Guidance for Flood Risk Analysis and Mapping

Flood Depth and Analysis Grids

May 2014

FEMA

This guidance document supports effective and efficient implementation of flood risk analysis and mapping standards codified in the Federal Insurance and Mitigation Administration Policy FP 204-07801.

For more information, please visit the Federal Emergency Management Agency (FEMA) Guidelines and Standards for Flood Risk Analysis and Mapping webpage (http://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping), which explains the policy, related guidance, technical references, and other information about the guidelines and standards process.

Nothing in this guidance document is mandatory other than standards codified separately in the aforementioned Policy. Alternate approaches that comply with FEMA standards that effectively and efficiently support program objectives are also acceptable.

Document History

Affected Section or Subsection	Date	Description
First Publication	May 2014	Initial version of new transformed guidance. The content was derived from the *Guidelines and Specifications for Flood Hazard Mapping Partners*, Procedure Memoranda, and/or Operating Guidance documents. It has been reorganized and is being published separately from the standards.

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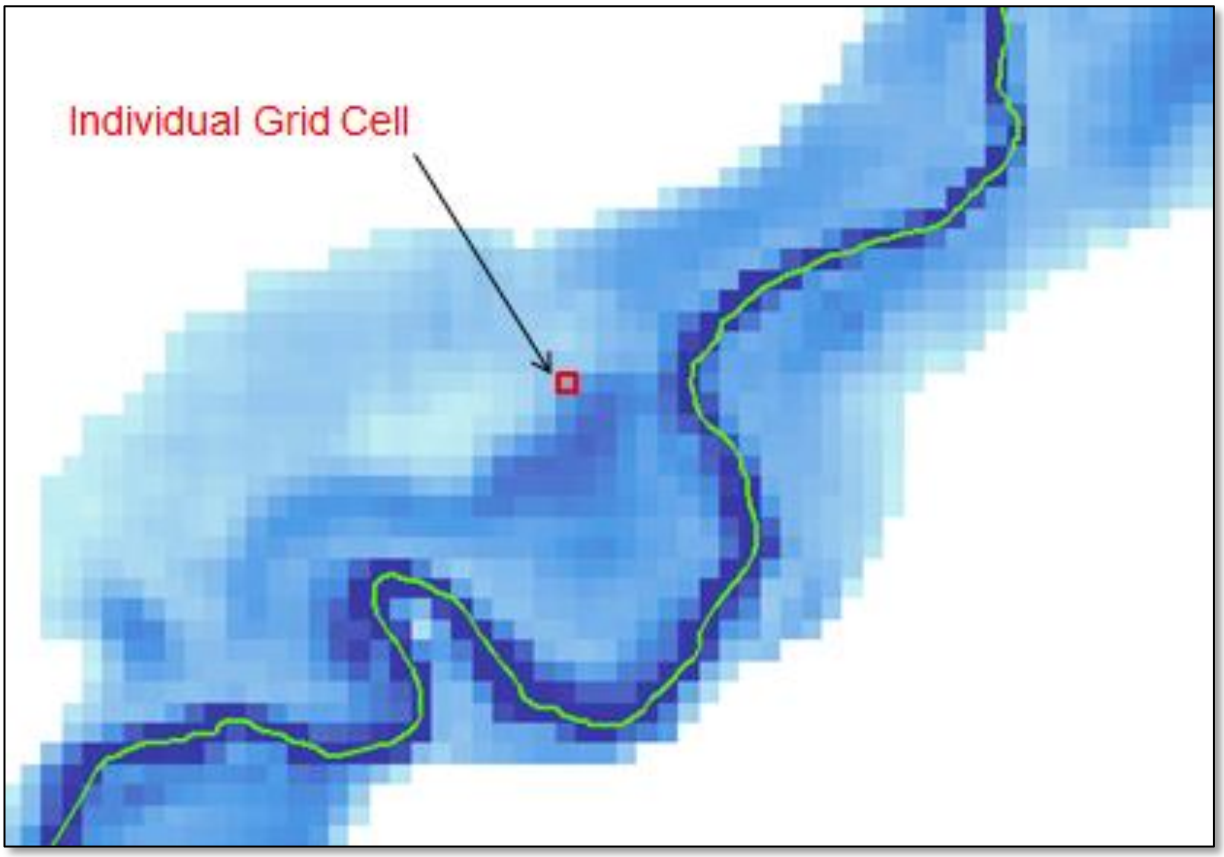
1.0 Definitions

One of the primary ways to communicate more complete flood risk information and to inform actions that can be taken to reduce flood risk is to deliver detailed information on depth of flooding, probability of flooding, and other flooding characteristics in the form of grid datasets (see Figure 1, where the darker blue areas represent greater flood depths). Similar to the pixels of a photo or graphic, a grid is a digital raster dataset that defines geographic space as an array of equally sized square cells arranged in rows and columns. The value in each cell represents the magnitude in that location of the flooding characteristic represented by that particular grid. Within the Flood Risk Database (FRD), grids can be produced to reflect water surface elevations, depths, velocities, percent annual chances of flooding, and other values. Other grid datasets that are unique to coastal areas and dams are also available within the *Coastal-Specific Non-Regulatory Datasets Guidance* and *Dam-Specific Non-Regulatory Datasets Guidance* documents.

Figure 1: Flood Depth Grid Example



1.1 Grid Cell Resolution

Several considerations should be taken into account when selecting the cell size for the grids to be delivered within the FRD. The depth and analysis rasters in the FRD have an inherent relationship to the underlying topographic data used during the development of the flood hazard delineations depicted on the Flood Insurance Rate Map (FIRM). The raster cell size (resolution) of all raster datasets in the FRD should be based on the density of the ground elevation data used and the appropriate precision that can be supported by the data. Normally, all the raster datasets should use the same raster cell size.

The overall file size of each grid dataset is directly related to the size of the grid cells selected. For example, the decision to use a 1 meter resolution grid as opposed to a 3 meter resolution grid will approximately increase the file size on disk by a factor of 9 (nine 1m x 1m grid cells can fit within one 3m x 3m grid cell). Using very small cell sizes (smaller than 1m resolution), however, may result in a flood risk database that is difficult for most users to be able to access and use.

1.2 Grid Cell Origin

In order to be able to properly orient each grid with one another, and to more accurately compare one flood risk data value (such as depth) to another (such as velocity) at a given location, each grid dataset within the FRD should use the same origin, cell size, and coordinate system. Since many of the grid datasets are derived from other grids (for example, the depth grids are derived from the water surface elevation grids, and the percent annual chance grids are derived from those), setting a common origin provides for proper alignment of grid cells when comparing one raster dataset to another.

2.0 Water Surface Elevation (WSEL) Grids

The Water Surface Elevation (WSEL) grid is generally the first raster dataset that will be produced as part of a Flood Risk Project, and becomes the source from which many of the other raster datasets are generated (see Figure 2). A separate WSEL grid is typically produced for each flood event (e.g. 1% annual chance, 0.2% annual chance, 1% annual chance future conditions, 1%+, etc.) or flood scenario (e.g. dam or levee overtopping) for which modeled elevations are available. Therefore, the 10% annual chance WSEL grid is one dataset, the 4% annual chance WSEL grid is another dataset, and so on. Each WSEL grid provides the modeled WSEL values within the inundation extent of that particular flood event or scenario (i.e. where the WSEL is higher than the terrain elevation). In locations where the WSEL is below the terrain elevation, or where WSELs have not been computed, a value of "NODATA" is assigned.

In the case of flood events that will be mapped on regulatory products (1% and 0.2% annual chance), the WSEL grids should generally be created to align to those regulatory flood boundaries, so as to build support and agreement between the various products and datasets produced as part of a Flood Risk Project. In other words, for a given flood event (such as the 1% annual chance flood), the 1% annual chance WSEL grid should have values of "NODATA" for cells outside of the mapped regulatory 1% annual chance floodplain. Similarly, the WSEL cells within the mapped floodplain should report a WSEL value. At confluences, WSEL grids created for a network of multiple flooding sources should be combined to reflect one overall, seamless WSEL grid for each flood event or scenario. Backwater elevations and extents at confluences should be correctly accounted for as part of the WSEL grid creation process (see Figure 3).

Figure 2: Example Showing Values Returned When Pointing and Clicking Different Locations on the WSEL Grid

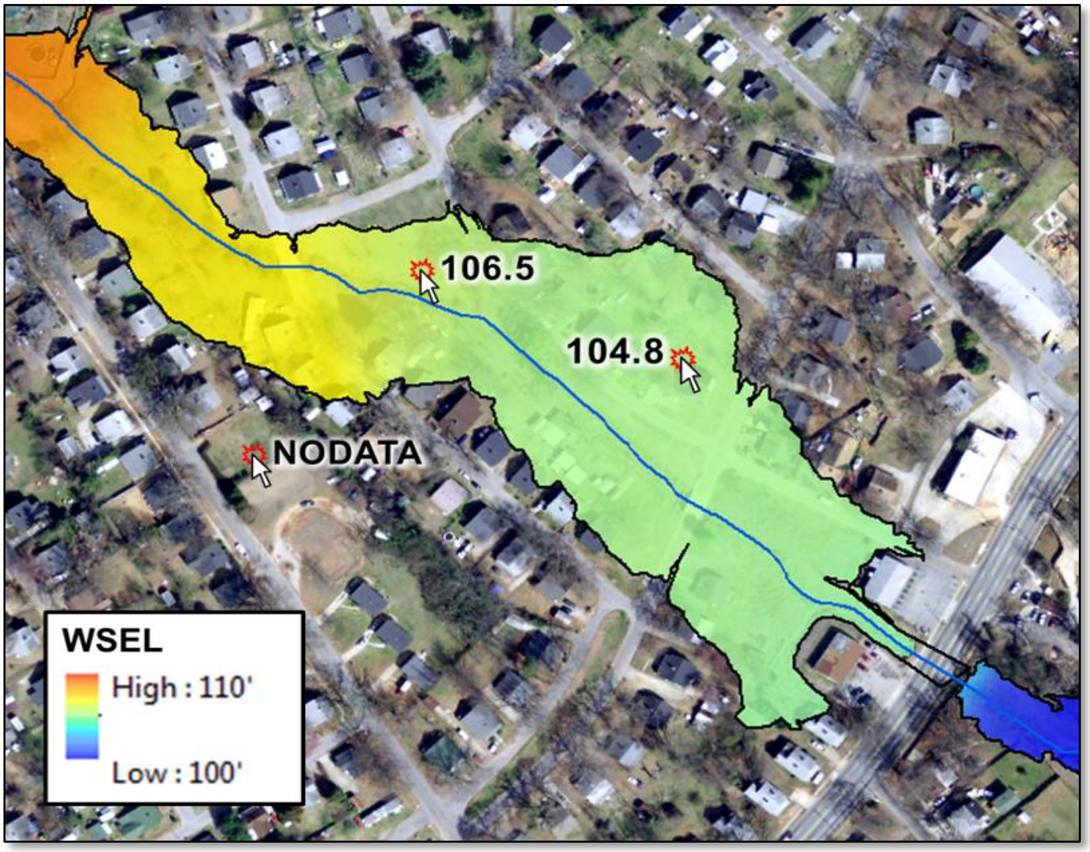
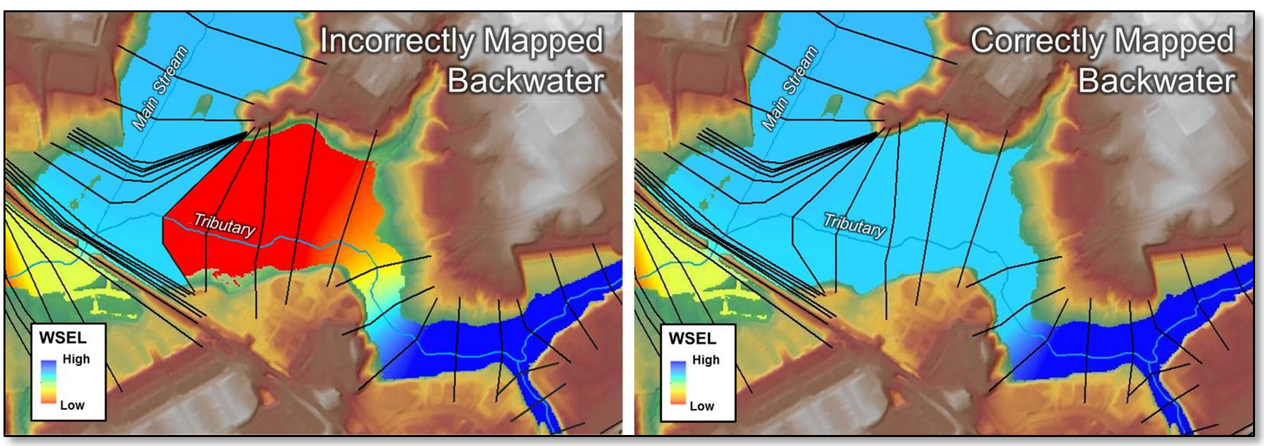


