Digital Flood Hazard Area Delineation (DFHAD) Guidelines

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Abbreviations and Acronyms

BFE	Base Flood Elevation
CAD	Computer- Aided Design
CD	Compact Disc
cfs	Cubic Feet per Second
DFHAD	Digital Flood Hazard Area Delineation
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation Study
ft	Feet
fps	Feet per Second
GIS	Geographical Information System
HEC-RAS	Hydrologic Engineering Center's River Analysis System
MDP	Master Drainageway Planning Study
OSP	Outfall Systems Plan
PDF	Portable Document Format
QC	Quality Control
SFHA	Special Flood Hazard Area
sq ft	Square Feet
UDFCD	Urban Drainage and Flood Control District

Revision Descriptions

May 2017

The May 2017 revision of the Digital Flood Hazard Area Delineation (DFHAD) Guidelines has been modified to specify GIS deliverable requirements, as well as updated FHAD Submittal Requirements.

January 2015

The January 2015 revision of the Digital Flood Hazard Area Delineation (DFHAD) Guidelines has been modified to clarify deliverables mainly for the drawings, report content and technical documentation.

June 2012

The June 2012 revision of the Digital Flood Hazard Area Delineation (DFHAD) Guidelines has been modified to mainly address clarification of deliverables.

Section 1 emphasizes the inclusion of both Report and Technical Appendix Checklists. Copies of the Checklists and the Agreement Table are provided with the Urban Drainage and Flood Control District (UDFCD) Agreement.

Section 2 clarifies digital file requirements for both the hydrologic and hydraulic analyses.

Section 3 clarifies Flood Map and Flood Profile components, and includes more emphasis on use of the Comment column contained in the Floodplain and Floodway Data Table.

Section4 regarding Submittal Requirements had been extensively revised to address three separate submittal phases for the DFHAD documentation.

Section 5 includes minor clarification to required Quality Control and Error Checking information.

The Appendix now includes the top-width example figures (previously included in the report text).

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1.0 Introduction and Purpose

The Digital Flood Hazard Area Delineation (DFHAD) Guidelines were written to offer guidance and direction for consultants developing FHAD studies in a digital PDF format. The guidelines cover the materials to be included in the DFHAD files, the process by which they are to be developed, and specific details for the final product.

1.1 Referenced Documents

The DFHAD guidelines reference several documents. When used in conjunction with these guidelines, these references offer important information for those developing the DFHAD. The following should be consulted routinely throughout the study:

- **Checklists** - The Digital Flood Hazard Area Delineation (DFHAD) Studies Report Checklist, (DFHAD Report Checklist), and the Technical Appendix Checklist for Flood Hazard Area Delineation Studies (Technical Appendix Checklist) identify the information that is required for submittals. The DFHAD checklists are provided in the Agreement with the Urban Drainage and Flood Control District (UDFCD). The DFHAD Report is discussed further in Section 3.

- **Agreement Table** - The Agreement Table is an error-checking tool to be completed by the consultant prior to any DFHAD submittal. It will also be used during submittal review by UDFCD to ensure that there is good correlation between the hydraulic model, Flood Maps, Flood Profiles, and floodplain and floodway data tables. The Agreement Table is also included in the Agreement with UDFCD. Use of the Agreement Table is discussed in more detail in Section 5.2.

- **UDFCD Specifications for Electronic Submittal of FHAD and Master Plan Documents in PDF Format** – Revised June 2007 (CH2M, 2006), this document was developed as guidance for creating PDFs of the traditional hard copy FHAD and Planning Study reports. These DFHAD Guidelines provide additional criteria specific to DFHAD reports.

