to available Flood Insurance Rate Map (FIRM) database information for geopolitical data. For a complete list of required attributes, refer to FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners, which can be found online at:

http://www.fema.gov /library/viewRecord.do?id=2206.

3.1.3. Hydrographic Data

The data gathering phase – needed to perform the engineering analysis and subsequent inundation modeling – should be limited to hydrographic information associated with the selected gage. Data essential in the development of an inundation map library includes obtaining the gage datum elevation and historic flood peak information. Rating curves and high water marks are also useful, though not required.

The map is required to have a single stream centerline defining the path of the main channel; smaller streamlines or tributaries should not be included. Additional details on the S_CENTERLINE deliverable is provided in Appendix D.

3.1.4. Hydraulic Structures

The mapping partner should work with the Regional Coordinator to develop a concise list of hydraulic structures in a geospatial format. Such structures may include dams, detention or retention ponds, levees, culverts, bridges and embankments. These are important aspects of the area near a river forecast point and can have impacts on the flood inundation mapping process.

While the FIM program does not currently have deliverable specifications for hydraulic structures, the mapping partner is encouraged to collect this information to support maintenance of the inundation maps at that location. For more information, please contact the NWS FIM Services Leader.

3.1.5. Aerial Imagery

Orthophotography is a required element for the Flood Inundation Map products since it allows for easy identification of landmarks and physical features. This also allows for a more visually appealing product. Standards for the orthophotography are shown below (Table 1):

Table 1: Standards for orthophotography.

Mapping Standards	Requirement	Additional format accepted*
Resolution	1 meter	
Display	Black & White	Color photography
Projection	NAD 1983	

* Format accepted ONLY if the Mapping Partner coordinates with the NWS FIM Services Leader and gains proper approval.

3.1.5.1. Resolution

The minimum resolution for orthophotographic imagery is one meter.

3.1.5.2. Requirements and Standards

The most recently available orthophotographic imagery must be submitted in black and white. However, if NWS chooses, color imagery may be used as a supplement, not as a substitute. If both options are presented to the NWS FIM Services Leader, the color imagery will be used on the AHPS site.

All orthographic imagery will be projected in a predefined geographic coordinate system that is applicable to all of North America and should use the North American Datum 1983.

Orthophotographic imagery may be obtained from the National Agriculture Imagery Program's Geospatial Data Gateway (http://datagateway.nrcs.usda. gov/). Its imagery is acquired at 1 meter ground sample distance with a horizontal accuracy that is within 5 meters of the ground control points. Imagery from other sources is required to, at a minimum, meet these horizontal spatial accuracy standards. For all photography, the NWS must have unrestricted permission to distribute and display the photography in conjunction with inundation mapping products.

3.1.6. Digital Terrain Data

This section describes the sensors used to collect digital terrain data, the data types, and the standards when using digital terrain data for flood inundation mapping. The section is not meant to be all-inclusive and other technologies exist that may be appropriate for mapping. Mapping partners should consult with the NWS Inundation Services Leader prior to utilizing a technology not discussed here.

3.1.6.1. Sensors

There are a number of different sensors available for collecting digital terrain data. The Guidelines here discuss the most-common type of sensors that will be used for flood inundation mapping. Other options, such as Interferometric Synthetic Aperture Radar (IFSAR), are also available, but may be constrained by accuracy. The mapping partner should consult with the NWS prior to using sensors not listed here.

Light Detection And Ranging (LiDAR)

For the purpose of these Guidelines, LiDAR is defined as an airborne laser system, flown aboard rotary or fixed-wing aircraft, that is used to acquire x, y, and z coordinates of terrain and terrain features that are both manmade and naturally occurring. LiDAR systems consist of an airborne GPS with attendant GPS base stations, Inertial Measurement Unit (IMU), and light-emitting scanning laser.

The system measures ranges from the scanning laser to terrain surfaces within a scan width beneath the aircraft. The time it takes for the emitted light (LiDAR return) to reach the earth's surface and reflect back to the onboard LiDAR detector is measured to determine the range to the ground. Scan widths will vary, depending on mission purpose, weather conditions, desired point density and spacing, and other factors.

The other two components of LiDAR systems are the airborne GPS, which ascertains the in-flight three-dimensional position of the sensor, and the IMU, which delivers precise information about the altitude of the sensor, i.e., the roll, pitch and heading.

Photogrammetry

Photogrammetry uses principles of geometry to determine the x, y, and z-coordinates of surfaces based upon photographs. Photographs are generally collected using aircraft and then analyzed using the principles of stereoscopy. A common point is identified on two or more aerial images and a line of sight (ray) from each sensor to the common point is developed. The intersection of the rays represents the 3-D location of the point. Across a large area, this information can be published in the form of mass points for hydrologic and hydraulic analysis and transformed into a digital elevation model.

For more information on sensors and data management, consult the publication: *Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition (American Society for Photogrammetry and Remote Sensing, 2007).*

3.1.6.2. Data Format

There are a number of different terrain data formats available for use in flood inundation mapping projects.

Mass Points

LiDAR produces irregularly spaced mass points. "First-return" LiDAR data provide elevation mass points on reflective surfaces (e.g., treetops, rooftops, towers). "Last-return" LiDAR data provide elevation mass points of the bare-earth terrain, but only after successful completion of automated and manual post processing for vegetation removal and cleaning (removal) of manmade features and artifacts. Mass points can also be produced when using photogrammetric methods. Mass points can be used to create digital elevation models (DEMs), triangulated irregular networks (TINs)k or digital terrain models.

Digital Elevation Models

DEMs model the elevation of the land (z-values) at regularly spaced intervals in x and y directions (eastings and northings). They are usually displayed as uniformly spaced grids. Because of the uniform point spacing, DEMs can "jump over" breaklines without identifying ditches, stream centerlines, steep banks, and other similar features. However, DEMs are simple data models, easy to store, and suitable for automated hydrologic analyses and modeling where breakline information is unimportant.

DEMs are normally produced by interpolation from surrounding mass points or TIN corners and are normally required for entire watersheds, for which automated hydrologic analyses and modeling will be performed. Because they are interpolated, DEMs are slightly less accurate than the TINs, mass points, or breaklines from which they are derived.

Triangulated Irregular Networks (TINs)

A TIN is a set of adjacent, non-overlapping triangles, computed from irregularly spaced points with x/y coordinates and z-values. The TIN data structure is based on irregularly spaced point, line, and polygon data interpreted as mass points and breaklines. The TIN model stores the topological relationship between triangles and their adjacent neighbors (i.e., which points define each triangle and which triangles are adjacent to each other). Its data structure allows for the efficient generation of surface models for the analysis and display of terrain and other types of surfaces while preserving the continuous structure of features such as levees and streambanks that are critical in hydrologic and hydraulic analyses.

ESRI Terrain

The terrain feature data type was first offered by ESRI in its ArcGIS 9.2 release. The terrain feature data type provides a fast, seamless and scalable approach to storing and visualizing high resolution and massively large point datasets. A terrain dataset is a multi-resolution TIN-based surface. The multi-resolution capability offers the ability, similar to pyramid levels for raster data, to change the accuracy with which the data are drawn, to allow rapid display at different scales. As a TIN-based surface, the user is assured the data is complete and is taking into consideration every bare earth LiDAR point and not just averaging them down to produce raster cells. This allows for the display, query, and analysis of billions of individual mass points, such as LiDAR.

3.1.6.3. Requirements and Standards

Because there are a variety of elevation data sources available, specific guidelines need to be provided to make sure consistent vertical accuracies and horizontal resolutions are used. A rule of thumb is to use "best available" elevation data. This has often led to inconsistencies in the Digital Elevation Model used to derive the inundation extent and depth grid. Therefore the following criteria regarding DEMs must be addressed for individual mapping locations.

- Vertical Accuracy: the closeness of an estimated value to its true value
- Horizontal Resolution: the average point spacing of mass points or size of grid cells – 30 meters, 10 meters, 5 meters, etc.

Vertical Accuracy

Topographic data with the highest available vertical accuracy [reported in Root Mean Square Error (RMSE)] should be used as the base topographic data source for NWS flood inundation mapping. Although, not all locations will have the same vertical accuracy, at a minimum, the standard FEMA requirements for NFIP flood insurance studies can be expressed as equivalent contour intervals (Table 2):

Table 2: Standard FEMA Requirement for Vertical Accuracy of Base Topographic Data

Terrain Setting	NSSDA Accuracy Interval	NMAS Contour	NSSDA RMSE
Flat Terrain (low relief)	1.2 ft at 95% confidence limit	2-foot	0.6 ft; 18.5 cm
Rolling to Hilly Terrain (moderate to high relief)	2.4 ft at 95% confidence limit	4-foot	1.2 ft; 37.0 cm
NMAS – National Map Accuracy Standards *NSSDA – National Standard for Spatial Data Accuracy*			

The basis for these standards is described in detail in Appendix A of *FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners*. Alternatives to the standard FEMA requirements can be specified for special situations, after a site-specific review to determine if the available topographic data is of sufficient accuracy.

Resolution

Employing optimal grid density (or cell size) is essential in order to delineate accurate inundation boundaries and optimize the usage of resources and systems invested in the development and distribution of flood hazard information. Generally cell size employed to develop DEMs are based on the horizontal accuracy of the underlying base topographic data. For example if the base data is collected using less than 5 meter post spacing LiDAR, a cell size of 5 meters is used.

The resolution of any DEM used for developing inundation map boundaries should not be greater than the resolution of the base topographic data source. For example, if the nominal post-spacing of the raw LiDAR data collection is 5m then the derived DEM should not have a horizontal resolution less than 5m. Use of a DEM built with greater resolution than is supported by the base topographic data implies a false precision in the final inundation mapping and is an inefficient use of resources, and may mislead people or audience by portraying more accuracy that is true. Older LiDAR collections were on the order of 5m post spacing. They newer LiDAR collects are generally higher resolution, on the order of 1m post spacing. A high resolution (smaller cell size) will require more processing time when creating inundation grids and polygons. An evaluation of needed resolution for mapping needs to be done to make sure the DEM resolution is adequate. In general the resolution of the DEM should not be less than 5 meter if the raw LiDAR post spacing allows. This will enable the capture of most features, but will not cause processing time to be too great. Finer resolution DEMs can be used if the LiDAR post spacing allows and if more detail is needed to capture smaller features. Finding the optimal DEM resolution to meet the needs of the mapping project in terms of resolution vs. processing time is unfortunately often a trial and error process.

3.1.7. Horizontal Datum

The North American Datum of 1983 (NAD 83) is the required definition for displaying the USGS stream gages, depth grid and other geospatial features. If conversion to this datum is needed, map developers should use the NOAA's North American Datum Conversion (NADCON) online tool: http://www.ngs.noaa.gov/cgi-bin/nadcon.prl. It uses a database of 150,000 horizontal control points that measures the shift between various datums; based on these changes, the appropriate transformation value is returned.

3.1.8. Vertical Datum

The North American Vertical Datum of 1988 (NAVD 88) is the required definition for the USGS stream gages and topography datasets. Any datasets referenced to datums other than NAVD 88 should be converted. Web based utilities developed by NOAA are recommended for such conversions, including the North American Vertical Datum conversion, VERTCON, online tool (http://www.ngs.noaa. gov/cgi-bin/VERTCON/vert_con.prl); and the Vertical Datum Transform, VDATUM, online tool (http://vdatum. noaa.gov/). It is important to note that while the utilities work well for point location, they are not applicable for topographic datasets that span large horizontal areas.

The development and application of a spatially averaged conversion factor for topographic data sets is described in Appendix B of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*. A summary of the procedure is provided below:

1) Identify the USGS 7.5 minute, 1:24,000 scale topographic quadrangle series maps that are spanned by the topographic data set.
2) Record the latitude and longitude of the corners of each USGS 7.5 minute quadrangle identified in step 1.
3) Using VERTCON, determine the datum shift (e.g. NGVD 29 to NAVD 88) for each corner point determined in Step 2.
4) Compute the average of the datum shifts for all corner points and the absolute value difference between the average conversion factor and the conversion factor for each corner point.
5) If the maximum difference between the average datum shift and the datum shift for each corner point is less than 0.25 feet, then the average datum shift shall be applicable to all points within the area spanned by the USG 7.5 minute quadrangle.

Since distortions from the conversion can be as high as 9 meters, mapping partners should proceed with topographic datum transformations prudently.