Figure 3: Proper Accounting for Backwater Mapping in the WSEL Grid



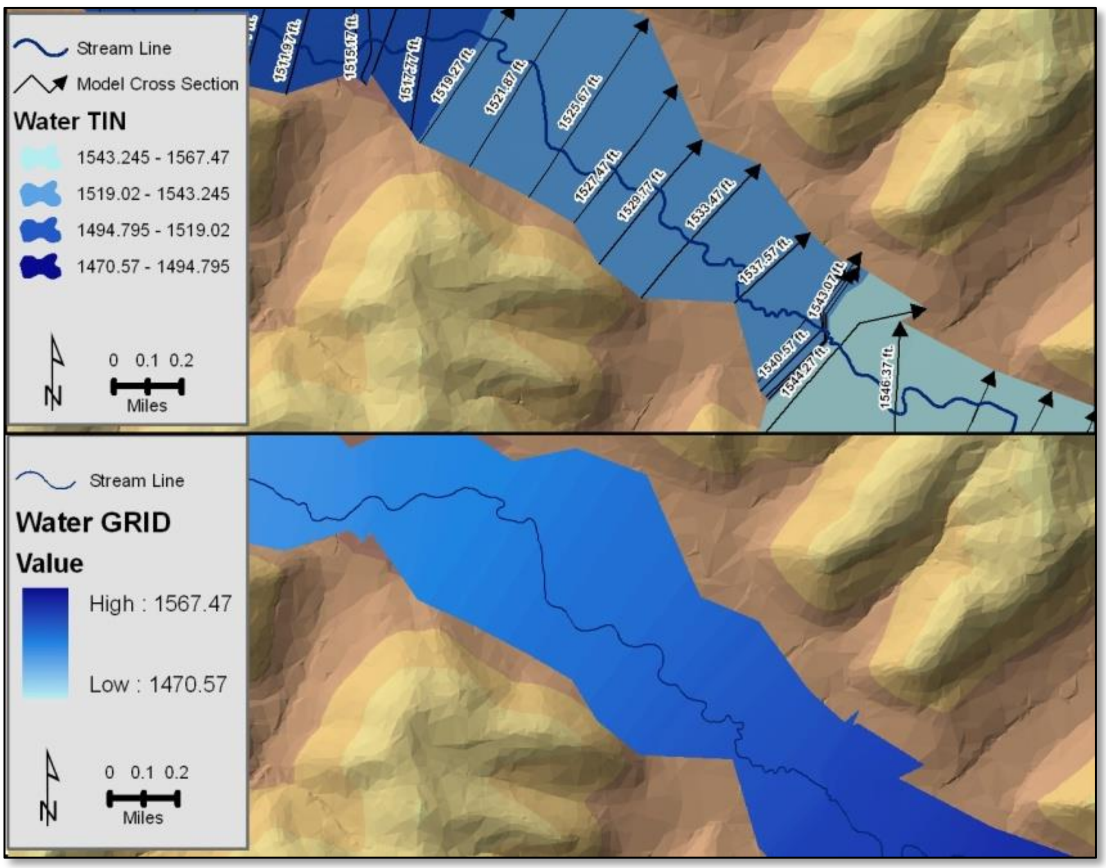
2.1 Riverine WSEL Grids

Water surface elevation grids form the basis from which the depth grids, percent annual chance grids, and many of the other gridded datasets are generated. For new or revised flooding sources, they should reflect the proposed regulatory elevations (i.e. reflect backwater conditions even if the new model does not). Water surface elevation grids created from effective data should reflect the effective regulatory elevations as shown on the FIRM and are expected to match the mapped boundaries as closely as possible. For effective streams where all the effective modeled cross sections may not be available, it may be necessary to add "mapping" cross sections prior to generating the WSEL grids to properly and accurately recreate the effective flood profile.

For 2-D modeling, the WSEL grid is typically one of the standard datasets that is output from the model, and may only require minor cleanup to be suitable. For 1-D models, however, while Mapping Partners may utilize differing hydraulic models, geospatial software and platforms, creation of the WSEL grids typically involve the following common elements:

- Use the water surface elevations from the hydraulic model to create a 3-D water surface. This can be accomplished by generating a Triangulated Irregular Network (TIN) from the vector water surface features and attributes and converting that TIN into GRID format (see Figure 4). In the case of 1-D step backwater analysis, the water surface elevations will be extracted from modeled cross-sections.

Figure 4: GRID Creation From a TIN



- Remove the cells from the grid (assigning a value of "NO DATA") where the water surface elevation is below the ground elevation.

- Make sure backwater is appropriately accounted for.

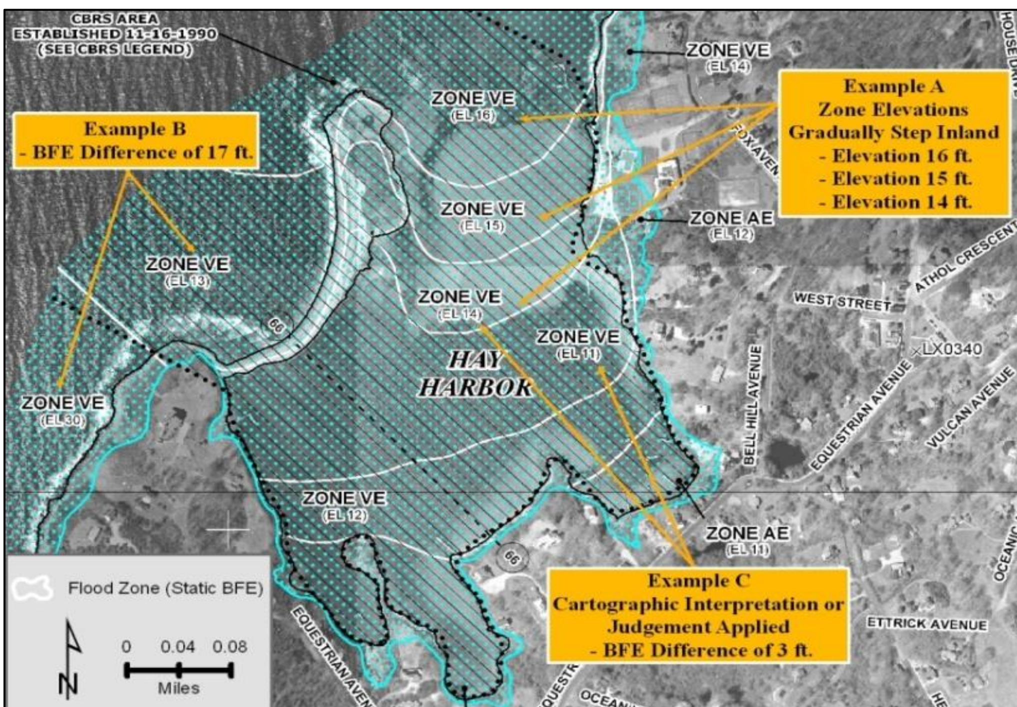
- If creating a WSEL grid for a flood frequency that is included on the FIRM (1% and 0.2% annual chance), “mask” the grid to the floodplain boundary. If islands exist in the WSEL grid that were removed from the regulatory boundaries on the FIRM, Mapping Partners may elect to fill those in so as to preserve agreement between the WSEL grid and the corresponding delineations on the FIRM.

2.2 Coastal WSEL Grids

WSEL grids for coastal flooding sources should reflect the total water level (combination of wave setup, stillwater, and wave height elevations), as opposed to just the stillwater elevation. As such, they are generally only created for the recurrence intervals for which the wave crest elevations have been calculated/estimated, such as the 1% annual chance flood. Coastal WSEL grids are most often created by using the regulatory-mapped coastal floodplain zones and their associated base flood elevations directly. It may not be appropriate to create them in areas controlled by wave runup (see Section 3.1 for more information).