1.2 Digital FHAD vs. Traditional FHAD Report

By definition, the DFHAD is a digital format of the FHAD report. Traditionally, the end product of the FHAD report had been a bound 11" x 17" printed document. This meant that all of the content was formatted to fit on 11" x 17" pages and still effectively illustrate the results of the flood study. Consequently, consultants would prepare 11” x 17” plan and profile sheets presenting the Flood Map and Flood Profile. This broke up the floodplain and Flood Profiles into very small sections. This not only was a very time consuming process, but often poorly illustrated the results of the flood study from the big picture.

The DFHAD is essentially the traditional FHAD report, but produced in PDF format. The key difference between traditional printed FHAD reports and the DFHAD is that the final document is not printed and "bound", thus the Flood Maps and Flood Profiles in the DFHAD can be formatted for sheet sizes larger than 11"x17". This allows more freedom in the page size resulting in fewer sheets and a less fractured depiction of the floodplains. In addition, some of the content customarily included on the FHAD plan and profile sheets (i.e. representative cross sections and structure sections) is now included in separate sections of the final PDF document.

1.3 Digital Flood Insurance Rate Map Requirements

DFHAD hydrology is typically based on existing infrastructure and future land use conditions. If there is

a significant difference in the 100-year peak discharges between the existing land use condition hydrology and the future land use conditions hydrology (see UDFCD Agreement), technical information will also be required for a Digital Flood Insurance Rate Map (DFIRM). The difference in hydrology shall be clearly documented in the FHAD report. The supporting documentation for a DFIRM will follow the same Technical Appendix Checklist included with the UDFCD Agreement.

2.0 Digital File Formats

2.1 Hydrology

Hydrology for the DFHAD may be baseline hydrology (future land use conditions) from an approved UDFCD parallel study [Major Drainageway Planning Study (MDP), Outfall Systems Plan (OSP), etc.]. The 500-year hydrology will need to be developed for the DFHAD, since it is not required in either the MDP or OSP. If the baseline hydrologic analysis is performed as part of the DFHAD, it must be completed in accordance with UDFCD MDP or OSP requirements for the 10-year, 25-year, 50-year, 100-year, and 500-year events. All pertinent electronic files and additional calculations used for the hydrologic analysis must be provided as supporting documentation. This includes spatial data (shapefiles, etc.) for the drainage basins, attributed with the required basin information. Files should be consistent with the Technical Appendix Checklist for Flood Hazard Area Delineation Studies as shown in the **Appendix**.

The baseline hydrology must have UDFCD approval prior to submittal of any DFHAD hydraulic analysis.

2.2 Hydraulics

The DFHAD hydraulic analysis is based on existing infrastructure and future land use conditions hydrology.

The hydraulic analysis is based on the standard step-backwater method using the most recent version of HEC-RAS, or another method approved in writing by UDFCD. The HEC-RAS model shall be spatially georeferenced. Special conditions, such as major flow splits, may require modeling additional hydraulic reaches based on sponsor consensus. Other conditions may require additional hydraulic calculations to support data used in the hydraulic model.

All pertinent electronic files and additional calculations used in the hydraulic analysis must be provided as supporting documentation for each formal submittal. For HEC-RAS these will typically include the Project (.prj) file with each Plan clearly identified. All files used to analyze pertinent Plans in the project must also be included. Each submittal will include a list of the Project (.prj) file, and individual Plan files (.p0#) with corresponding Geometry (.g0#) and Flow (.f0#) files (complete with file date) to support the analysis (i.e., regulatory multiple-profile run, floodway run, etc.).

A minimum of two submitted HEC-RAS hydraulic plans are required for the DFHAD. The HEC-RAS must include (at a minimum) a plan for the multiple-profile analysis (10-, 25-, 50-, 100-, and 500-year discharges), and a separate plan for the floodway determination. **A floodway model is required any time there is a designated floodway - even if floodway is equal to floodplain (i.e., confined within a design channel, etc.).**

2.3 Flood Maps

The Flood Map drawing files shall be provided in geographical information system (GIS) format. Computer-aided design (CAD) format may be used to generate flood maps. If the Flood Map data has been created with CAD, the hydraulic data will have to be converted to, and provided as, attributed GIS shapefiles with the final submittal per the Technical Appendix Checklist for Flood Hazard Area Delineation Studies as shown in the **Appendix**.