3.1.9. Metadata

Metadata should adhere to the Federal Geographic Data Committee (FGDC) standards and include on the following: topographic data, stage-discharge relations, boundary conditions, model selection, simulation and results, people and involved organizations, locations of data and processes, limitations, etc.

Qualitative information about the known uncertainty should be communicated within the metadata and addressed in the flood summary report. It should be written in a language whereby non-technical personnel will be able to subsequently assess the quality and uncertainty in the overall product. For example the known uncertainty in the LIDAR, modeling, and GIS processing should be provided as a +/- range, so that deterministic values of flood heights/depths can be communicated as one value +/- the uncertainty.

3.2. Hydrology and Hydraulics

Even though the AHPS Inundation Mapping Program utilizes various stream flows to generate water surface elevations to match the stages listed by the NWS, there remains an inherent level of uncertainty with water surface modeling. As a result, it is incumbent for decision makers to recognize this uncertainty, found in various aspects throughout process: including the uncertainty in the hydrologic and hydraulic models; using topographic data with an appropriate resolution; and recognizing that ongoing physical processes such as erosion, deposition, and infiltration are a constant source of change.

Decision makers should also be aware that debris jams along a study reach during a major flood event could negate the validity of a flood map for all or part of the study reach. Furthermore, as land use surrounding the study area changes, uncertainty on the reliance of previous models with commensurately increase since urbanization usually results in increased discharge and potentially higher flow velocities. For this reason, proper tools and methodologies should be employed, using the most recently available models and/or data. All products should specify the presence of uncertainty – such as the use of manning's values, routing methods, storage coefficients, etc. – according to the software's User Guide or Manual.

3.2.1. Modeling Techniques

Inundation Map libraries are based on the development of water surface profiles derived from flood depths for a respective flow along the river. To create these libraries, a combination of hydrological and hydraulic (H&H) modeling is required: options for the Mapping Partner include using one-dimensional or two-dimensional models, and steady or unsteady flows. For forecast points where steady flows are applicable, a hydraulic model suffices for the analysis; otherwise, if unsteady flows are required, then a hydrological and hydraulic model will be needed.

According to the FEMA's *Guidelines and Specification for Flood Hazard Mapping Partners: Appendix C*, an unsteady flow model is most applicable to urban systems with both open channels and closed conduits; and stream systems with significant storage changes, reversed flow, or subject to rapidly varied flow and wave changes.

In places where it is not obvious, it may be necessary to run a relatively simple unsteady event through the hydraulic model to determine the degree to which a rating curve is looped. An example criterion might be that if ½ the magnitude of the rating loop is more than ½ the profile interval, then a hydraulic model should be required before static map libraries can be implemented at a site. However, if the looped rating curve is correctly modeled to a proper stage forecast, a set of static-map libraries is acceptable for locations close to the gage.

One-dimensional hydraulic models are often independent from the hydrological model, thereby requiring two software packages for floodplain delineation, such as the Hydraulic Engineering Center's – Hydrological Modeling System (HEC-HMS) and River Analysis System (HEC-RAS) softwares. However, if a two-dimensional analysis is required, as is the case where areas of study include flat terrain or unconfined floodways, then a combined H&H software may be used. Additional guidance for choosing and developing a model is provided in this Guidance Document.

Before a model is extended upstream/downstream a gage, the assumptions inherent within the model and the modeling approach should be clearly understood. Because existing models may be used during this process, the following section begins with this approach.

3.2.1.1. Existing Models

The development and application of such models are resource-intensive and typically require a detailed survey of the stream channel's geometry and a digital cataloguing of hydraulic structures. For this reason, the application of an existing hydraulic model is the most efficient use of existing resources. In many cases, the stream reach surrounding the NWS forecast location has been studied as part of a FEMA Flood Insurance Study (FIS). For these cases, the hydraulic model will be available from FEMA or its Cooperating Technical Partner (CTP). A CTP is a local community, regional agency, or State agency that participates in the NFIP and actively works with FEMA in the development of local Flood Hazard Mapping. Hydraulic models developed for the NFIP flood insurance study can be obtained upon request from the FEMA Map Service Center (http://www.msc.fema.gov). In cases where a CTP agency has supported or developed the Flood Insurance Study, the hydraulic models that were used may be available from the CTP agency. A list of CTP agencies is maintained by FEMA.

Other agencies such as USGS, USACE, river basin commissions, or local or regional NWS offices may also have developed hydraulic models at the gage. Because available modeling data will vary according to site, it is first necessary for Mapping Partners to investigate what information is available.

For areas of study where hydraulic models have not been developed, NWS mapping partners will first have to collect detailed floodplain and hydraulic structure data. Examples of hydraulic structures include bridge decking, levees, dams, canals, culverts, and detention ponds. The data shall be collected, processed through a hydraulic model approved by FEMA (http://www.fema.gov/plan/prevent/fhm/en_hydra.shtm). The list of approved models is extensive and includes the following softwares: WSPRO, HEC-RAS, and FLDWAV. After the new hydraulic model has been selected, procedures for developing the library of water surface profiles will be similar to the guidance furnished below.

3.2.1.2. Model Evaluation

The principles of hydrology and hydraulics are combined together to create the range of flows necessary to generate a series of water surface profiles. A hydrologic analysis of the runoff model is conducted to establish a relationship between rainfall and runoff to achieve stream flow. This is later used as input for the hydraulic model, where water surface profiles are generated to represent the maximum flooding that that is expected from the respective stream flow.

Hydrologic analyses conducted for FEMA Flood Insurance Studies (FIS) are generally for pre-defined frequencies, such as the 10-year, 50-year, 100-year and 500-year event. For forecast locations that do not include a USGS gage, a rating curve may not be derived from these four frequencies; without additional frequency data, the discharges would be unreliable for lower frequencies.

At all AHPS Forecast Gage Locations, Mapping Partners are required to compare the rating curve from the USGS gage and the hydrologic model. If a hydrologic model rating curve does not exist, one should be developed. This is of critical importance in the event that the discharges exceed the original rating curve and would require a hydrologic model to examine greater flows.

At a minimum, the Mapping Partner should consider the following when evaluating an existing model for use in an inundation mapping project:

Data Requirements

Model(s) considered for inundation mapping projects should be certified by the entity responsible for the model.

Hydraulic model data should be accompanied with geospatial information such as streamline and cross section data. Geospatial data is required to ensure that floodplains mapped with stream centerlines and cross sections are consistent with the published FEMA floodplains. In cases where geospatial data is unavailable, additional effort might be required to recreate the geospatial datasets.

Model Extents

The extents of the hydraulic models should cover the full scope of the target reach. When full coverage of the study is available, model extensions are not required. However, in cases where the model coverage is restricted to a part of the target reach, the model should be extended or the reach should be trimmed. Generally when model extensions are required, additional data collection requirements such as survey or terrain data should be considered.

Model Calibration

If stream gages are available along the model reach, the model should be calibrated to the NWS or USGS provided rating curve (stage-discharge relation) established for the gage. Calibration validates the consistency between the model rating curve and the USGS rating curve.

FEMA models are generally developed for high flows, i.e. for flood frequencies greater than 1-year. These models either are calibrated to high water marks (HWMs) or left uncalibrated if no HWMs are available. Generally HWMs are sparse and do not represent the full range of flow conditions. Therefore models that are uncalibrated or calibrated only to HWMs should be further evaluated to validate the consistency between the rating curve of the model and the USGS rating curve. If issues arise, Mapping Partners should coordinate with the NWS or USGS.

3.2.1.3. Model Extent

The river stage observations are categorized as point data. Rating information must be available at selected locations because this information is necessary for the development of water surface profiles. In order to extend the inundation mapping upstream and downstream of the gage location, a water surface profile must be developed for each selected map interval in the map library. Because of hydraulic variations along a river reach, the extent of the validity for applying the gage rating information in the modeling analysis upstream and downstream is varied. As a result, the maximum extent of the river reach modeled will depend on local conditions. Depending on the variability of the topography and changes in discharge, these extents may be shortened considerably. Consequently, engineering judgment should be used when determining these extents in consultation with the NWS Regional Coordinator. For improved results, calibration on the extents of the model should be measured against prior storm events.

3.2.1.4. Model Simulations

As previously stated, in a steady state hydraulic model, the depth and flow do not change with time; therefore, a simulation will use a single flow to compute a water surface elevation at each cross section. Assuming that the model has been well calibrated, the modeler will select a flow by trial and error that will produce the desired water surface elevation at the NWS forecast location (USGS gage). For example, given a selected NWS forecast location where the action stage is 13.0 feet and the flood of record is 24.7 feet, water surface profiles between 13 and 25 feet at one-foot intervals would be desirable. The user will adjust the flow in the steady state model until a resultant profile with a stage of 13.0 feet is computed at the NWS forecast location. This process to generate the water surface profile is repeated for all other remaining target stages from up to 25.0 feet. At some locations, the hydraulic geometry of the stream reach may be such that producing water surface profiles at the target river stage is not feasible. In such cases, a tolerance of +/- 0.1 feet from the desired river stage shall be used (Figure 1). This minor tolerance will not affect the accuracy or validity of the inundation maps.

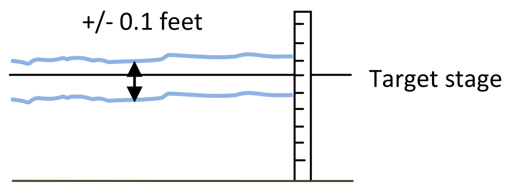


Figure 1: Water level tolerance between model and stream gage.

When unsteady-flow conditions exist and the depth and flow can change with time, the hydraulic model will use a hydrograph at the upstream cross section and a boundary condition at the downstream cross section as inputs. Flow and stage hydrographs will be computed for each cross section. Based on NOAA efforts within the Lower Colorado River basin of Texas, the NWS West Gulf River Forecast Center (WGRFC) have reviewed, tested, and established a protocol to generate water surface profiles. The procedure for calibrating an unsteady flow is outlined below:

1) Run an unsteady hydraulic model in steady state mode using trial and error flows to achieve a target stage at the forecast point.

2) Run an unsteady hydraulic model with a constant flow time series using trial and error flows to achieve a target stage at the forecast point.

3) Interpolate between upstream input hydrographs such that when routed to the forecast point the target stage is achieved.

4) Interpolate between the FEMA pre-determined profiles for additional recurrence intervals using the unsteady hydraulic model.

WGRFC concluded that options 1 and 2 would not correlate well with profiles from an unsteady model. Option 3 is computationally intensive and would add expense to the process. Option 4 provides results that would agree with the FEMA frequency recurrence interval profiles. In the case of the Lower Colorado River, unsteady state profiles were computed for the 2, 5, 10, 25, 50, 100, 500-flood events.

During flooding conditions high water levels in a main channel may cause water to back up into the tributaries and cause flooding in the lower areas of tributaries. This backwater phenomenon is especially problematic where a low-gradient tributary joins a larger river, and the main channel water surface profile exceeds the water surface profile of the tributary. The discussion about backwater can be split based on the type of hydraulic analysis:

Backwater Analysis

Back water conditions on the tributaries can be verified through an inspection of the tributary stream gage. If the gage is available and the peak stage measurements are tagged as being affected by back water from the main stem, then inclusion of the affected segment of the tributary in the inundation mapping analysis should be considered. In situations where a gage is not available on the tributary, but the tributary was included in the original model, back-water conditions can be assessed by comparing the water surface profile on the tributary to that on the main stem. If the profile on the main stem is above the profile of the tributary, back-water conditions exist; otherwise the tributary can be assumed to be unaffected by the main stem. If neither a gage nor an existing model is available for the tributary, the extent of the effect of backwater into the tributary can be addressed by extending the main-channel cross sections far enough across the floodplain to include the downstream end of the tributary. The area mapped should completely encompass the full inundation region, including tributary segments likely to be affected by backwater.

Steady vs. Unsteady Flow Analysis

The hydraulic models typically developed for an NFIP are usually steady flow models that assume a constant flow rate equal to the specified recurrence interval discharge. Steady-state models do not account for (a) channel storage and restrictions which attenuate the flow; (b) spatially varied flows that result from lateral inflows; and (c) reverse flow due to effects such as intervening backwater or tides. In addition, the steady flow approach assumes a constant relation between stage and discharge, which may pose problems in low gradient rivers where the discharge for a given stage might be higher on the rising limb of the hydrograph than on the falling limb of the hydrograph.