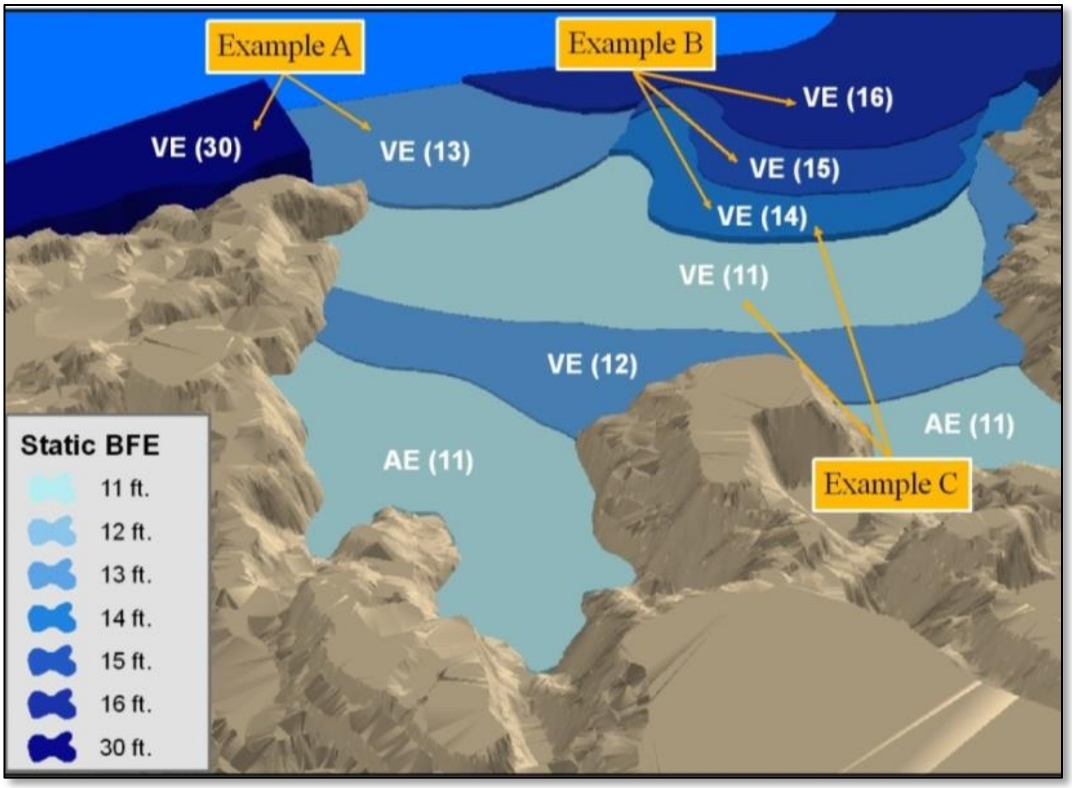
Coastal modeling culminates in static water surface elevations assigned to the mapped coastal floodplain zones. It is important to note that final mapped flood hazard areas often represent engineering judgment and/or intentional generalization of the specific coastal model outputs. Therefore, while users may be tempted to use coastal modeling Geographic Information System (GIS) layers such as coastal transects, use of the final mapped floodplains to generate coastal water surface grids is considered the best guidance to apply, as it is intended to yield results that most closely match the FIRM. Therefore, coastal floodplain mapping with associated static Base Flood Elevations (BFEs) (as shown on Figure 5) will normally be used to generate coastal 1% annual chance WSEL grids. This is accomplished by simply converting the FIRM-based polygons to a grid, and using the static elevations of each as the source from which to assign the water surface grid elevations.

Figure 5: Coastal Floodplain Mapping Examples



While coastal water surface mapping may produce outputs that appear unnatural; (noted in Example A - Figure 5 and Figure 6) the stair-step effect between coastal zones is considered normal and acceptable. The same applies even if the stair-stepping effect is like Example B (where the transition is gradual) or Example C, which may also appear unnatural but is a function of the mapping process where cartographic interpretation and/or engineering judgement has been applied.

Figure 6: Stair-Stepped Coastal Elevations



2.3 Shallow Flooding and Ponding WSEL Grids

Zone AH areas are used to depict shallow flooding areas, and most commonly report a static BFE on the FIRMs. Similarly, ponding areas can also be shown as a Zone AE on the FIRMs with a static BFE. The static BFEs in these cases are stored in the FIRM Database as an attribute of the S_FLD_HAZ_AR feature class.

To create the WSEL grid for areas with static BFEs, the following process generally applies. Variations that produce the same outcome may be followed.

1. The WSEL grid results should support the elevations shown on the FIRM. For the 1% annual chance WSEL grid, the Mapping Partner should convert the associated polygon area on the FIRM to a grid and attribute all the grid cells in that area with the static elevation shown on the FIRM and reflected in the FIRM Database. If the static elevation value in the FIRM Database has been rounded to the nearest whole foot, the WSEL grid should reflect the value rounded to the whole foot. If the value in the FIRM Database is shown to the tenth of a foot, the WSEL grid should similarly report the static elevation to the tenth of a foot.

2. If the 0.2% annual chance area has been calculated and mapped on the FIRM (shaded Zone X), its WSEL grid should also match the extents shown on the FIRM.

3. All WSEL grids (10%, 4%, etc.) in shallow flooding or ponding areas should be rounded using the same precision as the 1% annual chance WSEL grid.

Zone AO is also used to depict shallow flooding areas, but since Zone AO reports flood depths on the FIRM, and not flood elevations, WSEL grids should only be created in areas where the new or effective model from which the Zone AO depths were derived is available. In these cases, the process for creating the WSEL grid as outlined in Section 2.1 should be followed. Otherwise, if the model is not available, the WSEL grid should not be produced. Information is provided in Section 3.3 for producing depth grids in Zone AO areas.

2.4 Dam WSEL Grids

WSEL grids created for dam-related flooding are produced in much the same way as they are for a typical study. The only difference is that the WSEL grid may be based on a specific flood scenario rather than frequency-based results (such as the 1% or 0.2% annual chance floods). Unique combinations of flooding event, dam release type (piping, failure, or overtopping), and the hydrologic condition of the reservoir at the time of the release are used to differentiate the WSEL grids for dams. The L_Dam_Scenario table in the Flood Risk Database provides the naming conventions that can be used for each dam WSEL grid, depending on the type of dam release scenario depicted. For example, rather than produce the typical 1% annual chance WSEL grid, a dam-related WSEL grid could be created to reflect the flood elevations from a sunny day piping failure of the dam where the reservoir was full to capacity.

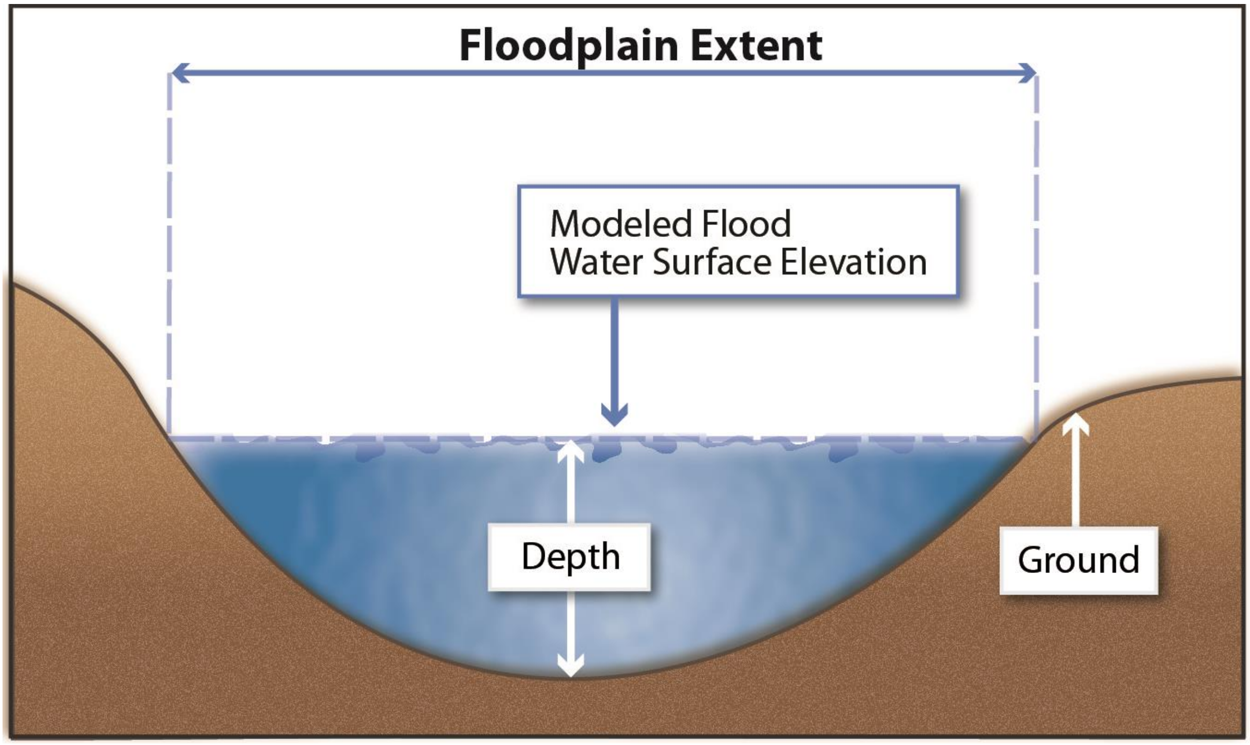
2.5 Levee WSEL Grids

Similar to dams, WSEL grids for levees can be developed to correspond to a percent annual chance of flooding, but also can be based on the flood elevations resulting from a historical flood event, or overtopping scenario, among others. The L_Levee_Scenario table in the Flood Risk Database provides the naming conventions that can be used for each levee WSEL grid, depending on the type of scenario depicted. The process to create levee WSEL grids is the same as for a typical study. The difference is simply in the flood scenario depicted.

3.0 Flood Depth Grids

In its simplest form, a flood depth grid is nothing more than the WSEL grid minus the grid representing the ground elevation. Regardless of the variety of methods that may be used to produce the WSEL grid, the process for creation of the depth grids is the same, with only minor exceptions (see Figure 7).

Figure 7: Depth Grid in Cross Section View



The depth values for each depth grid cell are computed by subtracting the ground elevation value from the water surface elevation value for each return period or flood scenario computed. Ideally, the topographic data used for the development of any depth grid should be the same source as used to generate the effective floodplain boundaries to ensure consistent and accurate results. New or revised studies should use the same source ground data used to generate the new floodplain boundaries.