GIS files must be compatible with ArcGIS 9.3 or later and include the .mxd file with relative references.

2.4 Flood Profiles

Flood Profile files are typically submitted as CAD files. The delivered CAD files must be compatible with AutoCAD 2000 or later and include the .dwg file, and pertinent associated files such as external references, data shortcuts, etc.

2.5 DFHAD Report File

The DFHAD Report is one PDF file containing all elements of the FHAD report including the text, figures, tables, Flood Maps, Flood Profiles, and other supporting material. The PDF file is created from the native software that originally produced the content (i.e. Microsoft Word, AutoCAD, HEC-RAS, etc.). The majority of the report is formatted as 11" x 17" similar to traditional FHAD reports except that the Flood Maps and Flood Profiles are formatted for larger sheet sizes as deemed necessary. See Sections 3.1 Flood Maps and 3.2 Flood Profiles for additional information about formatting Flood Maps and Flood Profiles.

Consultants should refer to the "UDFCD Specifications for Electronic Submittal of FHAD and Master Plan Documents in PDF Format" (CH2M, 2006). The criteria specified in the DFHAD guidelines take precedence for DFHAD electronic documents. It is important to make sure that the final DFHAD PDF document is well bookmarked and every item listed in the Table of Contents is linked to the appropriate page in the PDF document. This makes the DFHAD document easier to navigate and more user-friendly.

3.0 DFHAD REPORT

The DFHAD Report has two basic components. The first part is the textual discussion of the study process that provides the reader with background information and supports the hydrology (typically existing infrastructure and future land use conditions) and hydraulic analysis used in the study. The second part consists of the appendices that will contain the majority of the supporting figures, tables and documents for the DFHAD Report.

The engineering information in the DFHAD Report should be presented in an organized fashion for use in development of master drainage plan updates; road and bridge planning and design; design of channel modifications; and design of flood control structures.

The following is a brief outline of the report:

Section 1	Introduction
Section 2	Study Area Description
Section 3	Hydrologic Analysis
Section 4	Hydraulic Analysis
Section 5	References
Appendix A	Project Correspondence
Appendix B	Hydrologic Analysis Support Documents
Appendix C	Hydraulic Analysis Support Documents
Appendix D	Floodplain and Floodway Data Tables
Appendix E	Flood Maps
Appendix F	Flood Profiles

Detailed descriptions of what is to be provided in each of these components, (in addition to required figures and tables) are addressed in the UDFCD Agreement and Digital Flood Hazard Area Delineation Studies Report Checklist as shown in the **Appendix**.

A Technical Appendix will be required for the Final Report Submittal, and will include all final hydrologic and hydraulic models and supporting calculations used for the DFHAD. Please refer to the Technical Appendix Checklist for Flood Hazard Area Delineation Studies as shown in the **Appendix** for content.

The following sections provide additional direction for specific portions of the DFHAD Report:

3.1 Flood Maps
3.2 Flood Profiles
3.3 Floodplain and Floodway Data Tables
3.4 Additional Information

3.1 Flood Maps

Digital topographic work must use either GIS or AutoCAD formats, unless prior authorization is given by UDFCD in advance of the submittal. For GIS formats, the digital submittal must include the .mxd file with relative references; for AutoCAD formats, the digital submittal must include the .dwg file and pertinent associated files such as external references, data shortcuts, etc. If the Flood Map files have been created with CAD, they will have to be converted to, and provided as, GIS shapefiles attributed by feature with the final submittal.

3.1.1 Map Projection

A major aspect of transportability of mapping or survey files to a geographic information system (GIS) is horizontal and vertical positioning on the earth. Mapping data must be controlled to a grid or geographic projection and referenced to horizontal and vertical datums. These positional references are established prior to the surveying process. Survey control is expressed in the form of horizontal and vertical position plotted on a geographic projection or control grid (State Plane). All planimetric and topographic features must be collected/compiled and referenced to this survey control.