Steady flow modeling could be used for the development of floodplain boundaries and inundation mapping in the majority of applications. Multiple analytical runs of a steady flow hydraulic model would then be used to simulate the various water-surface profiles that are associated with the selected discharges. Steady state models could then provide a reasonable approximation of the water depth particularly where channel and flow conditions do not vary greatly in space or time.

However, if the depth of flow varies considerably – such as in steep, unconfined areas –, an unsteady flow simulation should be chosen. An unsteady flow or dynamic hydraulic model uses time dependent flow rates based on either computed or observed hydrograph outputs. The development and use of dynamic models can be several times more complex and time consuming than its counterparts. For this reason, Mapping Partners should develop unsteady flow models wherever steady flow modeling will not accurately represent the maximum flooding.

Further discussion about the applicability of steady state versus unsteady state analyses is discussed in the USACE Engineering Manual (EM 1110-2-1416) (USACE 1993). Because unsteady-flow analysis requires hydrographs as inputs, the analysis is generally accompanied with a watershed model.

2D-Analysis

Both the steady and unsteady flow analyses assume that direction of flow has one principal direction; as a result, it can be categorized as one dimensional (1-D) analysis. Though this assumption might be valid for channel flow, it may not be applicable to overland flows in certain situations. In some situations flows in the overland floodplain can have different directions at different locations. Generally such situations can be encountered in urban settings situated on the banks of big streams. Streets, gutters, and other conveyance systems can participate in transporting the flows thereby impacting the overland flow characteristics. As a result, whenever flows are conveyed in urban or flat areas, a two dimensional (2-D) analyses may be appropriate. Professional judgment and an impact-driven approach should be used to assess the need for a 2-D model. This involves that Mapping Partners talk to communities and discuss with stakeholders whether the 2-D model is more appropriate.

3.2.2. Deliverables

This section describes the hydrologic and hydraulic models that must be submitted to the National Weather Service. Its purpose is to provide a consistent submission framework of the technical and administrative data needed for an AHPS Flood Inundation Mapping dataset. The following subsections provide the Mapping Partner with the directory structure required for submission, the acceptable media types, as well as the required hydrology, hydraulic and GIS standards.

Hydrology Submittals

Hydrology models are often developed for areas of study with unsteady flows. Its platform may be separate from that of the hydraulic model (as in HEC-HMS and HEC-RAS), or bundled together (as in Flo-2D). Nevertheless, the following data files are required for mapping based on the NWS stage:

- A table file that contains information about riverine gages, such as period of record, recording interval, stream identification, and operator contact information.
- A table file that contains rating curve information for the USGS gage(s) and the hydrologic model.
- Other data used in the hydrologic model such as the time of concentration, runoff curve number computations, and infiltration parameters.
- Summary table of calibration results for each water-surface profile.
- Geospatial files and supporting data for the computation of watershed and climatic characteristics for regional regression equations such as drainage area, channel slope, soils data, and impervious area.

Hydraulics Submittal Standards

Hydraulic methods are developed as steady or unsteady models representing one-dimensional or two-dimensional flow conditions. A 1-D model utilizes cross-sectional data while the 2-D model utilizes a grid of ground-elevation points. The following data files are required for inundation mapping:

- A table file that stores elevation data for all the required NWS flood stages.
- A table file that contains the upstream and downstream hydrographs for the unsteady analysis, if applicable.
- A geospatial file (S_XS) that shows the cross sections used to compute the water surface elevations in the hydraulic model.
- Additional input and output files for the hydraulic model used for the area of study.
- Additional geospatial and database tables, if utilized (e.g. overbank distances used in certain models such as HEC-RAS; calibration information, e.g. high-water marks; maps of historical flooding; spatial files of n-value polygons used in model calibration). The structure of these

tables is at the discretion of the submitting Mapping Partner, but should include appropriate metadata.

Submittal Directory Structure and Folder Naming Conventions

The Mapping Partner is required to submit the input, output and any ancillary data related to the hydrology and hydraulics models. Data files must be submitted in the standards specified in this section and organized under an applicable 8-digit Hydrologic Unit Code (HUC-8), River Forecast Point ID (use NWS AHPS site ID), and Hydrology or Hydraulics sub-folder with all model files.

\HUC-8\RFP_ID\Hydrology Data\Simulations

- All input and output files from the Hydrology model.
- Appropriate metadata file(s) explaining content of each named file.

\HUC-8\RFP_ID\Hydrology Data\Spatial Files

- Applicable spatial files for nodes, sub-basins, gages, etc.
- Readme files explaining content of each named file.

\HUC-8\RFP_ID\Hydrology Data\Supplemental Data

- Database file(s) such as data and analyses for stream gages and computations for regional regression equations in native format.

\HUC-8\RFP_ID\Hydraulics Data\Simulations

- All input and output files (e.g. elevation data) from the Hydraulic model.
- Readme files explaining content of each named file.

\HUC-8\RFP_ID\Hydraulics Data\Spatial Files

- Applicable spatial files for gages, cross sections, etc.
- Readme files explaining content of each named file.

\HUC-8\RFP_ID\Hydraulics Data\Supplemental Data

- Database file(s) such as data and analyses of overbank areas, Manning's n-values, high-water marks or similar.

Data Exchange and Submittal

Mapping Partners should submit files via mail, the internet via FTP, or through one of the following electronic media:

- DVD
- External Hard Drive (for very large data submissions with a mailing label for return to the Mapping Partner.

When data is submitted via mail, all submitted digital media must be labeled with the following information:

- Mapping Partner Name
- HUC8 and RFP ID
- Date of Submission (mm/dd/yyyy)

- Appropriate numbering of media

3.3. Inundation Areas

This section describes the preparation of inundation maps and accompanying depth grids for each of the selected river stages. To create an inundation map, a hydraulic model is first developed in order to generate a series of water surface, 1D profiles that correspond to the selected river stages. Cross section locations in the hydraulic model and the respective water surface elevations generated are used to plot the 2D profiles. Next, a GIS platform is used to post-process the cross section elevations into a 3D water surface. This is done through a fill-in process where the water surface elevations are overlaid on the corresponding topography and subsequently smoothed to the extents of the resulting floodplain.

The resulting floodplain boundaries will be rectilinear, reflecting the square configuration of the raster cells. The rough boundaries may also contain small features indicating isolated inundated areas. The rough boundaries should then be reviewed and manually edited as necessary to:

- Ensure that the mapped boundaries are in agreement with the base topographic source data used.
- Smooth the rectilinear appearance resulting from the raster based mapping.
- Remove or revise small, isolated areas of inundation, using judgment based on map scale and the connection of the isolated areas with the main area of inundation (additional guidelines for removing disconnected inundation areas are provided in Section 3.4.).
- Ensure that inundation boundaries for lower river stages do not extend outside boundaries for higher river stages.

Once the inundation area is correctly delineated, compose metadata for the polygon layers according to FGDC standards, and ensure that all the flood layers extend from the riverbank to the flood of record or above NWS major flooding status, whichever occurs first.

At the time of publication, all products are required to be projected to Geographic Coordinate System (GCS) NAD83. Mapping Partners are also advised to consult the NWS and its status in moving toward a Google Maps platform; when the transformation is complete, all maps will need to be projected to the World Geodetic System of 1984 (WGS 84).

Removal of Disconnected Flooding

The following procedure provides guidelines for determining when to remove disconnected inundation areas. It is important to acknowledge that these instances are not only caused by inconsistency between the topographic data and H&H models, but also occur when disconnected inundation areas are linked to the larger floodplain through artificial or natural waterways. As a result, for a disconnected inundation area to be considered part of the larger floodplain, a waterway connection between the smaller and larger floodplain is required. Before removing any such areas, it is important to first scrutinize for any linking waterways – either culverts, canals, pipelines, streams, creeks, or other surface water bodies. Using Figure 2 as an example, imagery should first be used to inspect the surrounding disconnected inundation areas for such waterways: if one is present, then the disconnected inundation area should remain; if not, it qualifies for removal. For the example below, a waterway is not present and therefore qualifies for removal.

Figure 2: Disconnected inundation areas and suggested solutions for floodplain removal.

Once an inundation area is qualified for removal, the next step is to inspect the topography used for delineating the floodplain. If the elevation differences between the primary floodplain and the disconnected inundated area are sufficient to indicate that flooding is not from the main flooding source, then the analyst may conclude that the disconnected area is in fact a discrepancy caused by the overextension of hydraulic modeling cross-sections. In the other hand, if the elevation differences are not small, and especially if a culvert is present, then the analyst can conclude that the indicated flooding as derived from the main flooding source and the disconnected inundation area should be retained. In such situations, professional engineering judgment should be applied.

To summarize, when a question regarding removal of a disconnected inundation area arises, any adjacent artificial and natural waterways should be inspected in the surrounding area. If none are present, a topographic data should be used to check the slope and location of the disconnected inundation area and confirm whether the existence of the disconnected area makes hydrologic sense. Using both criteria, the analyst should be able to make justifiable modifications to the inundation area delineated by the H&H models.

3.3.1. Levees

The regional coordinator is to collaborate with the funding partner on the best method to map the flooding behind a levee.

There are complexities, in terms of availability of as-built drawings pertaining to the levee construction, post-construction levee structural surveys, repairs to the levees, sand-bagging operations during flood fight, and the identification of potential breach location(s). Thus, this section only discusses possible considerations for mapping the floodwaters, namely its spatial extent and depth of water, for the main channel and areas behind the levee(s). The following represent some potential situations, although there may be more. Professional judgment must be exercised to determine the methodology that is most applicable to a particular situation and location.

A – Consider no levee failure and map the floodwaters up to top of levee.

B – Consider no levee failure and map the floodwaters up to the levee freeboard.

C – Consider no levee failure and map the floodwaters up to an additional 25% of the river discharge above overtopping.

D – Consider levee failure at freeboard, specify the breach parameters, and map the floodwaters at least 1 foot above freeboard.

E – Consider sandbagging as part of a levee system only when approved and permitted. The modeling of the levee should be based on the elevation of the levee and not the added height of the sandbags. The added height afforded by the sandbags will only be considered if the sandbagging operation is specified in the original design plan, the plan is submitted to all project stakeholders for their approval, and the responsible operators certify their intent to maintain this operation during flooding.

F – For multiple levees, assume no levee failures and map the floodwaters until first levee overtops.

G – For multiple levees, assume no levee failures and map the floodwaters until first levee reaches freeboard.

H – For multiple levees, consider a levee failure to occur when freeboard is exceeded, specify breach parameters, and map the floodwaters up to 1 foot above the freeboard of the first failed levee.

3.3.2. Bridges, Overpasses, and Other Structures

Given the fact that most LiDAR data processing removes elevated roads from the bare earth, automated inundation mapping will show most stream road crossings as inundated. Therefore, special attention needs to be applied to how to handle depiction of flood inundation risks at these crossings.

There are largely three scenarios that can occur near bridges.

1. The lowest structural chord is directly in contact by floodwaters (based on survey elevation of the structure and the modeled water surface elevation). In this case, the bridge should be shown as inundated by the lowest stage that intersects the lowest structural chord. For example, if the low chord of a bridge is 515.3 ft above sea level, and the WSEL for Major Flood Stage is 515.9, then the bridge should be shown as being inundated by the Major Flood Stage.

2. The approach to the bridge floods before the lowest structural chord is inundated. If this occurs, the bridge will become impossible to cross by non-emergency vehicles and access will need to be restricted. In this case, the bridge should be shown as inundated by the lowest stage that completely inundates an approach to the bridge. An example of this solution is provided below (Figure 3). In this example, the left-most approach is inundated by moderate flood stage and would restrict travel when the river reaches the accompanying stage.

Figure 3: Inundation mapping demonstrating scenario #2. Notice that the bridge approach is blocked by floodwaters at moderate flood stage, yet the bridge deck is shown in green.