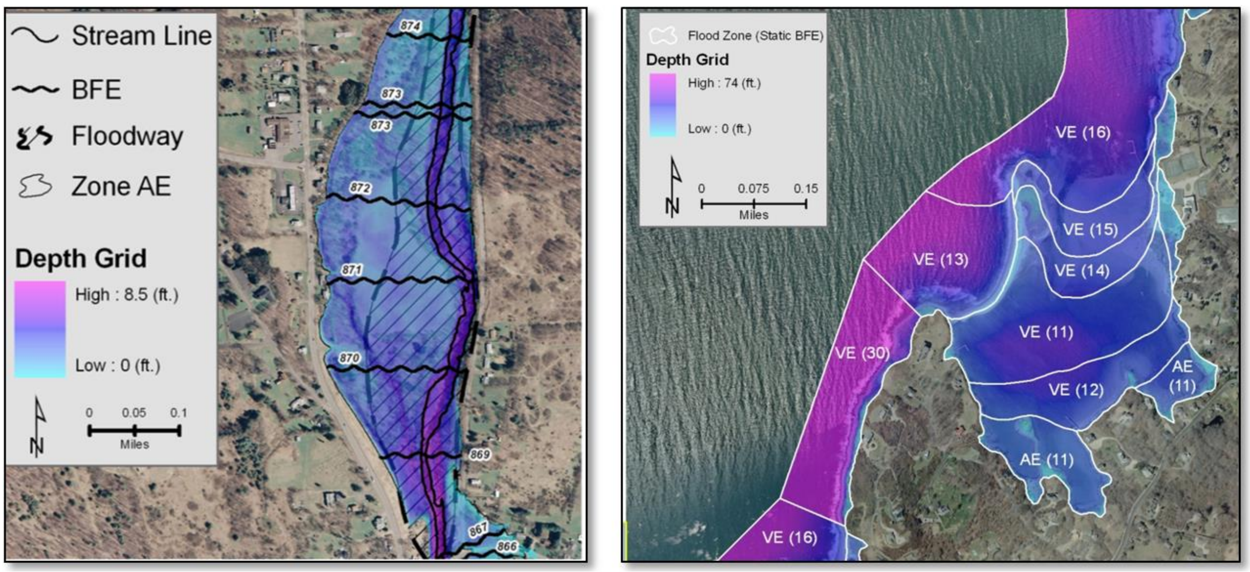
While Mapping Partners may utilize differing engineering models and/or geospatial software or platforms, creation of a depth grid involves the following generic steps that may be performed universally across all GIS platforms:

1. Development of the WSEL grid, per the guidance outlined in Section 2
2. Development of a ground source grid using the same topographic information that was used in the engineering analysis to produce the flood elevations
3. Computation of the depth grid by subtracting the ground elevation grid from the WSEL grid for the return period or scenario selected
4. Removal of any negative values from the resulting depth grid (by either removing the cells or setting them to depths of zero, depending on project preference and/or mapped regulatory floodplain depiction)
5. Rounding of all values to the nearest tenth of a foot

3.1 Depth Grid Considerations for Coastal Areas

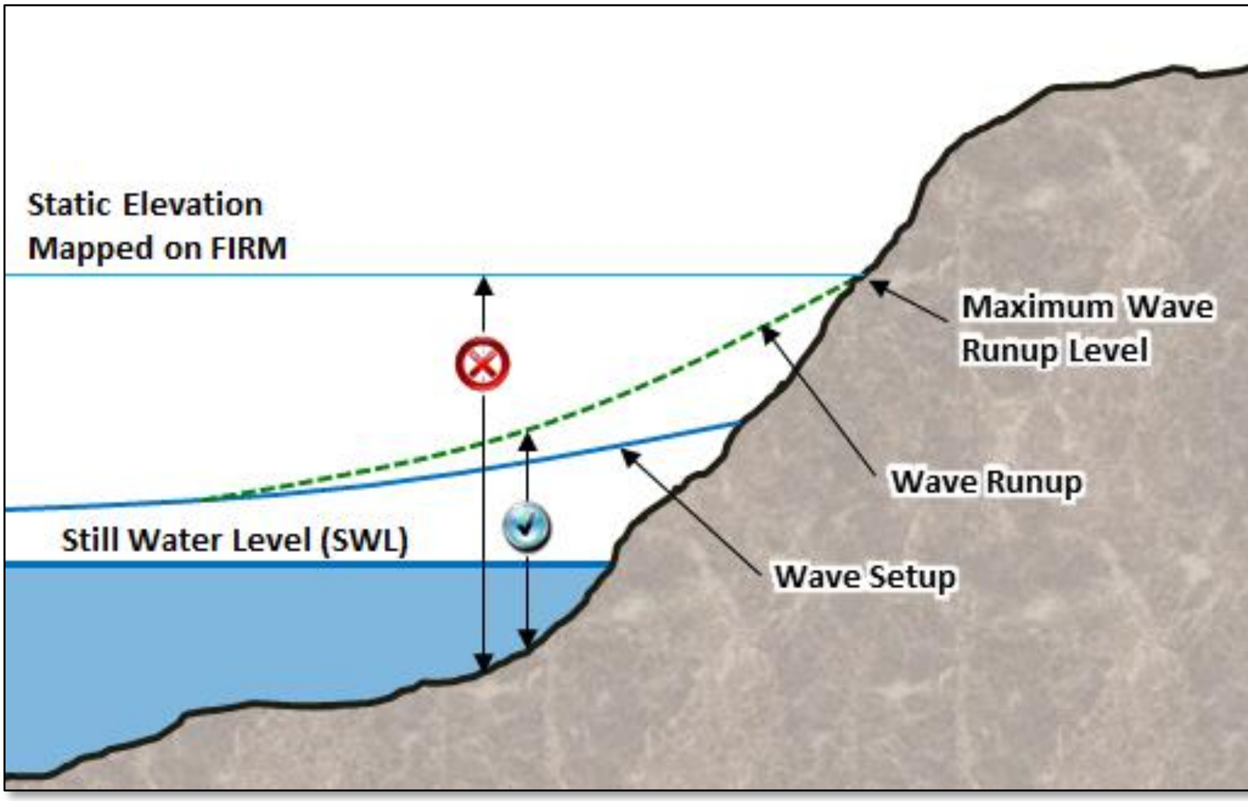
For coastal depth grids, special awareness is needed in areas dominated by wave runup and/or sheet flow (e.g. bluffs, cliffs, or areas protected by coastal structures). Because wave runup-dominated areas are mapped on the FIRMs as static elevations using the maximum wave runup level (as represented by the VE (30) area in Figure 8 and shown in Figure 9), depth grids created by subtracting the ground elevation from the WSEL grid would produce artificially-high depths (red “x” in Figure 9), rather than the more natural depths one would expect (checkmark in Figure 9). The coastal modeling results can help identify where wave runup-dominated areas exist. Prior to the creation of coastal depth grids in areas dominated by wave runup and the publication of that data in the FRD, Mapping Partners should discuss the methodology to ensure that the correct depths are produced in these areas with FEMA, and should receive approval of the methodology. The agreed-upon approach should be explained and included in the project documentation. Otherwise, these areas should be excluded from the final coastal depth grid.

Figure 8: Examples of Riverine and Coastal Depth Grids



For depth grids whose extents cover open water at the coast, it is acceptable to use bathymetric data (if available) to produce the associated depth grid(s). However, in the areas over open water, it is preferred to have the coastal depth grids reflect the depth relative to Mean Sea Level.

Figure 9: Coastal Flood Depth Calculation Methods in Wave Runup-Dominated Areas



Because it is required that Primary Frontal Dunes (PFDs) be included within the mapped coastal high hazard areas on the FIRM, the coastal WSEL grid creation process outlined in Section 2.2 will result in these PFDs being included within the inundated areas of the WSEL grid. Since the creation of the depth grids should leverage existing data and information from the studies, it is expected that the ground surface used in the creation of the depth grids along the coast should reflect existing conditions, rather than the eroded dune calculated as part of the analysis process. Thus, because the ground Digital Elevation Model (DEM) used in the creation of the depth grids does not reflect this erosion, there will likely be locations where the dune elevation reflected in the ground DEM is higher than the elevation reported in the WSEL grid. Similar to riverine areas, rather than reporting negative flood depths, the flood depth grid should reflect depths of zero in these locations.

3.2 Depth Grid Considerations for Inland Open Water Areas

The creation of a seamless depth grid across flooding sources will frequently result in depth grid cells comprised entirely of open water (such as for a lake or pond). For inland open water areas, the ground surface within those cells should not be computed from bathymetric data due to the fact that flood depths are primarily intended to represent an increase in water surface elevation from a non-flooding condition.

To create depth grids in areas of inland open water, a false terrain surface should be created based on the normal pool water surface elevation as opposed to using bathymetric data (see Figure 10 and Figure 11**Error! Reference source not found.**). This process involves two basic steps as follows:

1. Obtain the normal pool elevation for the open water body. If the normal pool elevation is unavailable, the shoreline elevation may be used to determine a "pseudo" normal pool elevation.

2. Calculate the depth values for each depth grid cell by subtracting the normal pool (or "pseudo" normal pool) value from the calculated water surface elevation values. Figure 10 provides a profile view example showing depths that are based on correct (checkmark) and incorrect (red "x") methods for these types of open water bodies.

Figure 10: Profile View of Correctly (Checkmark) and Incorrectly ("X") Calculated Depths in Water Bodies