The DFHAD maps shall be delivered in Colorado State Plane Central, with a NAD83 horizontal datum, and NAVD88 vertical datum. The mapping source and projections are to be documented in the DFHAD text and included as a note on the Flood Map.

Either the conversion factor from ground coordinates to State Plane at the District specified elevation, or a table showing XY values for several known points in both grid and ground coordinates shall be included in the submittal. This information is generally available from the organization providing the base data. This will allow the study area to be used with local government base data.

3.1.2 Base Mapping and Topography

Base mapping must show all current features, streets, railroads, airfields, etc. All streets and roads within or near the floodplain shall be shown and labeled. There must be adequate planimetrics to distinguish major hydraulic structures, as well as potential buildings impacted by the flood hazard information.

Table 3-1. Basemap

Data	Deliverable Layer	Layer type
Existing ground contours (Differentiating major and minor contours)[1]	Contours	Polyline
Jurisdictional boundaries (City and County Limits)	Layer	Polygon
Hydrologic features (Streams, Rivers, Canals, Flood Control Structures)	STREAM_CENTERLINE	Polyline
Major Junctions and Confluences[2]	--	--
Streets, Roadways, and other transportation features[2]	--	--
Houses and buildings (Especially any insurable potentially impacted by the 100-year flood)	BUILDING_FOOTPRINTS / S_Gen_Struct	Polygon
Hydraulic Structures (Culverts, Bridges, Dams, Levees, etc.)	STRUCTURES	Polygon
Any other pertinent features located in, or directly adjacent to the flood hazard area[2]	--	--

[1] – Major Contours should be a minimum of 10-ft intervals
[2] – Data to be labeled only, not associated with a spatial data deliverable

3.1.3 Units

Units for all distances and elevations are in feet.

3.1.4 Map Scale and Size

Flood Maps and Flood Profiles must be at the same horizontal scale. The minimum printed- scale of Flood Maps is 1" = 200'. The horizontal scale should be illustrated by a bar scale and text stating the print scale (e.g. 1" = 200'). The orientation of the printed Flood Map should be horizontal. The north arrow on the Flood Map should always point to the left, top, or right of the sheet and never towards the bottom or bottom corners.

Note that Flood Profiles must be oriented with the downstream end on the left side of the sheet regardless of the Flood Map orientation (see Section 3.2 for more information on Flood Profiles).

The Flood Maps and Flood Profile layouts are to be created to minimize the number of sheets. The printed map size is not to exceed 36" x 120", but no smaller than 11" x 17". If multiple sheets are necessary because the maximum map size would be exceeded, clearly indicate match lines between the multiple sheets to indicate breaks and provide a key map on each sheet.

3.1.5 Stream Alignment

Stream alignment (or profile baseline): The stream alignment is the line that determines the Flood Profile. Generally, this follows the channel thalweg or invert. It is important that the length of the channel along the alignment shown on the topographic work map and Flood Profile matches the channel length used in the HEC-RAS hydraulic model. The stream alignment should depict the flood flow path and generally follow the alignment of the channel stream bed. **Any questions on alignment for the stream centerline/stationing need to be resolved with the District prior to beginning the hydraulic analysis.**

If there are two or more possible flow paths along a drainageway, a consensus will need to be reached on which flow path will be considered dominant (and the basis for the main drainageway stream alignment and stationing). Stream alignments and stationing typically need to follow the surface flow path for floodplain mapping. For example, if there is a minor storm sewer under a development but the majority of the flood flow will be on the surface, then the stream alignment and stationing need to follow the surface flow path regardless of the minor storm sewer alignment. Significant overtopping of roadway crossings may also warrant alignment consideration.