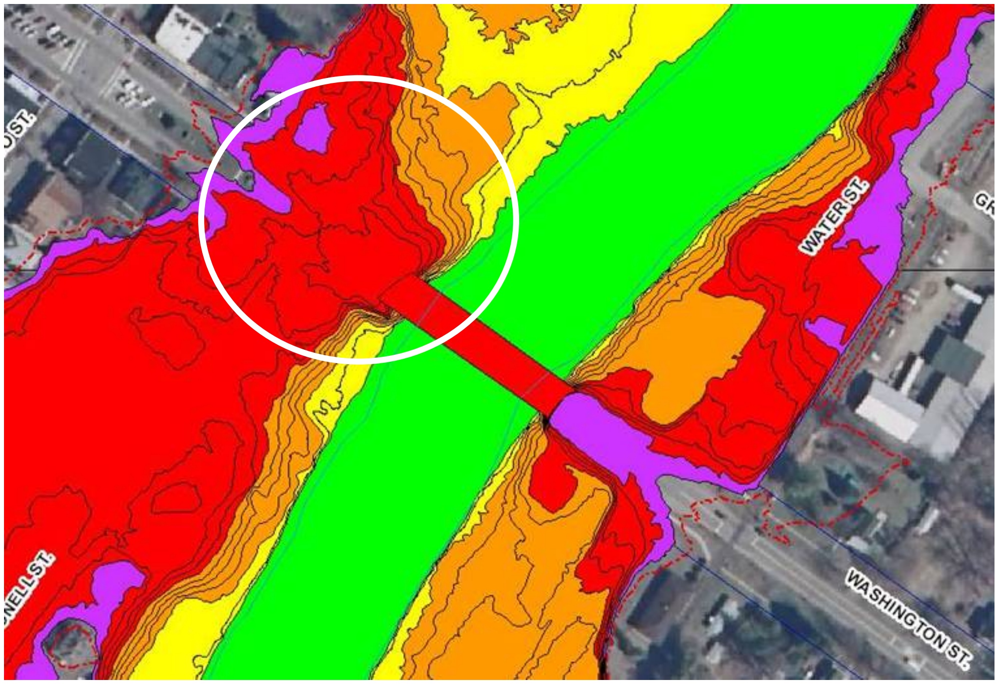


Figure 4: Inundation mapping demonstrating scenario #2. In this example, the bridge deck shown in green (below flood stage) in Figure 3 is now shown as blocked at the moderate flood stage.

3. Neither the lowest structural chord nor bridge approaches are inundated, permitting unabated access to the bridge. In this case, the bridge deck should be completely removed from the inundation area. An example is shown below (Figure 5).

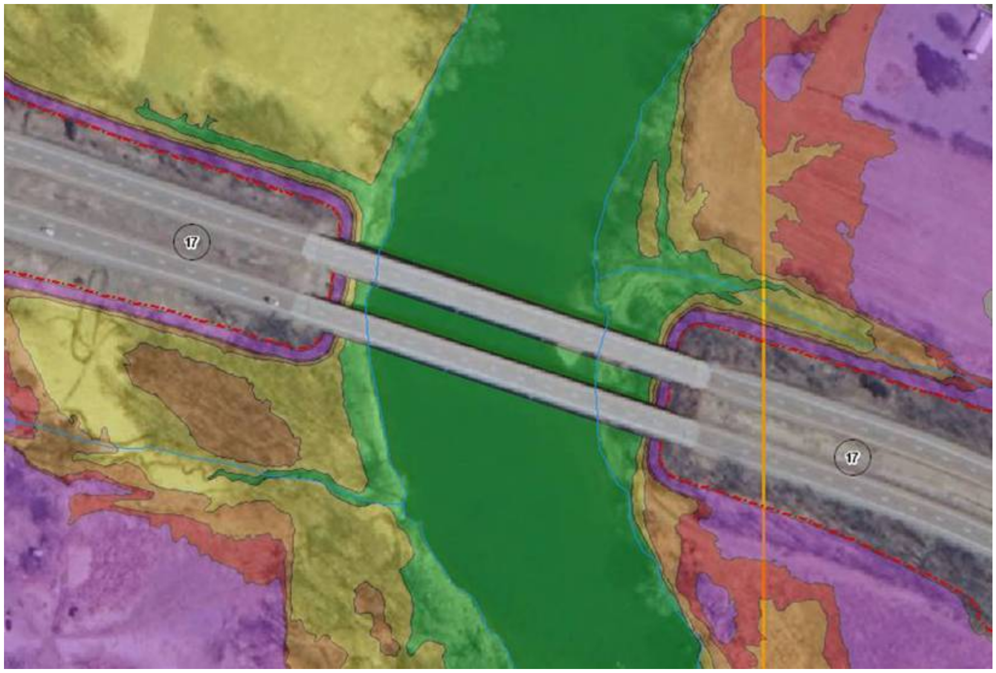


Figure 5: Inundation mapping showing a bridge that is not subject to inundation of its lowest structural chord or approach by a modeled water surface elevation. As a result, the bridge deck is removed from the inundation area.

3.4. Depth Grids

Depth grids are a required component for AHPS inundation mapping. Depth grids are created by subtracting the elevation of the terrain from the water surface elevation, normally in a GIS environment. Any negative values (representing 'dry' areas) are removed from the grid and the result is a depth grid for the mapped water surface elevation.

3.4.1. Requirements and Standards

Depth grids must be developed to within acceptable tolerance values set forth here. By performing the tasks set out in the Section 3.3, many issues with jagged edges, unconnected polygons and inconsistencies with the terrain can be avoided. As a result, it is recommended that the inundation areas be developed prior to development of the depth grids. The depth grids require an inspection to ensure that they match the inundation polygons.

The acceptable horizontal tolerance for disagreement between the depth grid rasters and the inundation polygons is not more than the resolution of depth grid (one grid cell). Therefore, if the resolution of the depth grid is 10 ft, the inundation polygon boundary must fall within 10 ft of the boundary of the depth grid (Figure 6).

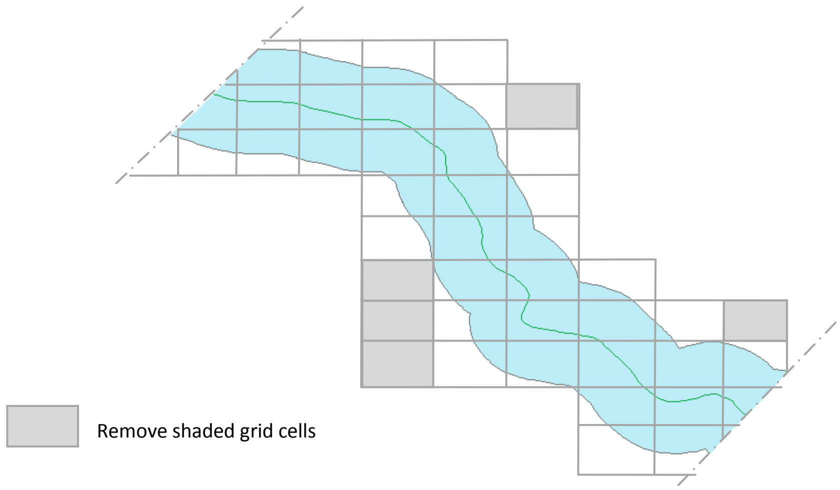


Figure 6: Tolerance limits between inundation polygon and raster depth grid.

A quality control check should also ensure that all grid cells that intersect that bridge decks or ramps that are **not inundated** are removed. In the example below (Figure 7), the bridge is not overtopped and therefore the depth grid should be trimmed so that no cells overlay the bridge itself.

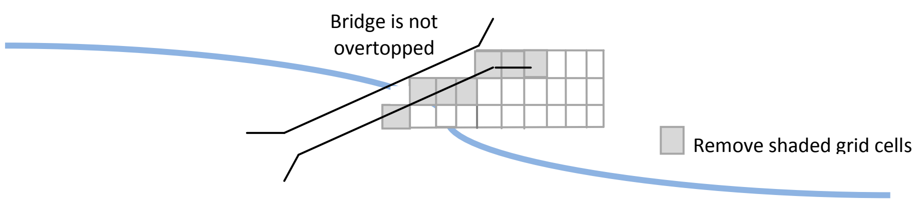


Figure 7: Grid tolerance with hydraulic structures.

3.4.2. Deliverables

Each map library should include depth grids that correspond with each modeled forecast stage and the accompanying inundation area. Grids should be submitted in ESRI raster or similar format and be named in the manner specified in Appendix D**.**

3.5. Flood Summary Report

The Mapping Partner will provide a flood summary report to describe the process and methodology for creating the Flood Inundation Maps. Below are the headings required in the report, along with information necessary for each section. The Mapping Partner will take any and all further steps to document unique circumstances of any methodologies that are not outlined here. The goal of the flood summary report is to clearly outline the location and the methodologies employed; all other methodologies should be documented for future reference. The structure of the Flood Summary Report is provided below. Each report should include:

Introduction

- The purpose of the report.
- The location and extent of the study area.
- A description on the importance of flood mapping for the community and/or the general area.
- A discussion of any unique circumstances or methodologies used in the study.
- An overview map of the study area.

Analysis

- A discussion of the hydrologic analysis.
  - A description on the stream gage, its drainage area, and its period of record.
  - A description of the model and the version used.
  - If a hydrologic model was not used, explain *why*.
  - If a hydrologic model was used, provide a description on the calibration and verification techniques.
- A discussion of the hydraulic analysis.
  - A description of the model and the version used. Describe the rationale for choosing a one- or two-dimensional analysis and a steady or unsteady flow rate.
  - A table of stages and corresponding flows used in the analysis and its equivalent values obtained from the hydraulic model.
  - A description on the calibration and verification techniques used.
- An error analysis on the flood depths based on high-water mark observations and available gauge data.

Map Development

- A discussion of the data used in the maps.
  - The aerial imagery source and its description.
  - The topographic data source and its description.
  - The base data source and its description.
  - Any additional images for areas of interest and its description.
- A discussion of the QA/QC checks on the datasets.

Conclusion

- A summary of the results of the study.
- Any lessons learned with a description of potential solutions and/or difficulties associated with the potential solutions.

3.6. Cartographic Zoom Level Standards

Data developed for display on AHPS should be prepared at a scale applicable for both digital and hard-copy media. One example is to assess the maps' quality based on the zoom levels from Google Maps – of which the second lowest zoom level is approximately 1:2250. This scale would allow a user to view property-level information for a structure or parcel. Furthermore, the NWS is anticipating its inundation mapping viewer will transition to a Google Maps platform, so a common display scale of 1:2,000 would be appropriate for the development of inundation information. It is recommended that all data be prepared and reviewed for this standard.

4. Phase 3 – AHPS Implementation

Upon completion of the hydrologic, hydraulic, and geospatial analyses and subsequent NWS QC processes, the inundation mapping boundaries and depth grid products are provided to the AHPS contractor for further processing. This includes conversion of the GIS data to the format that is displayed on the AHPS Web site. All supporting data used during Phase 2 of the process (depth grids, engineering support data, base mapping, and orthophotographic imagery) is also provided to the AHPS contractor. The supporting data is provided for when reanalysis or review may be needed. In addition, available digital versions of the effective FIS mapping should be provided to the AHPS contractor so that the NFIP 1- and 0.2-percent-annual-chance flood zones can be displayed and compared to the NWS inundation mapping data.

Upon completion of the data conversion, the maps are posted to a preliminary, non-public AHPS developmental Web server, referred to as the "test bed" server. Using the website, additional review is performed by local WFO personnel, Mapping Partners, and stakeholders. The review should include:

- The technical accuracy of the inundation mapping.
- The overall accuracy of the implementation and conversion of the inundation data into the AHPS server format.
- The overall accuracy of the base mapping data.

Details of the Phase 3 QC review are described in the subsequent section, "Quality Assurance and Quality Control Procedures."

4.1. Deliverables to NWS

Please see Appendix D for a description of the deliverables to be provided to the NWS.

5. Quality Assurance and Quality Control Procedures

The following sections provide a description of the general QA and QC procedures that have been developed for the implementation of AHPS flood inundation mapping projects. The QA procedures for each of the four phases are described in the following subsections.

5.1. Team Roles and Responsibilities

5.1.1. Regional Coordinator / Project Manager

A regional coordinator / project manager (RC/PM) will be responsible for the overall coordination and management of the NWS review of a flood inundation mapping project. This position will be filled by a member of the regional headquarters staff who will create a Flood Inundation Mapping (FIM) team, composed of local, NWS and stakeholder experts. Furthermore, the RC/PM will (1) serve as the primary liaison between the partner agency/contractor and the NWS; (2) will provide project updates and program feedback to NWS HQ; and (3) will arrange NWS-funded training for FIM teams.

5.1.2. Phase 1 Review Team (Planning)

Members of the Phase I review team should include NWS and local experts who are knowledgeable of flooding issues in the community.