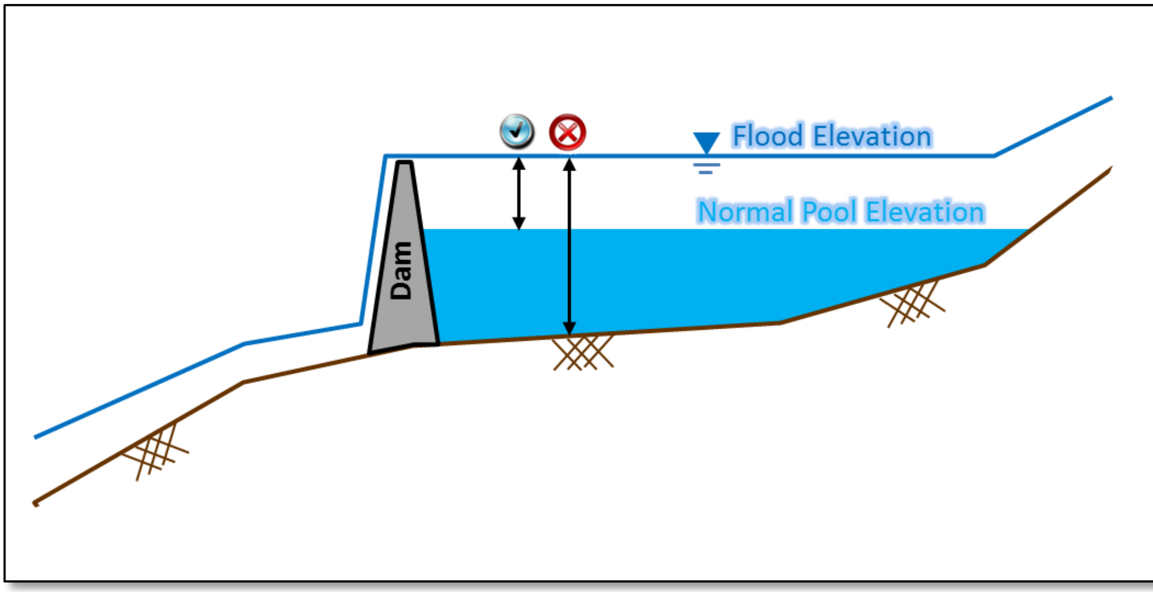
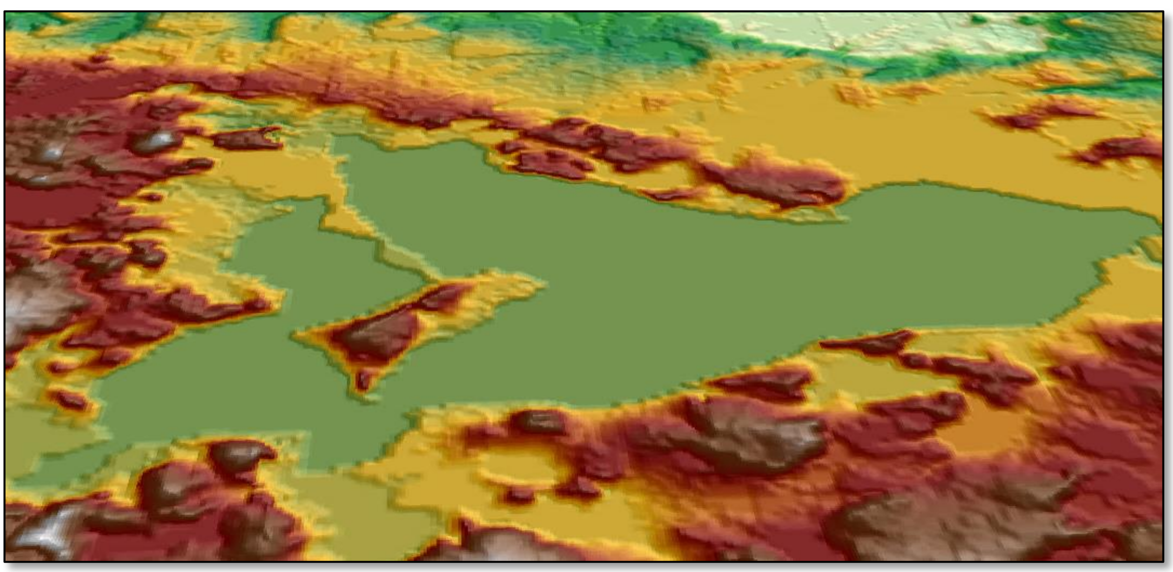


Figure 11: Where Possible, Normal Pool Elevation should be Used to Calculate Flood Depths in Water Bodies



3.3 Depth Grid Considerations for Zone AO Areas

For areas where the new or effective model from which the Zone AO depths were derived is available and the associated WSEL grid has been created, the process for creating the depth grid is the same as described in Section 3. Each depth grid cell can be rounded to the nearest whole-foot value or to the tenth of a foot, provided that the values, when rounded, would equal the whole foot depth reported on the FIRM.

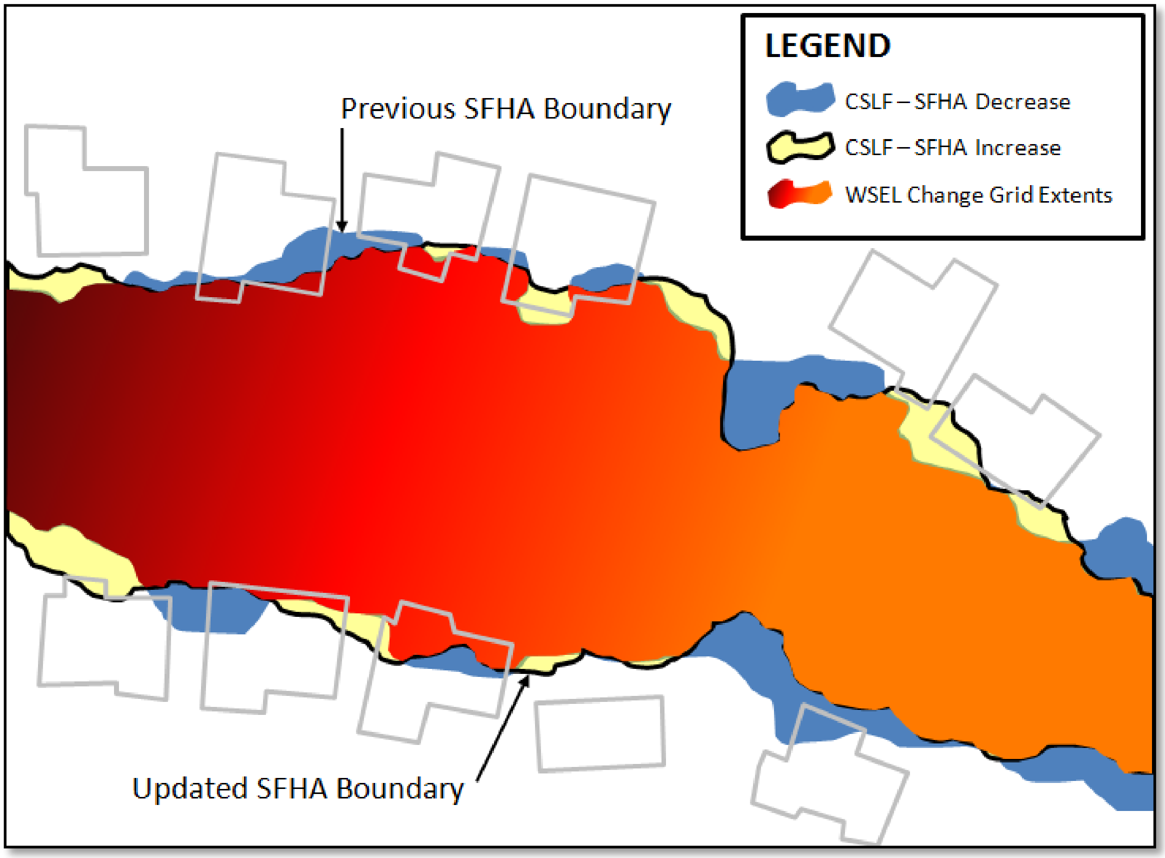
When depth grids are created for areas where the new or effective model is not available, the 1% annual chance depth grid should be created to match what is shown on the effective FIRMs. The process in these cases is to simply convert the Zone AO polygons to a grid, with the grid values based on the Zone AO depths.

4.0 Water Surface Elevation (WSEL) Change Grids

WSEL Change Grids are the vertical equivalent of the horizontal CSLF dataset, whereby areas of increase and decrease to the 1% annual chance water surface elevations from the previous to the new FIRM can be visualized and communicated. It is important to understand that the extent of the WSEL change grid should generally reflect only those areas that were both Special Flood Hazard Area (SFHA) <u>before</u> the revision and <u>after</u> the revision, as illustrated in Figure 12

Figure. Areas that reflect an SFHA increase and those that reflect an SFHA decrease do not need to be included in this dataset. This grid can be used in conjunction with the CSLF dataset to provide a more integrated picture of both the horizontal and vertical changes that have occurred to the floodplains within the project area since the previous study was completed.

Figure 12: Water Surface Elevation Change Grid Extents



The creation of a WSEL Change Grid is the result of subtracting the WSEL grid associated with the effective hydraulic study from the WSEL grid created from the revised study. The following are basic steps for creation of this dataset:

1. Using the WSEL grid derived from the existing hydraulic modeling and the WSEL grid derived from the revised hydraulic modeling, perform a subtraction of the two surfaces using the following formula:

   WSEL Change = *Revised WSEL - Effective WSEL*

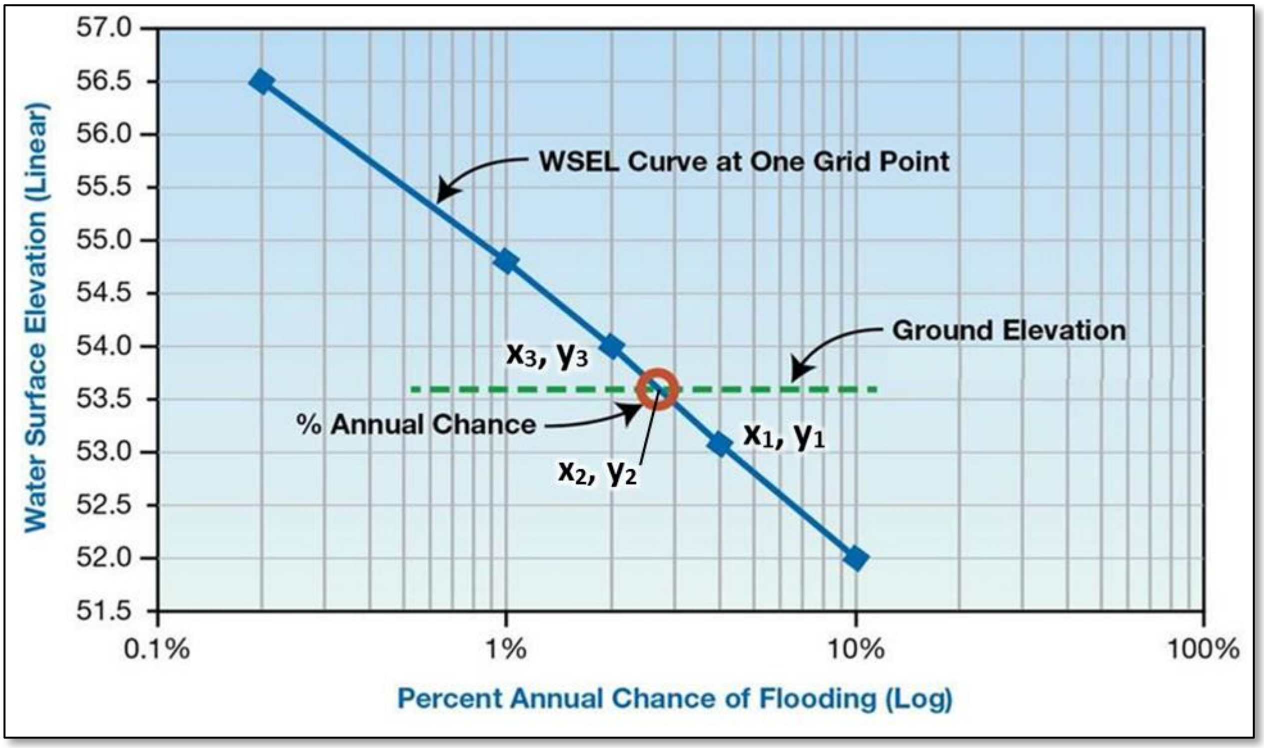
2. To limit the extents of the WSEL change grid to only those areas that were in the SFHA before and remain in the SFHA, other geospatial operations can be applied, such as using a separate polygon data layer as a mask to limit the area of output.

5.0 Percent Annual Chance of Flooding Grid

As an enhancement to the “in or out” format of the FIRM, the Percent Annual Chance grid provides local stakeholders with a better understanding of the relative probability of being flooded for any given location within the mapped floodplain. The grid is computed by using multiple water surface elevation results and their associated percent-annual-chance of exceedance (e.g. 0.2%, 1%, 2%, 4%, and 10%) and interpolating the percent annual chance of flooding at each grid cell based on those inputs coupled with the ground elevation at each specified point.

The percent-annual-chance flood event associated with inundating the ground elevation at each given location should be computed by interpolating the log-linear relationship between the associated flood elevations at each point and the ground elevation (linear interpolation of the Water Surface Elevations, log interpolation of the percent annual chance), as shown in Figure 13.

Figure 131: Log-Linear Relationship for Determining Percent Annual Chance Flood Event



This calculation is performed for each grid cell within the floodplain, using the equation shown in Figure 14.

As part of this analysis, there will be locations where these calculations are performed within the 10% annual chance floodplain. These values would mathematically yield a percent annual chance in excess of 10%. However, rather than extrapolate values beyond the 10% annual chance, estimates should be capped at 10% and considered as locations with at least a 10% annual chance of flooding. If more frequent flood events (such as the 20% or 50% annual chance floods) were analyzed as part of the Flood Risk Project and their results are available, the Percent Annual Chance grid can reflect values up to those higher percentages, but similarly, results should not be extrapolated out beyond those points.

Figure 14: Percent Annual Chance Equation

$$x_2 = 10^{\left[\frac{(y_2 - y_1)(\log(x_3) - \log(x_1))}{(y_3 - y_1)} + \log(x_1)\right]}$$

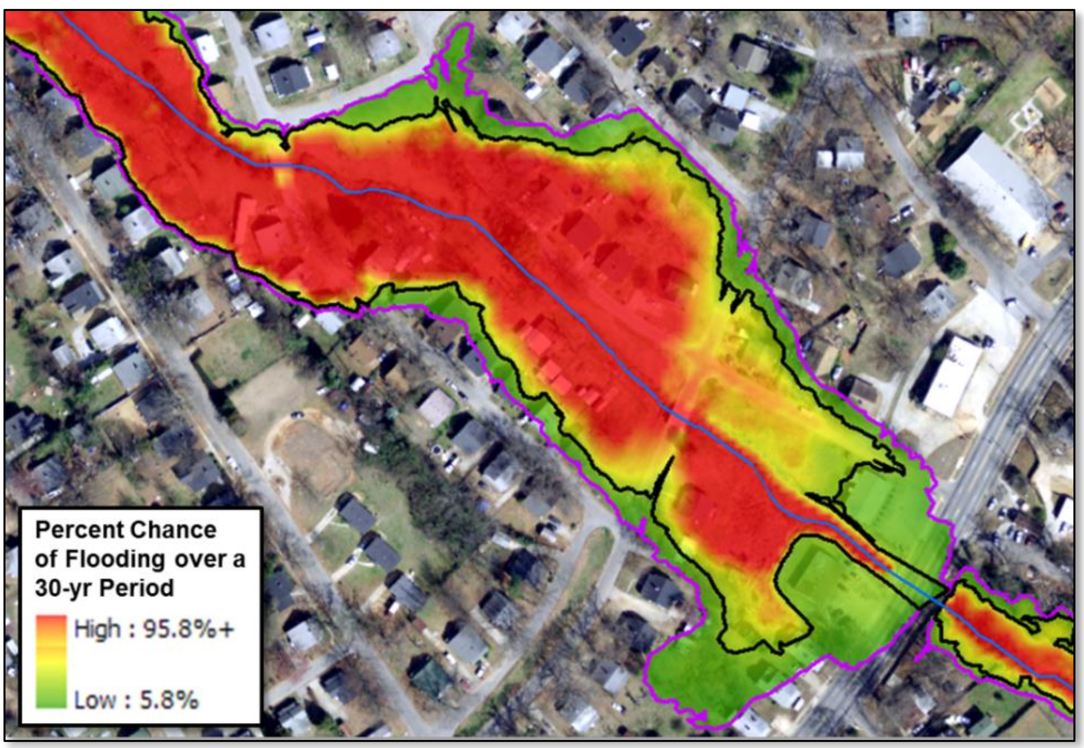
where

- x_1 = Percent annual chance corresponding to y_1 flood elevation
- x_2 = Percent annual chance at test point (red circle in Figure 13)
- x_3 = Percent annual chance corresponding to y_3 flood elevation
- y_1 = next closest modeled WSEL just lower than the Ground elevation
- y_2 = Ground elevation at test point (red circle in Figure 13)
- y_3 = next closest modeled WSEL just higher the Ground elevation

6.0 Percent Chance of Flooding over a 30-yr Period Grid

The Percent Chance of Flooding over a 30-yr Period grid represents the percent chance of flooding at least one time during a 30-year period for a given cell, or location, within the mapped floodplain (see Figure 15). Although a 30-year interval was chosen for this dataset, other time periods may also be selected and the likelihood can be computed for other floodplain management and risk assessment/communication applications.

Figure 15: Example of a Percent Annual Chance of Flooding Over a 30-yr Period Grid



The process for developing the Percent 30-Year Chance Grid is not complex, assuming that the Percent-Annual-Chance Grid has been developed. Once the Mapping Partner has the Percent Annual Chance Grid developed, the process for developing the Percent 30-year Chance Grid uses the following statistical equation:

Probability = $1 - (1-p)^{n}$ where…

- *p* = percent annual chance of flooding (values derived from the Percent Annual Chance raster layer)
- *n* = time period in years (30 years for this dataset)

7.0 Velocity Grids

The Velocity Grid dataset is comprised of a digital representation of flood velocity distribution throughout the floodplain by mapping the velocity output data using engineering models. Any point on the grid describes the average flood velocity for that floodplain location for a given flood frequency. The extents of each velocity grid (10%, 1%, etc.) produced should align with the extents of its corresponding WSEL and depth grid. In addition to the guidance below, additional velocity grid guidance can be found in the FEMA publication entitled *Recommended Procedures for Flood Velocity Data Development*, published in November 2012.

7.1 Riverine Velocity Grids

The following general guidance is provided for the creation of Velocity Grids for studies where digital models are available.

- Floodplain conveyance should be subdivided and included in the model output of each cross section. For a 1-D hydraulic model such as HEC-RAS, this can be done by using the flow distribution option.
- Although there is no standard for the capture of flood velocity distribution data, the scale or number of velocity points or subdivisions to be specified per cross section should be representative of the variation of velocity across the channel and overbank areas.
- It may be necessary to augment user defined cross sections with interpolated cross sections in order to obtain sufficient flood depth velocity data at areas of interest such as known flooding “hot spots,” existing flood prone structures, critical facilities, populated areas, etc.
- For older or un-modernized studies where the flow distribution option may not be readily available, the flood velocity at specific locations along a cross section can be approximated using average flow velocities provided in the Floodway Data Tables of Flood Insurance Study (FIS) Reports in conjunction with generalized patterns of velocity distribution for different channel shapes (see Figure 16).

Figure 16: Riverine Velocity Grid

While Mapping Partners may utilize differing hydraulic models and geospatial software, velocity grids can often be developed directly as an output of the modeling software itself, such as is the case with HEC-GeoRAS. Velocity grids are also an output that can typically be generated from 2-D hydraulic modeling software. Their associated software manuals should be referred to for more details about the creation process.

For flooding sources modeled by 1-D methods, care should be taken when using the velocity grids to communicate specific velocity values in between cross-sections. Velocity distributions and values generated from 1-D models are typically linearly interpolated from cross-section to cross-section, whereas there is likely more variation of flood velocities in reality. The velocity grid can, however, provide a general awareness of areas within the floodplain where flood velocities are likely to be higher than their surrounding areas.

7.2 Coastal Velocity Grids

Velocity grids produced from coastal flooding are intended to provide general information about circulation patterns and magnitudes of open water and onshore flooding. They are not use to delineate regulatory VE zones, and should not be expected to align to VE zone delineations on the FIRMs.

Several methods for calculation of the coastal velocity grids from stillwater depth grids are presented in *FEMA's Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas* (CCM). Note that estimation of design flood velocities in coastal flood hazard areas by this methodology is subject to considerable uncertainty as discussed in the CCM. Given this uncertainty, it is recommended that equation #2 from the CCM be used for the upper bound velocities. Similarly, for areas subject to tsunami hazards, Mapping Partners should apply the extreme form of the equation (equation #3) for approximation of water velocity.

- Equation #2: *Velocity (ft⁄s) = (32.2× stillwater depth) ^ 0.5*
- Equation #3: *Extreme Velocity (ft⁄s)=2[(32.2× stillwater depth) ^ 0.5]*

If 2-D storm surge modeling is being undertaken for the study area, the water velocity will be included in the output and can be used to develop the velocity grid. This effort would require defining scenarios that produce peak water velocities and would best match with the CCM-based upper bound velocities and tsunami velocities.