5.1.3. Phase 2 Review Team (Production)

5.1.3.1. Hydraulic Model Review

Members of the FIM team are knowledgeable of open channel hydraulics and hydraulic modeling techniques. The team reviews the model and its output to determine if it has been reasonably calibrated. Team members provide contractor support for hydraulic related questions and coordinate with the WFOs and RFCs to ensure that important structures, channel geometry and channel conditions are included in the model.

5.1.3.2. Geospatial Data Review

The FIM team consists of the WFO or RFC staff that has GIS expertise and has taken the NOAA CSC training on inundation mapping QC procedures. This team will check each GIS layer submitted by the contractor, identify errors in the layers, and verify that the contractor has addressed the errors in future submittals. At least one member of this team should be a Service Hydrologist, RFC or other WFO staff member with significant local hydrologic knowledge of the site. Other team members do not require hydrologic knowledge of the site but should be proficient with ArcView GIS. A team leader will be selected to coordinate the workload of this team.

5.1.4. Phase 3 Review Team (Implementation)

This team consists of WFO or RFC staff who will review the "test bed" server for AHPS implementation. Members of this team should be familiar with local hydrologic conditions at the site and the FIM mapping process.

5.2. Quality Control Processes

5.2.1. Phase 1 Quality Control

The QC process for Phase 1 is divided into two parts – data inventory and inspection –, and it operates on a review-comment-revise/response basis.

5.2.1.1. Inspection Requirements

The planning of the project should include an inventory of available topographic and engineering data. Forecast sites for inundation mapping have been selected primarily on the availability of suitable data; as a result, they should be reviewed.

A checklist of required data has been developed to ensure completeness of the data acquisition. This checklist is part of the QA checklist provided in Appendix A of this report. It should then be reviewed by the FIM team.

5.2.1.2. Validation

After the inventory and inspection, the mapping partner, project manager and NWS project manager should sign off on the data collected. This validation will allow the project to proceed to Phase 2 (Production). If any information is not acquired to the satisfaction of project managers, corrective actions should be identified to allow the project to continue at the earliest possible time.

5.2.2. Phase 2 Quality Control

5.2.2.1. Inspection Requirements

The QC process for Phase 2 is divided into two parts – data inventory and inspection –, and it operates on a review-comment-revise/response basis.

Mapping

This part of the Phase 2 review focuses on assuring that the GIS data comprising the inundation maps are complete, internally consistent, and meet the required cartographic standards – in its topology, projection, and metadata. The reviewer imports the inundation polygons, along with supporting GIS base data, streamlines, and orthophotographic imagery into a single project file to be sure the mapping polygons correspond with the surrounding areas. Once completed, the reviewer should check the following:

- Streamline alignment with the mapping boundaries and the orthophotographic imagery.
- Hydraulic connectivity and mapping consistency.
- Internal consistency & alignment of all mapping layers.
- Correct projection of mapping boundaries.
- Assess and ensure the polygons and rasters match within one cell size of the depth grid

H&H Analysis

The Hydraulic model review is interpreted as a verification of the inundation area. The responsibility for this task is shared amongst the project's partners – and not limited to the Weather Service Office Service Hydrologist, though his or her participation is greatly recommended. The guidelines for verifying the hydraulic model are as follows:

- Ensure proper cross-section placement at locations before and after hydraulic structures, bridges, and areas with quick changes in topography.
- If applicable, verify the dimensions and attributes used for defining bridges/culverts, inline structures, lateral structures, and storage areas.
- Since flow rate data is used to derive the inundation area, import the value(s) appropriately.
- Calibrate the model using high water marks, manning's values or other parameters.

The Hydrologic model review is interpreted as a verification of the parameters used to estimate the flows for an unsteady one-dimensional or two-dimensional flow model. The guidelines for verifying the hydrologic model are as follows:

- Verify the quality of any paired-data used, such as: storage-discharge, elevation-storage, elevation-area, and elevation-discharge.
- Verify the flow source used and its parameters, such as: surface, loss, transform, base flow and routing values.

Review the checklist, and add comments where needed. Furthermore, provide sample images and screenshots to the contractor as part of an overall quality control review.

Data Submission

All data should be provided in digital format; hard copies will not be accepted. The contractor then reviews and responds to the comments, makes the appropriate revisions, and resubmits the revised inundation data along with a written response to the reviewer's comments. If no revisions are needed, the contractor will address the comments with an explanation as to why the revisions were not required. CSC staff will then review the contractor's comment response and either approve or make additional comments for the contractor's consideration.

Responsibility for coordinating a Phase 2 review is assigned on a project-specific basis by NWS regional or Headquarters staff. These reviews will be conducted by local NWS offices, based on their availability and staff capability.

After completion and successful submission to the AHPS contractor, The AHPS contractor further processes and converts the GIS data to the format that is displayed as inundation mapping on the AHPS Web site. Upon completion of the data conversion, the inundation mapping data is posted to a preliminary, non-public AHPS developmental Web server, referred to as the 'test bed' server.

5.2.2.2. Validation

After the inventory and inspection, the mapping partner project manager and NWS project manager should sign off on the Phase 2 QC comments. This will allow the study to move to Phase 3, AHPS Implementation.

5.2.3. Phase 3 Quality Control

5.2.3.1. Inspection Requirements

Phase 3 QC review begins after the inundation mapping data has been posted to the test bed server. Phase 3 reviews have been performed by the NWS service hydrologist at Weather Forecast Offices (WFOs) that have responsibility for the specific site or sites. These reviews have focused primarily on the technical accuracy of the inundation data and require the experience, expertise and local knowledge that reside in the local WFO offices.

During Phase 3 review, the inundation mapping is compared with the existing NWS Form E-19 data for the specific site in order to ensure the mapping is in agreement with the text description of impacts. In addition, the inundation mapping is reviewed at this time for consistency with other known impacts not included in the E-19 reports. Inundation mapping is also compared with FEMA Digital Flood Insurance Rate Map (DFIRM) mapping for agreement and consistency. Stage 2 review comments are compiled and transmitted to the study contractor or mapping agency using a template developed by NWS Headquarters staff. Phase 3 reviews for all inundation mapping studies are performed by local RFC/WFO staff.

5.2.3.2. Validation

After the inspection is complete, the Project Manager and NWS sign off on the validation form.

5.2.4. Second-Generation Products QA/QC

In some situations, inundation mapping will be prepared using previously completed data provided by an outside party. For example, a mapping partner may be using a recently completed FEMA model to prepare NWS inundation mapping. The partner should work with the local FEMA regional office to receive verification that the product as received meets the original provider's quality assurance metrics. The mapping partner should request the following:

- *Inventory* - Provider of the original product gives a detailed list of the available data
- *Pre-Inspection* - The quality control records should have been kept for the original product. The provider will verify that the records are complete and also conduct a cursory review of the product. This review will ensure that the data from the inventory is complete and is the correct data.
- *Self-Certification* - The provider will certify that the data is ready for use. The proper form must be filled out and signed and dated.
- *Self-Certification Verification* - Prior to starting the study, the mapping partner project manager and NWS project manager will verify that the self-certification form is complete.

6. Phase 4 – Mapping Maintenance

Phase 4 of the NWS inundation mapping process describes the maintenance procedures for the finalized products. Each map represents a snapshot of the hydraulic settings and conditions at the time the study is performed; changes to these variables could potentially result in changes to the stream's flood response, its impact within the floodplain, or a combination of both. Therefore, a key component of this phase is map verification. This is complemented by continuing checks on the base map data to ensure it is current followed by a reanalysis of the floodplains, if necessary.

Because the NWS inundation mapping process is considered a nascent program, the ongoing map maintenance program has not been fully developed. However, several suggestions for developing an ongoing map maintenance program are provided below.

6.1. Post-Implementation Ground Truth/Verification

The ongoing evaluation of flood impacts and categories is part of the role and responsibility of local NWS offices. In the wake of new and significant flood events, the flooding impacts should be observed, documented, and compared to the impacts depicted by current flood categories and inundation maps. In addition, any subsequent changes to the hydraulic setting and conditions in the study reach should be noted and evaluated for significance. This will include changes in bridge structure, in channel or floodplain geometry, and in floodplain development. Their effects on the floodplain will not be observed until the next large event occurs. However, observed or anticipated changes in hydraulic settings and conditions could be modeled and tested for significance if the hydraulic model –used to create the inundation map- is available and amended.

The local NWS office, in coordination with regional offices and its Headquarters, should develop procedures for the update and replacement of the inundation maps. Procedures should also be developed for the suspension or the removal of inaccurate or unreliable inundation maps.

6.2. Evaluation of and Coordination with Subsequent FEMA Studies

Due to the reliance on river forecast points by FEMA, it is important for mapping partners to keep up with the type of model presented at each gage. FEMA has recently developed its Coordinated Needs Management Strategy (CNMS), a database-driven inventory management system that tracks the validation status of all mapped FEMA flood zones. It analyzes whether the current study is a valid or unverified representation of the flood hazard based on analysis of seven critical factors and ten secondary factors (Table 3). If a critical factor is found to be deficient, then the FEMA study results are labeled as an unverified representation of the flood risk, and the stream is considered a prime candidate for restudy and remapping. For secondary factors, if four or more elements are deficient then the respective study results are also deemed unverified.

Table 3: CNMS evaluation elements used to determine stream validation status. For each element, if the answer to the question is 'yes', then it represents a deficiency in the study.

Critical Elements	Secondary Elements
1. Major Change in Gage Record? 2. Updated and Effective Discharges Differ Significantly? 3. Inappropriate Model Methodology? 4. Addition / removal of a Major Flood Control Structure? 5. Channel reconfiguration outside the Special Flood Hazard Area (SFHA)? 6. Five or more New or Removed Hydraulic Structures? 7. Significant channel fill or scour?	1. Use of rural regression equations in urban area? 2. Repetitive Losses outside SFHA? 3. Increase of 50% or more in impervious area? 4. 1-4 new or removed hydraulic structures? 5. Channel Improvements / Shoreline Changes? 6. Availability of better topography / bathymetry? 7. Changes in vegetation or land-use? 8. Failure to identify Primary Frontal Dune? 9. Significant storms with High Water Marks? 10. New Regression Equations?

The Regional Headquarters and the Regional Services Center (RSC, operated by the FEMA Production and Technical Services contractors) are considered the CNMS database custodians for their respective region. Information, such as reasons why a stream was classified as valid or unverified, is available in these databases. However, for additional information, the mapping partner should contact the local FEMA region responsible for the study area.

6.3. Impacts of Land-use Changes and Significant Flood Events

Over time, it is expected that changes in land use and new flood events will require the inundation mapping at a river forecast point to be re-evaluated. The National Weather Service does not have specific guidance in place for managing these changes at the current time. Nonetheless, mapping partners should consider these changes and plan for future updates in their respective programs. For further information, please contact the NWS program services leader.

APPENDIX A – STATEMENT OF WORK TEMPLATE

(6/2/2008)

1.0 Purpose

The purpose of this solicitation is to obtain support for development of inundation map libraries that is consistent with Flood Inundation Mapping Services of National Oceanic Atmospheric Administration (NOAA) National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS).

2.0 General Description

The National Weather Service (NWS) is enhancing the communication of flood risk and impacts by expanding Advanced Hydrologic Prediction Service (AHPS) to support flood inundation mapping services. Developed in partnership with ***<<local government agency>>***, the web-based flood inundation maps will provide information on the spatial extent and depth of flood waters in the vicinity of NWS river forecast locations. Combined with river observations and NWS river forecasts, flood inundation map services provide decision-makers additional information needed to better mitigate the impacts of flooding and build more resilient communities.

The work to be accomplished in this task is to (1) assist ***<<local government agency>>*** in evaluating the feasibility of building a Flood Inundation Maps for selected river segments in ___________________ watersheds in accordance to guidance provided in Attachment A, (2) work with NWS and ***<<local government agency>>*** to select, prioritize, and determine the project scope, (3) perform Hydrologic, Hydraulic, and Terrain Analyses, to create flood inundation maps, and (4) assemble, document, and archive the numeric, informational, and geographical datasets necessary for the Flood Inundation Map Library on behalf of ***<<local government agency>>***. The final implementation of the datasets onto NOAA NWS AHPS is beyond the scope of this contract.

3.0 Knowledge Required

Contractor must possess the following:

(1) Knowledge of the theories, principles, practices and techniques of hydrology, hydraulic, and/or river and coastal engineering and surveying.
(2) Knowledge of Geographic information systems (GIS), digital mapping, remote sensing, spatial analysis, and state-of-the-art ground surveying techniques (Global Positioning Systems).
(3) Familiarity with Federal Emergency Management Agency's National Flood Insurance Program (NFIP) regulations and standards for mapping.
(4) Experience in the contracting and procurement of civil engineering, hydrologic, and

hydraulic professional services.
(5) Experience in spatial and terrain analysis.
(6) Skill in verbal and written communication.
(7) Ability to organize and prioritize work and to meet deadlines.

4.0 Nature of Work

4.1 <<local government agency>> Responsibilities

The ***<<local government agency>>*** shall furnish the contractor the following:

(1) Any recent Flood Insurance Studies (FIS) performed in accordance to FEMA (Federal Emergency Management Agency) NFIP (National Flood Insurance Program), including hydraulic models used in the FIS studies;
(2) Most recent DFIRM (Digital Flood Insurance Rate Map), and
(3) Supporting data used in the FIS, such as LIDAR surveys,.

In addition, at the conclusion of this task order, the ***<<local government agency>>***, with the assistance of the contractor, shall furnish NOAA the following:

(4) Brief project summary report capturing calibration techniques and results, quality assurance, lessons learned, new methods developed, other issues encountered, new recommendations, and overall synopsis of both topographic and engineering data assessment/inventory.

4.2 Contractor Responsibilities

The contractor shall:

(1) Perform a feasibility assessment by developing an inventory of all existing and best available topographic/engineering data for the production of flood maps for NWS river forecast points within ___________________ watersheds. The inventory will include the following:

a. Topographic data from federal, state, or local (county or municipality) sources, such as information collected for the FEMA NFIP Map Modernization Programs, used in FEMA studies by FEMA cooperating technical partners, and/or furnished to create a digital elevation model (DEM), but not limited to. Minimum topographic data standards should follow those outlined in Federal Flood Inundation Map Library Guidelines (Attachment A).
b. Engineering data, cross-sectional information, hydrologic and hydraulic analyses from flood insurance studies, and hydraulic structures data. The FEMA Depot could be used to locate existing flood insurance data resources, including model data in HEC-RAS.

And deliver results to NWS and ***<<local government agency>>***.

(2) Meet with NWS and ***<<local government agency>>*** to discuss, select, and prioritize NWS river forecast points for mapping based on availability of data and mapping recommendations from the NWS.

(3) For each select forecast point, work with local Weather Forecast Offices (WFOs) service hydrologists, River Forecast Center (RFC) hydrologists, and/or NWS Regional Headquarters to:

a. Evaluate the existing flood advisory categories for use in mapping,
b. Collect NWS E-19 information for model development and mapping verification,
c. Obtain Rating Curve information for stage/flow interpolation,
d. Determine appropriate vertical range of intervals for mapping areal extent of flooding,
e. Ensure the vertical difference between each successive intervals is no less than half the contour interval of the supporting DEM data,
f. Determine the lowest vertical elevation to be mapped, which should be below flood stage and normally higher than 75% of bankful capacity, and
g. Ensure that the vertical elevations include the flood advisory, minor flooding, moderate flooding, major flooding, FEMA 1% chance flood, and the largest flood on record.

(4) Collect supporting data for Hydrologic, Hydraulic, and Terrain Analyses, including but not limited to:

- ESRI shapefiles of the FEMA floodway, 100-yr, 500-yr boundaries, and stream centerline,
- Digital Elevation Model (DEM),
- GIS base data of Roads, Highways, Streets, Water-bodies, Lakes, Creeks, Streams, Stream Centerline, Airports, and any significant geographic areas,
- Digital Orthophotography Images, and
- LIDAR Surveys

In particular, use of LIDAR surveys to provide detail map resolution for vertical intervals of 1 foot or less is recommended. Perform additional survey, if the select forecast points require additional cross-section information or engineering data, particular concerning storages, structures, or obstructions to flow. This may require field surveying and/or field data measurements in coordination with State Departments of Transportation or Public Works Departments.

(5) If required, build new or revised existing hydraulic models with new cross-sectional data. Modeling methods, based on standards provided in Attachment A, are preferred but may vary based on available engineering. Models used must conform to FEMA approved models for Flood Insurance Studies (FIS) (a web link to acceptable models is available in Attachment A).
(6) Determine study reach based on proximity to NWS forecast point, normally 1-mile upstream and downstream or less if there are abrupt changes in the hydrology/hydraulics

(e.g. tributaries, structures.) which renders difficulties and extreme uncertainties in mapping the water surfaces and profiles,

(7) Truncate FIS hydraulic models to match chosen study reach,

(8) Calibrate FIS models for a range of interpolated flows to develop flood profiles for the range of vertical intervals, factoring in the select forecast point and associated rating curve as either the lower or intermediate boundary condition,

(9) Using standard GIS techniques, map the flood profiles to create a series of inundation maps/shapefiles and water depth grids for the selected water surface elevations with the following considerations:

   a. Flood inundation polygons should be created and edited in conformance to FEMA approved techniques, with the exception being the removal of unconnected polygons (small ponds) to show realistic incremental overland flooding,
   b. Flood depth grids, generated by subtracting elevation grid from water surface grid, should match final inundation polygons, as technically best possible, to minimize data gaps in the mapping.
   c. Specifically, horizontal and vertical datums used for all mapping and water level assessments are North American Datum 1983, and North American Vertical Datum 1988 respectively. Geographic projection shall be used for all GIS data layers.

(10) Perform QA/QC checks to ensure the water surface profiles and depths are hydrologically, hydraulically, and scientifically reasonable approximations,

(11) Submit the following items NWS and ***<<local government agency>>*** for review downloadable via contractor FTP site:

   a. A series of Inundation maps for all selected water surface elevations in the form of ESRI Shapefile, edited to remove unconnected ponding areas,
   b. Flood Depth Grids in raster format with attributes in feet for each mapped inundation level,
   c. FGDC compliant metadata records for all GIS files,
   d. Supporting data used in the Hydrologic, Hydraulic, and Terrain Analyses for the study area with any geographically data referenced to Geographic Coordinates, North American Datum 1983, North American Vertical Datum 1988, and
   e. Brief project summary report capturing calibration techniques and results, quality assurance, lessons learned, new methods developed, other issues encountered, new recommendations, and overall synopsis of both topographic and engineering data assessment / inventory and inundation map libraries.

(12) Resolve any differences identified in the review and make final submission in digital format via CD-ROM or DVD (3 copies).

After deliverable of the ESRI Inundation Shapefiles and Water Depth Grids, the contractor shall be responsible for changes to correct any improperly model results for said period of time, as identified in ***Schedule and Term***. After said period of time, ***<<local government agency>>*** will assume responsibilities to maintain data and ensure inundation maps remain valid.

5.0 Location of Work

The work to produce the raw ingredients for the AHPS flood inundation map library/libraries will be performed at the contractor's location and made available for review via contractor's FTP website. Once completed, the mapping components will be temporarily available for download via contractor's FTP website and permanently captured onto digital format such as CD-ROM or DVD with one copy furnished to NWS and two copies to ***<<local government agency>>***. Upon the request of ***<<local government agency>>*** , travel to ***<<site of local government agency>>*** and/or NOAA facilities required to support planning, implementation, and quality assurance of the library/libraries will be financed by the contractor. Travel will not exceed two trips without additional funding being provided to the contractor.

5.1 Kickoff and Other Meetings

The contractor shall attend a kickoff meeting at the designated ***<<local government agency>>***, or other designated site within 30 days of contract award unless otherwise agreed upon by ***<<local government agency>>*** and the contractor. This meeting will serve as an information exchange and planning meeting for future activities. The contractor shall prepare an agenda for this meeting with input from NOAA and ***<<local government agency>>***. Additional meetings with NWS staff ***<<local government agency>>*** will be required to coordinate the final selection and prioritization of the NWS river forecast points to be mapped and the vertical intervals to be used. It is anticipated that several meetings or conference calls will need to occur at/with either ***<<local government agency>>***, NWS Region Headquarters, or at the local WFOs or RFCs.

5.2 Contractor Coordination

Communication and coordination between both the contractor and the ***<<local government agency>>*** is considered vital to the satisfactory accomplishment of this SOW. The Contractor shall expect periodic interaction with the ***<<local government agency>>*** to ensure clear understanding of the anticipated products and satisfactory progress in the delivery of products.

The contractor shall submit monthly progress reports to the ***<<local government agency>>*** as a summary of the progress and encountered problems. After submittal of each of these reports the contractor shall schedule a conference call with the government to discuss the progress of the project and any issues that need to be addressed. The contractor shall prepare and distribute a conference call agenda at least 3 days prior to the call and shall distribute the meeting minutes within 5 days of the conclusion of the call.

6.0 Quotation

The quotation shall be provided for labor, materials, and travel associated with the tasks described above.

7.0 Milestones

(1) Complete Feasibility Evaluation and Data Collection by ***<<MMM DD, YYYY>>*** (tasks 1

to 4).

(2) Complete H&H/GIS Analyses for review by ***<<MMM DD, YYYY>>*** (tasks 5 to 11).

(3) Complete final task of assembling components for Flood Inundation Map Library implementation by ***<<MMM DD, YYYY>>***.

(4) Ensure inundation maps remain valid for 90 days after final acceptance.

7.1 Deliverables

This section contains other items to be delivered with this project. Each deliverable must include a proposed measure of acceptability. All plans shall be of sufficient detail so that the ***<<local government agency>>*** can verify that the contractor has a thorough understanding of the requirements of this SOW. This data will be used to track milestone performances and for approval of invoices. The contractor may propose additional deliverables/ milestones in their technical proposal if they determine they are required. The following project deliverables are required:

(1) Work/QA Plans – The plans, describing the tasks and quality measures, shall be in Microsoft Word format. In some instances, the technical proposal may be accepted as the work plan.

(2) Project schedule – The schedule shall be appended to the work plan and represented by a weekly Gantt chart showing the major milestones, task deliverables, completion dates, and any interdependencies. The schedule is to be updated as necessary and furnished to ***<<local government agency>>*** and NWS, when there are changes

(3) Monthly progress reports – Reports are to be in Microsoft Word format. In some cases, a more appropriate regularly scheduled reporting timetable may be substituted contingent on agreement by all parties.

(4) Meeting minutes - Notes from all meetings and conference calls with ***<<local government agency>>*** and NWS are to be in MS Word format and appended to monthly progress reports or urgent communications, as needed.

(5) Lists of Milestones and Other Deliverables – Refer to Attachment "B" for complete list.

Note: All geospatial deliverables (shapefiles, imagery, grids) shall be referenced to the North American Datum of 1983 (NAD83) and North American Vertical Datum of 1988 (NAVD88). In addition, all GIS layers should be provided in Geographic Projection.

7.2 Product Delivery Schedule

The contractor shall develop a timeline for completion of this task order in a Microsoft Project format. Use the milestones and the following government schedule requirements in developing the timeline.

(1) Kick-off meeting, work plan, QA plan 30 days after award of task order.
(2) Monthly progress reports on the 7th day of the month.
(3) Deliver topographic and engineering data assessment / inventory database by 6 months after award of task order.
(4) Conduct topographic and engineering data assessment coordination meeting NWS after receiving comments at 6 months after award of task order.
(5) Deliver inundation map library polygons and all base data for NWS forecast point locations no later than 1 year from award of task order.
(6) Deliver project summary report by 1 year 6 months from award of task order.
(7) Summary of quality assurance and calibration report should be included with each inundation polygon deliverable.
(8) NOAA NWS will have a 1 month time frame to review the deliverables for acceptance.
(9) NOAA NWS will have complete control over the deliverables and how they get posted to the web. The mapping contractor will not be directly involved in the posting of any information directly to the web.

7.3 Product Delivery Addresses

The deliverables listed above shall be delivered to the Contract Officer at following address.

<<local government agency>>
<<#### streetname>>
<<city/town, state #####-####>>
<<Attn: xxxxxx>>

<<Phone: xxx-xxx-xxxx>>
<<E-mail: xxxxxxxxxx@xxxxx.xxx>>

Technical questions shall be addressed to the technical POC.