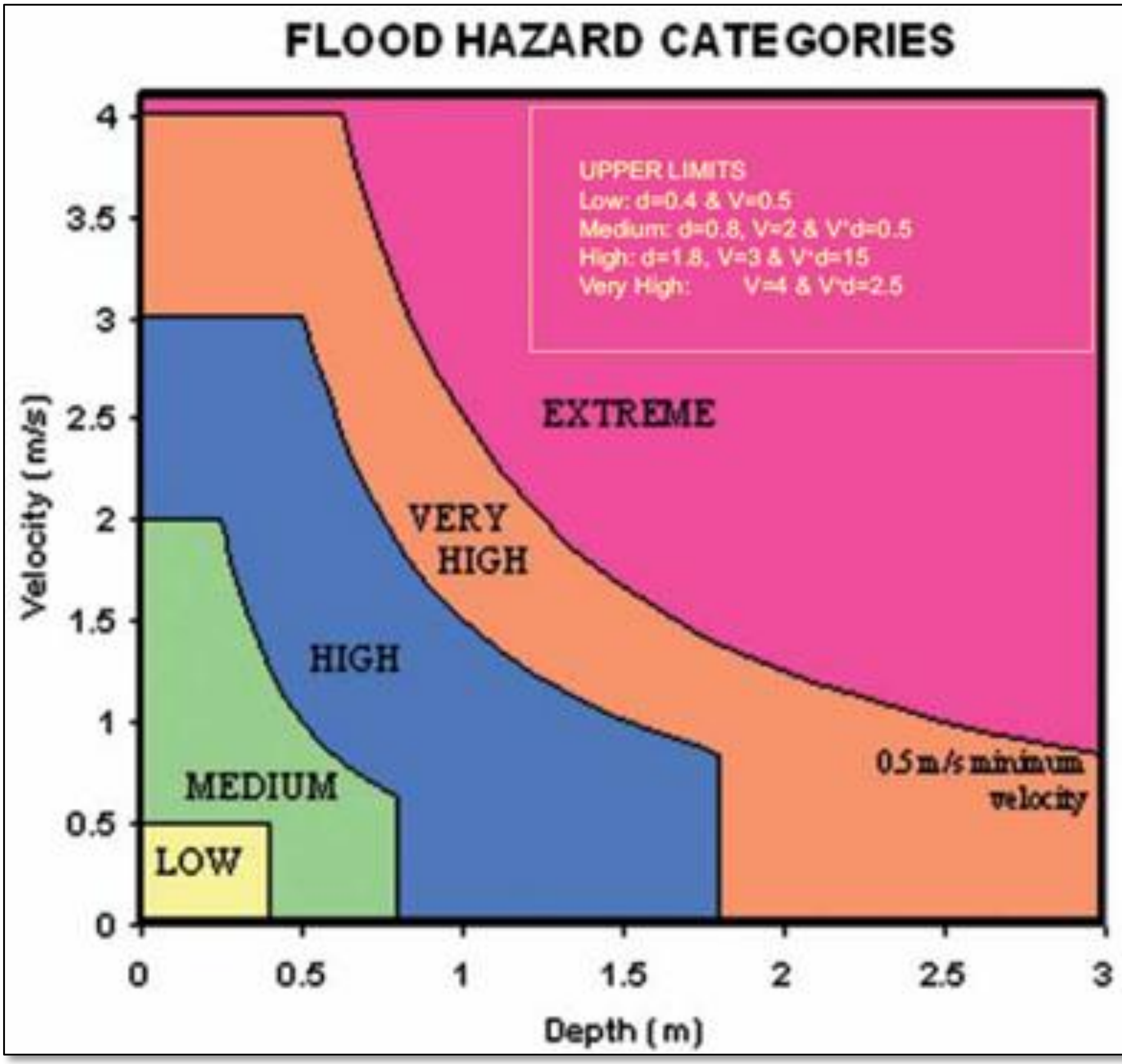
8.0 Flood Severity Grid

The flood severity grid represents the combined effect of depth and velocity, most often communicated in categories of Low, Medium, High, Very High and Extreme Hazard. Studies have been performed in multiple countries to categorize the depth x velocity result into various flood hazard or flood severity classifications. The example graph in Figure 17 is based on studies in Australia and published in the 2006 *Designing Safer Subdivisions - Guidance on Subdivision Design in Flood Prone Areas* (http://www.ses.nsw.gov.au/content/documents/pdf/resources/Subdivision_Guidelines.pdf) manual, which was derived from earlier work from the New South Wales Floodplain Development Manual (2005).

Other flood hazard classifications exist, such as the US Bureau of Reclamation ACER Technical Memorandum No. 11, to communicate the combined effects of flood depth and velocity on structures, mobile homes, varying types of vehicles, and pedestrians. Mapping Partners may utilize an alternate classification method, although documentation and explanation of the calculations, classification breaks, etc., should be provided.

The creation of the flood severity grid is very simple. Once the depth grid and velocity grid for a particular flood event (such as the 1% annual chance event) have been produced, the severity grid is created by multiplying the depth grid times the velocity grid. The dataset can then be symbolized by the different flood severity categories as shown in Figure 18, or by some other user-defined criteria.

Figure 172: Example of Flood Severity Grid Classification



To produce a flood severity grid that exactly matches the categorization shown in Figure 17, additional rules would need to be applied when calculating the depth * velocity product, to take into account the depth and velocity upper limits of each category. Additionally, the flood severity thresholds are different depending on whether they are being considered related to the impact on humans, vehicles, or buildings. As a simplified approach, the following depth * velocity categories can be applied when symbolizing the results of the dataset (see Table 1). However, other categorizations of this data may be used where desired.

Figure 18: Flood Severity Grid Example

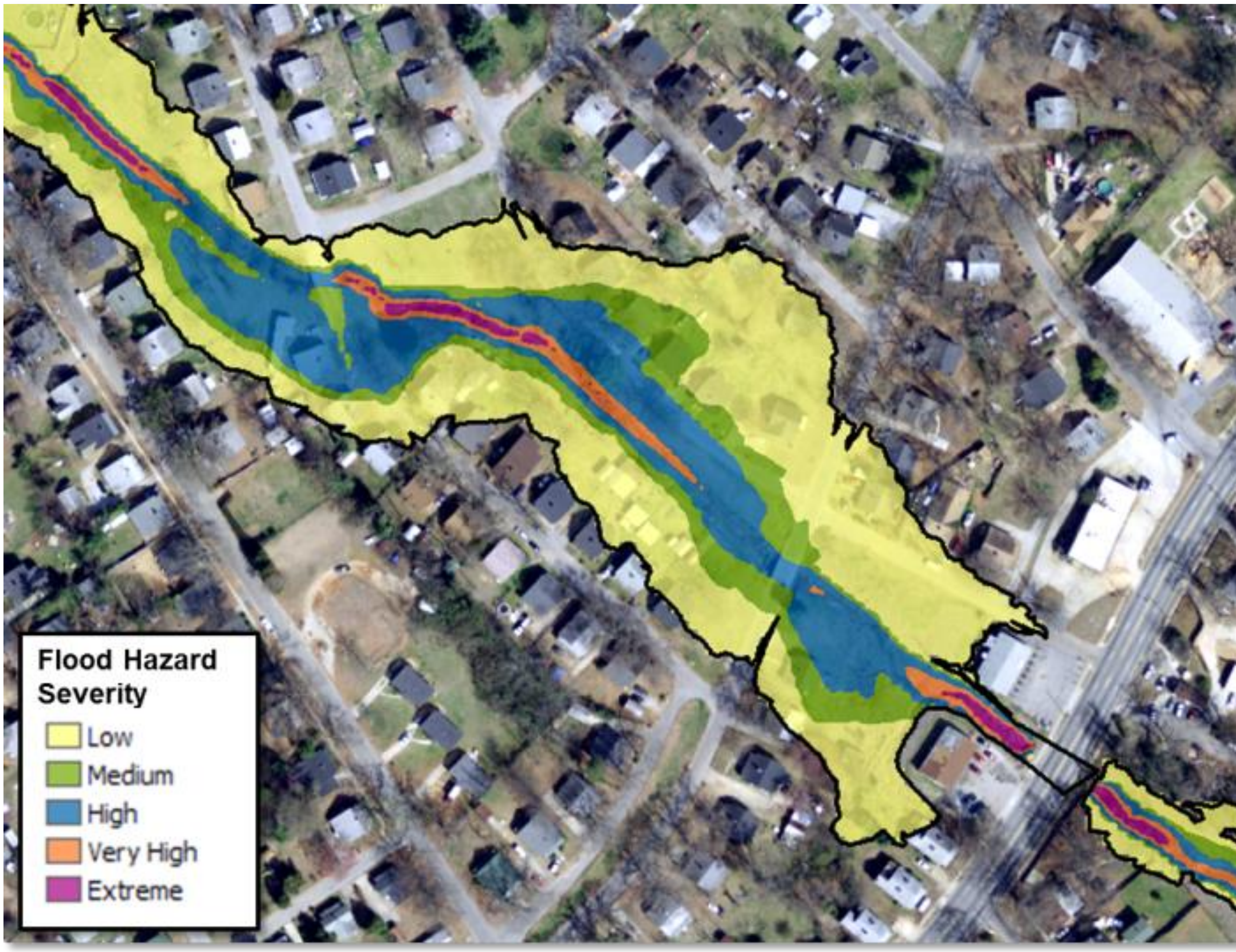


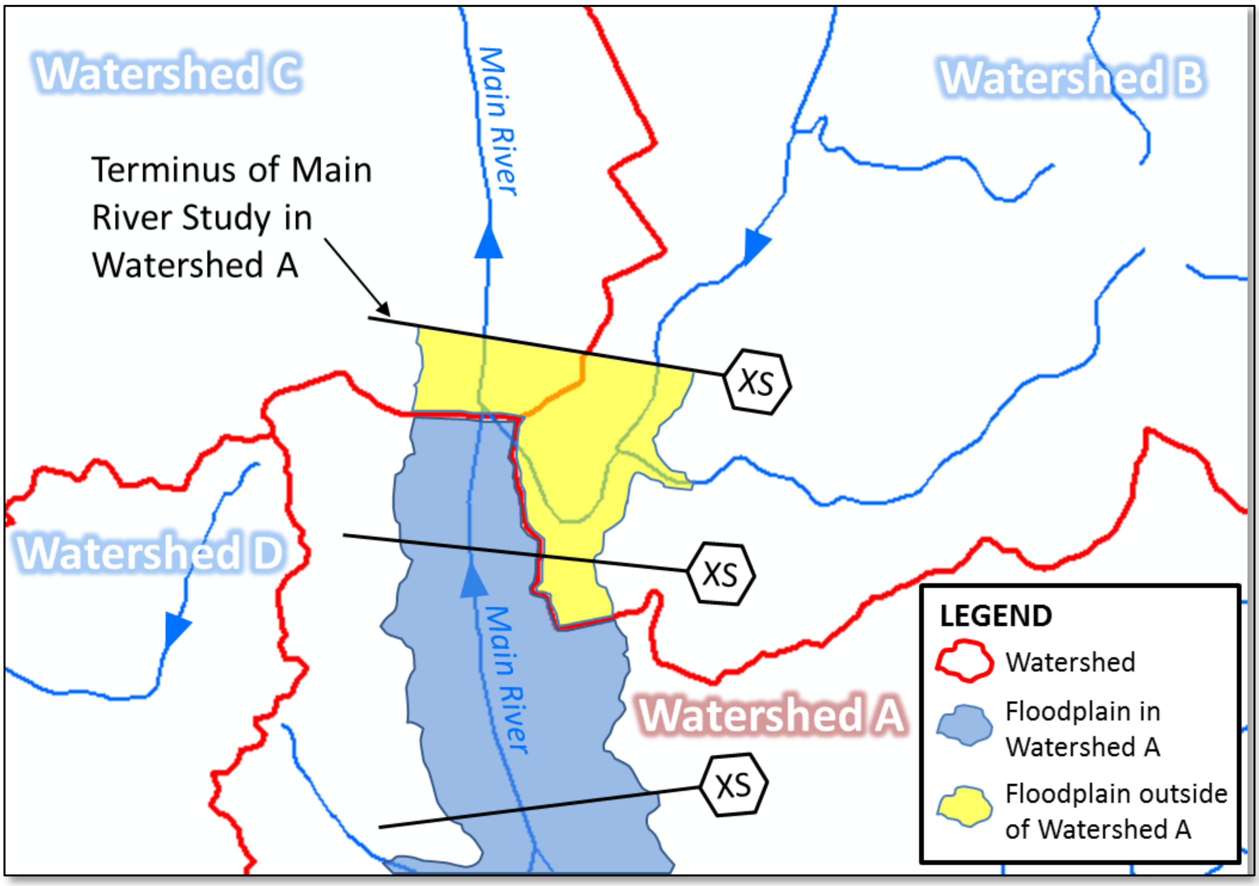
Table 1: Simplified Flood Depth and Velocity Severity Grid Symbolization Categories