Technical Contact:
<<local government agency>>
<<#### streetname>>
<<city/town, state #####-####>>
<<Attn: xxxxxx>>

<<Phone: xxx-xxx-xxxx>>
<<E-mail: xxxxxxxxxx@xxxxx.xxx>>

8.0 Acceptance

The sponsor or ***<<local government agency>>*** shall not be obligated to issue new tasks to the Contractor, nor shall the contractor be obligated to accept any new task beyond the scope of this Statement of Work, as stated herein. Each developmental task item shall require the contractor to demonstrate that the tasks have met specific operational criteria defined in written or electronically transmitted task statements. A task item shall be considered completed and accepted when it is demonstrated to the ***<<local government agency>>*** and NOAA that the task item have been completed satisfactorily as demonstrated in submittals or deliverables. Task items which are determined to be unacceptable shall be assessed to determine whether they are caused by contractor deficiencies or conditions beyond the responsibility of the contractor, such as hardware failures, communications errors, or outdated base information. If it is determined that the contractor is responsible, the contractor shall correct the deficiency. Payment for completed milestones shall be authorized within 30 days after the ***<<local government agency>>*** receives and approves final Contractor invoice for each milestone. Interim payments shall be authorized, as necessary, under the terms described herein.

8.1 Records and Metadata

The contractor shall document all delivered data and data products according to Executive Order 12906 (http://www.fgdc.gov/publications/documents/geninfo/execord.html) Specifically, the contractor shall deliver for all data and data products, metadata records which detail datums, re-projections, re-sampling algorithms, processing steps, field records, and any other pertinent information. The metadata records shall conform to the Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998) as published on May 1, 2000, by the Federal Geographic Data Committee (FGDC) or to any format that supersedes it as determined by the FGDC. (http://www.fgdc.gov/metadata/csdgm/). Profiles and extensions to the standard that have been endorsed by the FGDC shall be used if they are applicable to the data or data products. The metadata records shall contain any and all elements, including those that are considered optional, wherever applicable to the data or data product. The metadata record shall contain sufficient detail to ensure the data or data product can be fully understood for future use and for posterity. The metadata records shall be delivered free of errors in both content and format as determined by the metadata parser (mp) program developed by the United States Geological Survey or an equivalent. The metadata records will be subject to review and approval prior to final acceptance by the ***<<local government agency>>***.

9.0 Warranty

The period of performance for this contract is ***<<MMM DD, YYYY to MMM DD, YYYY >>***.

The contractor warrants that the work performed will meet or exceed the acceptance criteria for a 90 day period after completion. If Contractor fails to comply with the terms of this agreement, Contractor shall be considered in default.

10.0 Sole Source Justification

Not Applicable

11.0 References:

- Advance Hydrologic Prediction Services http://water.weather.gov/ahps/

- Flood Inundation Map Locations http://water.weather.gov/ahps/inundation.php
- NWS Web Directive http://www.weather.gov/os/water/policy.shtml#60

APPENDIX B – NWS PROJECT CHECKLIST

NWS Inundation Mapping QA/QC Checklist (1-D)				Version 4

Project:		Lowest inundation elevation:	
Site Name/LID:		Action Stage:	
USGS gage ID:		Flood Stage:	
Reach Limits & Length:		Moderate Flood Stage:	
# of elevations:		Major Flood Stage:	
		Highest inundation elevation:	

Reviewer	Agency	Phase(s)	Contact phone #	Contact e-mail address
		1A		

PHASE 1A - PROJECT SCOPING AND PLANNING

Category	Explanation	Applicable	Project Chief Comments	Reviewer Comments
Site Selection and Evaluation				
Project scope	Obtain stakeholder input on definition of the study extent. Evaluate study extent impact on AHPS web appearance.	YES		
Modeling approach	Establish suitability of 1-D modeling approach and static map library. Select FEMA approved hydraulic model.	YES		
Stream gage selection	Verify USGS river gage. Is gage a NWS forecast point or suitable to be a new forecast point? Coordinate with partners, USGS, and NWS sponsoring office.	YES		
Stream gage rating suitability	Ensure rating is well defined by streamflow measurements. Coordinate with USGS and NWS sponsoring office.	YES		
Base data availability / suitability	Verify resolution and spatial extent of available GIS data is sufficient for inundation mapping, etc.	YES		
Establish minimum/maximum stage and depth increments	Ensure highest modeled inundation elevations (WSELs) do not exceed rating. Verify lowest inundation elevation is approximately equal to bank-full conditions. Depth increment should not exceed resolution of digital elevation data. For example, depth increments should not be less than 1/2 the contour interval.	YES		
Establish project timeline and reviewers		YES		

Mandatory review at this point.	Target Date	Reviewed and Approved By	Date(s)

PHASE 1B - BASE DATA COLLECTION AND PROCESSING

Category	Explanation	Applicable	Project Chief Comments	Reviewer Comments
Obtain GIS and other pertinent base data				
Obtain/review hydraulic model(s)	Research any existing hydraulic models. Initial preference is for and existing FEMA FIS.	YES		
Obtain/review GIS data	Includes stream centerline , topography, orthophotography, FEMA Flood Insurance Study data (if available and current), and transportation data (road centerlines). Transportation layers should contain a "RoadName" field and extend at least 2000 ft beyond the study area extent.	YES		
GIS data processing	Ensure GIS has been processed for the intended use.	YES		
GIS data projection	Verify agreement of datum and projection for all GIS data.	YES		
Gage rating and datum checks				
Rating check	If FEMA FIS exists, compare 10-, 5-, 1-, and 0.2- annual percent chance flows and corresponding water surface elevations (WSEL) to rating curve to check for reasonability. Review site for possible backwater effects from downstream confluences and/or structures.	YES		
Rating changes	Verify historical changes to datum and/or location of gage at forecast point location. Coordinate with USGS and NWS sponsoring office.	YES		
Datum conversion	Establish conversion from gage datum to NAVD88 if necessary.	YES		

Mandatory review at this point.	Target Date	Reviewed and Approved By	Date(s)

PHASE 2A - HYDROLOGIC AND HYDRAULIC ANALYSES				
Category	**Explanation**	**Applicable**	**Project Chief Comments**	**Reviewer Comments**
Hydrologic Analyses				
Discharge Selection	Discharges selected from rating curve to achieve incremental WSEL profiles	YES		
Hydraulic Modeling				
Model conversion	Pre-existing hydraulic model adapted to workable FEMA approved model (if needed).	YES		
Hydraulic structure verification	Coordinate with local/state transportation agency to verify hydraulic model represents current bridge/structure and to determine imminent plans for structure replacement and/or revision	YES		
Profile validation/calibration	WSELs validated/calibrated against HWM and other historical gage data or other study data (if available). Check agreement with FEMA Flood Insurance Study (if available and current).	YES		
Target WS elevations	Verify for each Q, modeled WSEL at gage +/-0.1 foot of rating.	YES		
Technical Summary	Complete Technical Summary Checksheet	YES		
Review-quality mapping development	Create review-quality (post RAS / RASMapper without refinement) floodplain boundaries for use by reviewer(s). Used to check appropriate use of ineffective flow area, possible overland flow, discharge loss, etc.	YES		

Mandatory review at this point.	Target Date	Reviewed and Approved By	Date(s)

PHASE 2B - MAPPING				
Category	**Explanation**	**Applicable**	**Project Chief Comments**	**Reviewer Comments**
Inundation Polygons				
WSEL boundary checks	Perform reasonability check with WSEL boundary shapefiles, orthophotography, and rasters /contours. Ensure transitions along the boundary are consistent with the raster/contour data. Check agreement with FEMA Flood Insurance Study (if available and current).	YES		
Inter-profile consistency	Ensure boundaries for higher WSELs are always coincident or outside boundaries for lower WSELs.	YES		
Minimum elevation mapping	Ensure lowest WSEL polygon covers stream and channel banks visible from orthophotography.	YES		
Islands	Delete "islands" with no straight line distance greater than 250 feet as appropriate.	YES		
Disconnected wetted areas	Remove wetted areas that result from depressions not connected with the flow.	YES		
Overtopping	Ensure structures indicated as overtopped in the hydraulic model are mapped accordingly.	YES		
Depth Grid Rasters				
Grid/Layer pairing	Ensure there is a corresponding depth grid raster for each WSEL boundary.	YES		
Edge trimming	Ensure depth grid rasters are trimmed to extents of WSEL polygons.	YES		
Overtopping	Ensure grid cells for dry areas should have their depths set to zero. This is particularly important for parts of roadways/bridges that are not overtopped.	YES		
Grid/Layer consistency	Ensure that wetted areas have positive depths and non-wetted area depths are set to zero. For islands that were removed from the polygon mapping the overlying grid cell depths should be set to be equal to those of the nearest adjacent wetted cells.	YES		
Mapping File Management				
Projection	Set the coordinate system for shapefiles and rasters to Geographic NAD83.	YES		
Map scale	Select the largest map scale that allows display of the full extent of inundation. Map scales of 1:12,000, 1:18,000, 1:24,000, and 1:30,000 are acceptable.	YES		
Naming Convention	Verify file naming convention maintained for inundation polygons and depth rasters layers conforms to: elev_feet_tenth.shp. Example for a inundation layer at 78.3 feet NAVD88 the file would be named elev_78_3.shp.	YES		
Metadata	Review and verify that metadata is attached to all GIS data and meets FGDC standards.	YES		

Mandatory review at this point.	Target Date	Reviewed and Approved By	Date(s)

PHASE 2C - DATA SUBMISSION				
Category	**Explanation**	**Applicable**	**Project Chief Comments**	**Reviewer Comments**
Final Data Submission				
Partner Approval	Obtain local approval for geospatial data and data publications.	YES		
GIS Layers	Include inundation polygons, depth grids, stream centerline data, cross sections, topography, and gage location data. Also Include pertinent supporting base data such as transportation, political boundaries, and other base data layers as applicable. Include FEMA Flood Insurance Study inundation polygons if found to be in agreement during phases 2A and 2B. For each shapefile include files with the following file extensions: dbf, prj, shp, shp.xml, shx and, if available, sbn and sbx.	YES		
Orthophoto/Imagery	Include ortho imagery data used to develop hydraulic modeling and inundation mapping.	YES		
Hydraulic Model	Include hydraulic model data (as digital files).	YES		
Technical Summary Document	Include completed Technical Summary document.	YES		

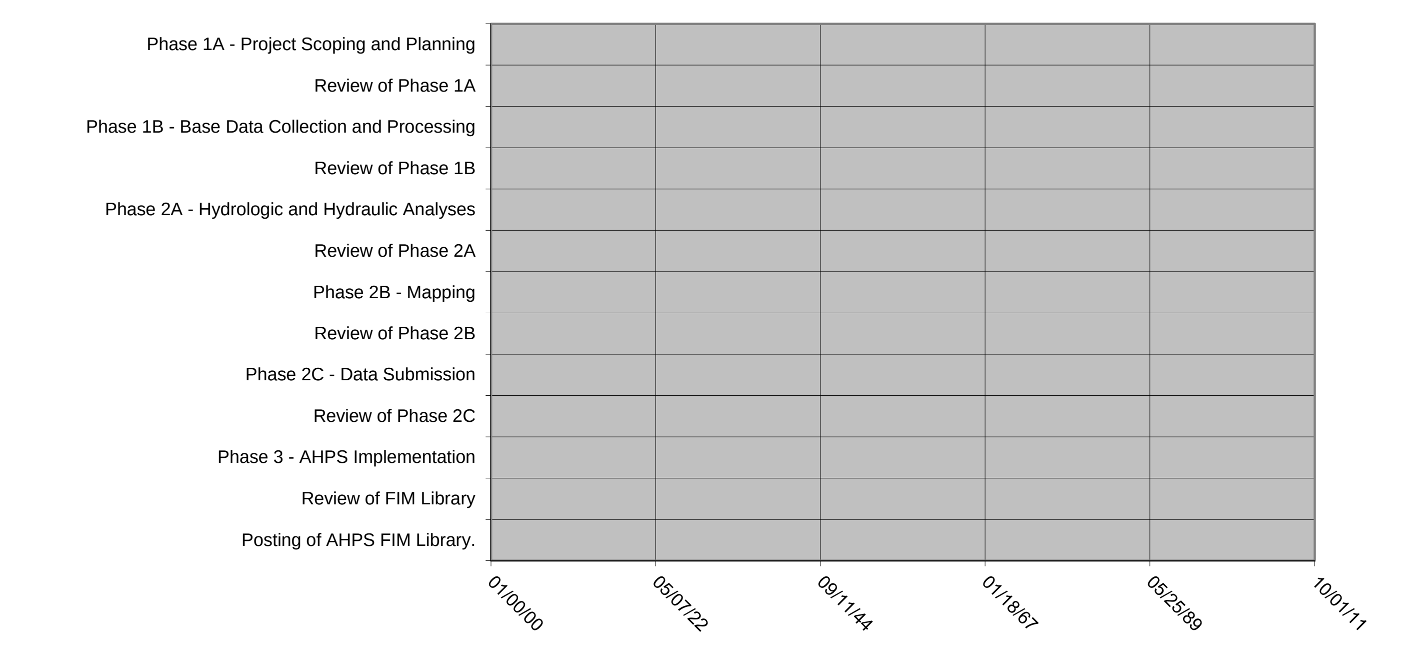
Confirm data are received by NWS. Partner provides deliverables to NWS.	Target Date	Receiving Agent	Date(s)

PHASE 3 - AHPS Implementation				
Category	**Explanation**	**Applicable**	**Project Chief Comments**	**Reviewer Comments**
Final Data Submission				
Process Data into Flood Inundation Mapping Library	NWS contractor to assemble data and build Flood Inundation Mapping Library.	YES		
Posting of Flood Inundation Map Library onto Development Test Server	NWS contractor to post FIM library onto Development Test Server for Partner, Stakeholder, and NWS Review.	YES		
Review Flood Inundation Map Library	NWS to coordinate partner and stakeholder Phase 3 review to ensure the deliverables are displayed accordingly This step is not to evaluate the hydraulics, the models, or the flood mapping. However, if the rendering of spatial extent of flood waters and depth rasters are questionable, the NWS regional coordinator should notify NWS Flood Inundation Mapping Services Program manager to consider whether the project should be kicked back into Phase 2.	YES		
Final corrections to Flood Inundation Map Library	NWS to coordinate any changes, oversight, and corrections, requested by the partner and stakeholders.	YES		
Approval of Flood Inundation Map Library	NWS Regional Coordinator and NWSH to approve FIM for AHPS Implementation	YES		
AHPS Implementation	NWS to coordinate with the public to announce this new service via Service Change Notifictaion (SCN) and provide NWS contractor authority to implement onto AHPS.	YES		
Project Archiving	Partner to submit the DEM, hydraulic model, metadata, and pertinent data either by allowing access to partner's FTP server for NWS retrieval or submission of three DVD(s) to NWS.	YES		

NWS posts Flood Inundation Map Library onto AHPS Partner provides supporting work data to NWS for archival.	Target Date	Receiving Agent	Date(s)

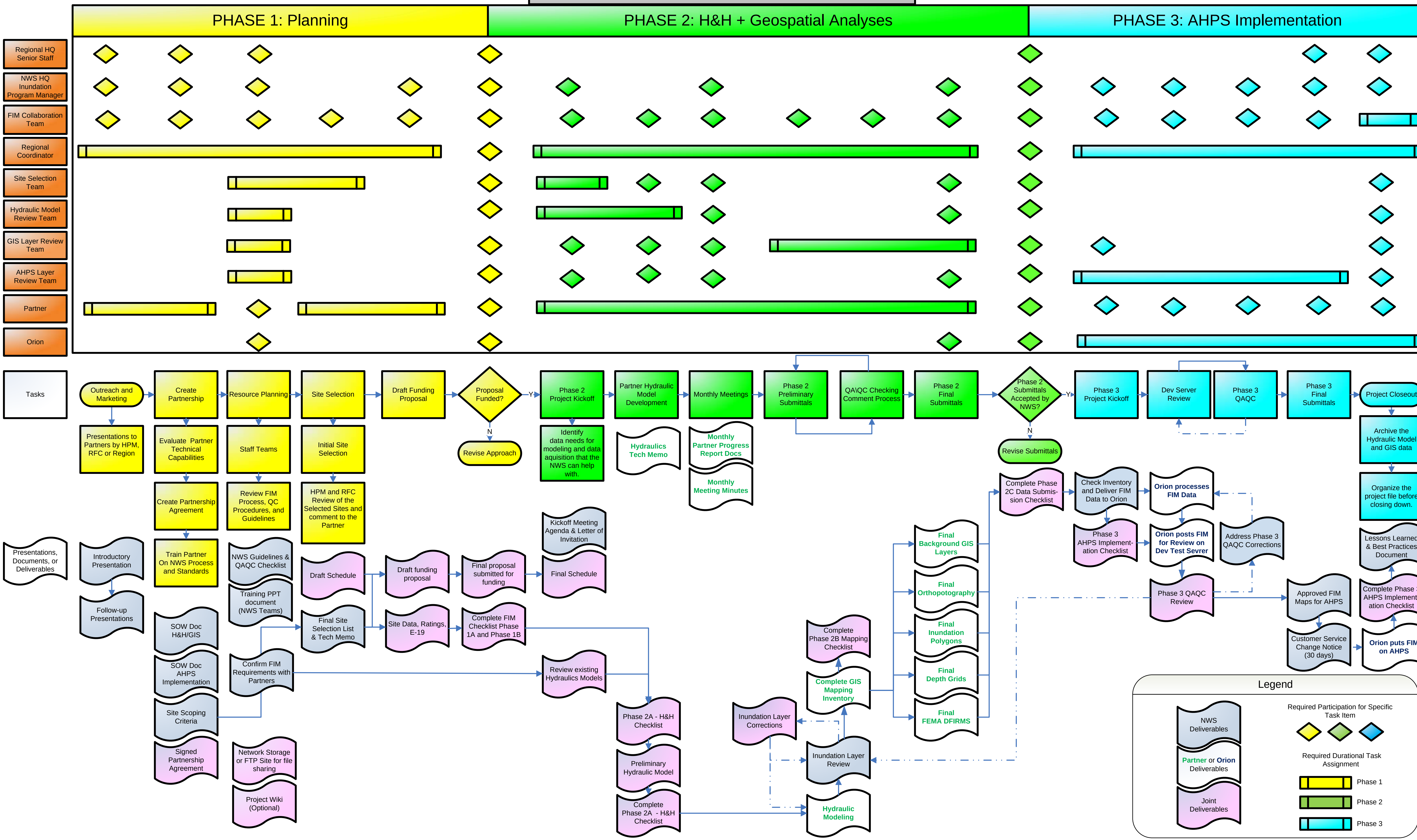
FIM Project Timeline

Element	Start date (mm/dd/yyyy)	End date (mm/dd/yyyy)	Duration (days)
Phase 1A - Project Scoping and Planning			
Review of Phase 1A			
Phase 1B - Base Data Collection and Processing			
Review of Phase 1B			
Phase 2A - Hydrologic and Hydraulic Analyses			
Review of Phase 2A			
Phase 2B - Mapping			
Review of Phase 2B			
Phase 2C - Data Submission			
Review of Phase 2C			
Phase 3 - AHPS Implementation			
Review of FIM Library			
Posting of AHPS FIM Library.			



APPENDIX C – PROJECT ROADMAP

Flood Inundation Project Roadmap (10-2011)



APPENDIX D – GEOSPATIAL DELIVERABLES

The attributes for each of the required geospatial deliverables are provided below: the three columns represent the GIS format, the filename, and the general description of the deliverable, respectively. These attributes should be specified in any statement of work for NWS inundation mapping. Furthermore, all products should have an associated clause regarding its inherent uncertainty.

Cross Sections		
File Type	*Naming Convention*	*Description*
Shapefile / FGDB	S_XS	Please include the hydraulic model cross-sections used to develop the inundation mapping. This will allow the modeling to be archived for future applications and updates to the inundation mapping.
Depth Grids		
Grid	raster_elev_*feet_tenth*	Depth grids corresponding to mapped inundation areas from action stage through at least the flood of record at 1 ft intervals or less. For example, a depth grid with a water surface elevation of 78.3 feet NAVD88 at the gage would be named "raster_elev_78_3.shp". Each depth grid should include the appropriate support files, with extensions # dblbnd.adf, # hdr.adf, # sta.adf; # vat.adf; # w001001.adf; # w001001x.adf
Inundation Areas		
Shapefile / FGDB	elev_*feet_tenth* (shapefiles) S_INUNDATION_AR (FGDBs with single layer for inundation areas)	Mapped inundation areas from action stage through at least the flood of record at 1 ft intervals or less. For example, an inundation area with a water surface elevation of 78.3 feet NAVD88 at the gage would be named "elev_78_3.shp". Each mapped inundation area should include the following file extensions: .dbf, .prj, .sbn, .sbx, .shp, .shp, .xml, and .shx.
FEMA 0.2% Annual Chance Floodplain		
Shapefile / FGDB	S_FEMA_02PCT	The effective 0.2% annual chance floodplain (if applicable) for the study reach, clipped to the study area.
FEMA 1% Annual Chance Floodplain		
Shapefile / FGDB	S_FEMA_1PCT	The effective FEMA 1% annual chance floodplain (also known as the Special Flood Hazard Area) for the study reach, clipped to the study area.
FEMA Floodway		
Shapefile / FGDB	S_FEMA_FLDW	The effective FEMA floodway for the study reach, clipped to the study area.
Gage		
Shapefile	S_GAGE	The location should be use the NAD83 (horizontal) and NAVD88 (vertical) datums.

Orthophotography		
Raster	*MrSID, JPEG200 (JP2)*	If a third party owns the orthophotographic data, please provide a copy of the permission for unrestricted use by the NWS.
Stream Centerline		
Shapefile / FGDB	S_CENTERLINE	The stream centerline should be consistent with what was used in the hydraulic model.
Study Area		
Shapefile	S_STUDY_AREA	This shapefile should show the study area for the inundation mapping project.
Transportation		
Shapefile	S_TRNSPORT	Please include a summary transportation file for use with the AHPS web viewer. Include the road name and its classification as a major or minor roadway. The file should be clipped to slightly larger than the study area. Please check the detail of the dataset along with capitalization/spelling of road names prior to submission of the file. No changes will be made by the AHPS contractor.

The mapping partner is required to submit a file geodatabase or shapefiles listing all the above mentioned geospatial files, with their respective attributes as provided below:

S_CENTERLINE		
Attribute	*Type*	*Description*
WTR_NM	Text	The name or other geographic identifier of the stream or river.
S_GAGE		
NAME	Text	The name of the river forecast point based, available from the USGS (i.e. Delaware River at Trenton, NJ).
USGS_ID	Text	Eight-digit USGS gage identifier (i.e. 01463500).
RFP_ID	Text	AHPS forecast point identification (i.e. TREN4)
STAGE_ACT	Double	Action Stage for the identified river forecast point at the time of inundation mapping.
STAGE_FLD	Double	Flood Stage for the identified river forecast point at the time of inundation mapping.
STAGE_MOD	Double	Moderate Flood Stage for the identified river forecast point at the time of inundation mapping.
STAGE_MAJ	Double	Major Flood Stage for the identified river forecast point at the time of inundation mapping.
AHPS_URL	Text	URL for AHPS forecast information for the identified gage. (ex. http://water.weather.gov/ahps2/hydrograph.php?wfo=phi&gage=tren4&view=1,1,1,1,1,1,1,1)
USGS_URL	Text	URL for USGS real time gage information for the identified gage. (ex. http://waterdata.usgs.gov/nj/nwis/uv/? site_no=01463500)
***elev_feet_tenth* (S_INUNDATION_AR)**		
STAGE	Double	The target stage at the gage for which inundation mapping was modeled.
WSEL	Double	The modeled water surface elevation for a mapped stage at the gage.
GAGE_ID	Long Integer	The USGS Gage number for the inundation mapping location.
RFP_ID	Long Integer	The NWS AHPS identifier for the river forecast point.
DISCHARGE	Double	The discharge at the gage required to produce the mapped water surface elevation and stage.
DEPTH_GRID	Text	The accompanying depth grid for the mapped WSEL and STAGE

		(i.e. *raster_elev_feet_tenths)*.

S_TRNSPORT		
ROAD_NM	Text	The name of the roadway (i.e., Interstate 90, State Route 9, Main St.)
ROAD_TYP	Text	Designation of the roadway as either a 'major' or 'minor' road.
S_XS		
STREAM_STN	Double	Stationing of the cross section along the hydraulic model stream centerline.
WSEL_UNITS	Text	Units in which water surface elevations are displayed.
WSEL_*feet_tenth*	Double	Modeled water surface elevation for a corresponding mapped stage at the gage. Create duplicate fields for each mapped interval