Flood Severity Category	Depth * Velocity Range (ft^2/sec)	Depth * Velocity Range (m^2/sec)
Low	< 2.2	< 0.2
Medium	2.2 – 5.4	0.2 – 0.5
High	5.4 – 16.1	0.5 – 1.5
Very High	16.1 – 26.9	1.5 – 2.5
Extreme	> 26.9	> 2.5

9.0 Dataset Spatial Extents

Certain flood risk datasets will naturally extend beyond the limits of the Flood Risk Project footprint. This additional data may be needed to ensure a complete picture of flood risks within the project area. Figure 19 provides an example of a typical scenario that will regularly occur at the outlet of watersheds that are being studied. In these cases, the depth and analysis grids should not be clipped to the project footprint, but should remain in their entirety to cover the area studied.

Figure 193: Flood Risk Data Outside of the Project Area



Raster datasets are rectangular in shape by design. For those cells whose centroid is outside the project area, the value of each cell is set to “NO DATA” (see Figure 20). For those cells whose centroid is inside the project area, the value of each cell is calculated based on the data being represented (e.g., depth, velocity, percent chance, etc.) Similarly, for a project composed of multiple, non-contiguous study areas, the depth and analysis grids should cover the maximum footprint of the multiple study areas (see Figure 21). Each raster dataset should include all studied flooding sources within the project area, as opposed to delivering separate raster datasets by flooding source. For example, there should only be one 1% annual chance depth grid delivered within the FRD for the riverine flooding sources. There should not be multiple 1% annual chance depth grids delivered by individual flooding sources, or as several groups of flooding sources.

Figure 20: Raster Extents

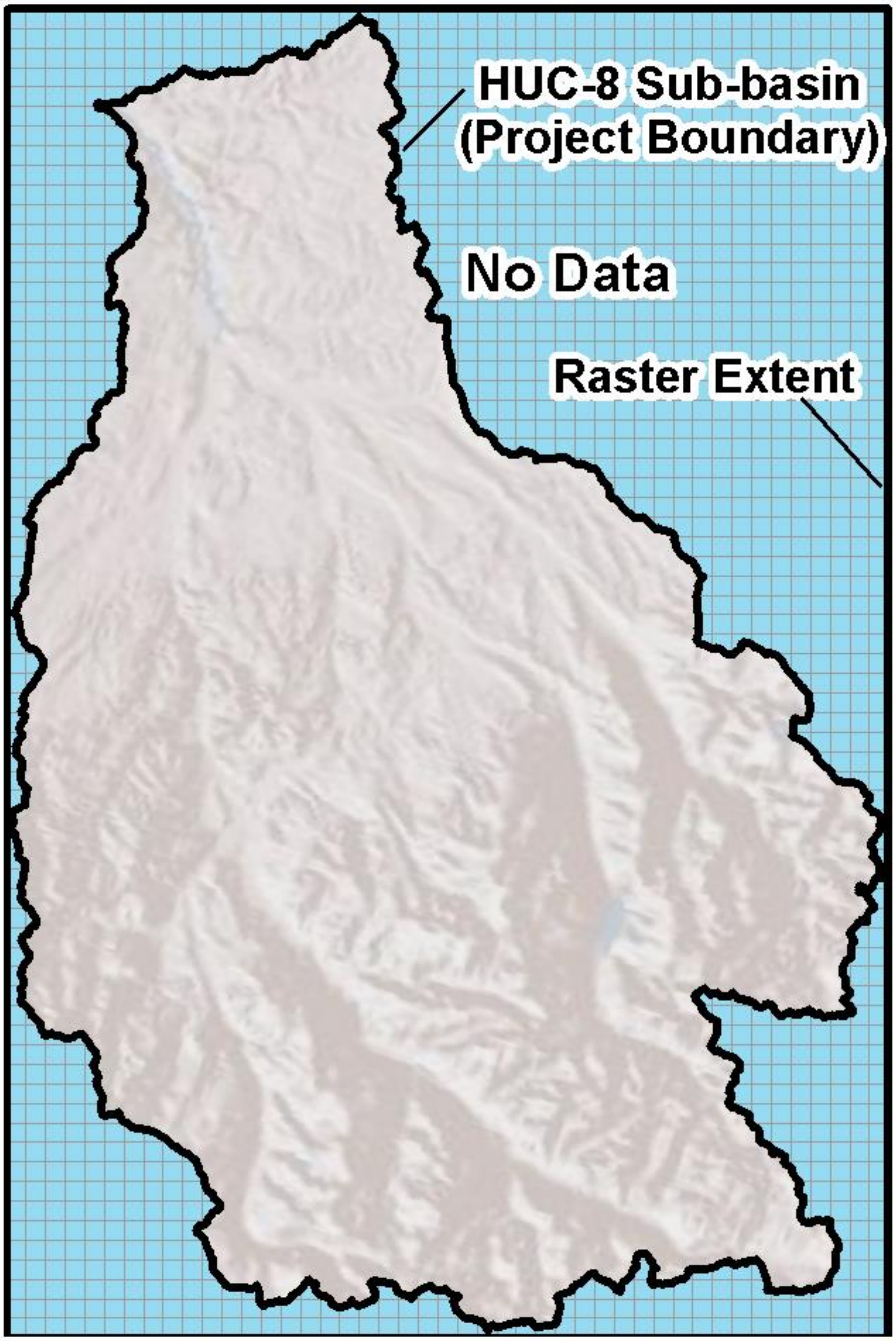
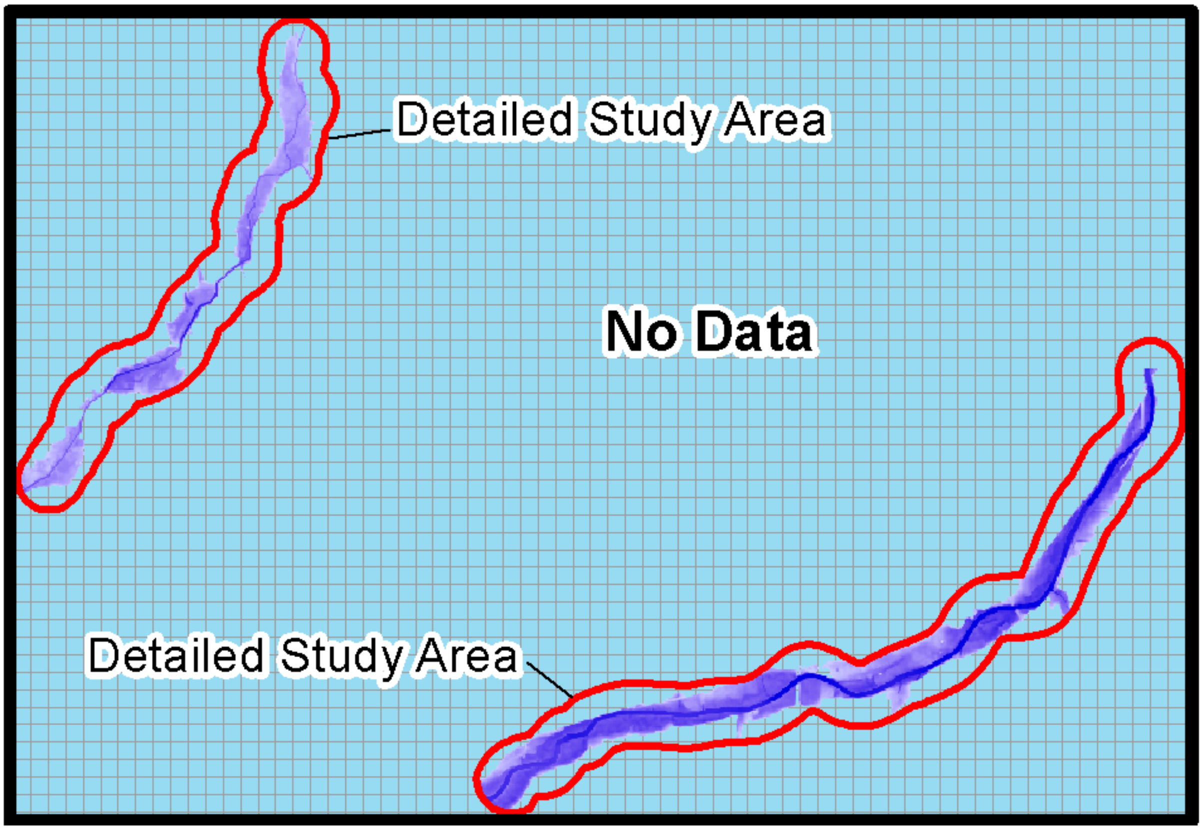


Figure 21: Raster Extents for Multiple Study Areas



10.0 Data Delivery Timeline

The *Flood Risk Database Guidance* provides recommendations as to when the flood depth and analysis grids should generally be provided to communities during the life of a Flood Risk Project, and the conditions under which it should be updated after its initial delivery.

11.0 Uses in Outreach, Collaboration, and Flood Risk Communication

The value of all the flood depth and analysis grids lies in their ability to communicate varying degrees of risk within the mapped floodplains. This allows community officials, emergency responders, and other stakeholders identify specific areas and buildings within the floodplain where flood depths are higher, where flood velocities are more severe, and where flooding may occur more frequently. Used in conjunction with one another, these raster datasets are helpful in communicating flood risk that can be more personalized to individual property owners within the floodplain. In meetings with local officials and stakeholders, it is most effective to use the raster datasets within GIS and look at specific areas where mitigation opportunities may be warranted.

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