When a large percentage of the discharge follows a distinctly separate flow path than the main channel, a split floodplain (with a distinctive alignment, modeling reach, cross section locations, Flood Profiles, etc.) may be required. The split flow floodplain delineation will be determined using the split flow discharge. For the majority of situations, the main channel floodplain delineation will still be determined based on the total discharge (i.e., do not reduce the discharge to account for the spill flow). When determining the floodway delineation, if the total discharge cannot be confined to the main channel within the 0.5-foot floodway criteria, a separate, split floodway will likely be required. **It is imperative to discuss split flow areas with the District before analyzing split flows.**

In a few cases for our area, the low-flow channel may be very sinuous with little flow capacity and the overbanks would convey the majority of the flood flows. With this situation, the channel alignment (or profile baseline) may be different from the channel bed and the modeled length of the flood flow path between cross sections may be different (most likely shorter) than the channel bed length between cross sections. **Before deciding that the sinuosity of the low-flow channel is considered to be so extreme that separate alignments (both a stream alignment and profile baseline alignment) will be required for the more frequent events (10-yr and 50-yr) versus the major flood events (100-yr and 500-yr), the Engineer must get approval from UDFCD and the local sponsors.**

The consequences of using a separate profile baseline for flood flows (i.e., 100-yr and 500-yr events)

have a significant impact to the products required for the DFHAD. In addition to the stream alignment that follows the channel bed on the topographic work map, the corresponding HEC-RAS hydraulic model and resulting water surface profiles for the more frequent events (i.e., the 10-yr and 50-yr events) must be provided. Additionally, the following items must also be included:

- The profile baseline must be shown and clearly labeled on the topographic work map in addition to the stream alignment (and include relative stationing);
- Channel distances between cross sections in the HEC-RAS hydraulic model will match those along the profile baseline for the 100-yr and 500-yr events;
- A separate geometry file for the HEC-RAS hydraulic model will be required to reflect the profile baseline distances for the 100-yr and 500-yr events (versus one geometry file for all storm frequencies);
- A separate plan will need to be included in the HEC-RAS model specifically for the 100-yr and 500-yr events (versus one plan for all storm frequencies);
- A separate water surface profile will need to be provided (for the 100-yr and 500-yr events) that reflects the stationing and relative distances between cross sections along the profile baseline (versus one plan for all storm frequencies).

The consequences of using the stream alignment for all storm frequencies in the DFHAD would be the potential to over-estimate the upstream water surface in some reaches with high sinuosity due to additional friction losses accounted for along the stream alignment. The HEC-RAS model, however, already compensates for the differences in channel and overbank reach lengths by using a discharge-weighted reach length between cross sections based on the discharges conveyed in the main channel and left and right overbank segments for a given reach along the drainageway.

All stationing for a given drainageway will use continuous stream stationing from the confluence with the receiving stream regardless of jurisdictional boundaries and increase going upstream. This means that Station 0+00 for the main drainageway will be at the confluence with the receiving stream regardless of the downstream limit of the study area. All drainageways in the study need to have a unique station numbering sequence. For tributaries to the main drainageway, if stationing starts at 0+00 for the tributary at the confluence with the main drainageway, then there must be clear reach identification associated with the cross section stations provided in all models and tables that will result in a unique identifier for each cross section used in the hydraulic model. To establish stationing in GIS, create a route from the water centerline and hatch along the line to create the stationing labels. This process is explained further in the **Appendix**.

The required attributes for the stream line and stationing layer can be seen below:

Table 3-2. Stream Layer Attributes

STREAM_CENTERLINE Layer (Polyline)

Field Name	Field Type	Field Description
DWAY_NAME	TEXT	Drainageway Name
DWAY_ID	TEXT	UDFCD 4 digit tributary number

Table 3-3. Stream Stationing Layer Attributes

STATIONING Layer (Polyline)

Field Name	Field Type	Field Description
ET_LENGTH	STRING	Length of the line. Stationing text will be created using hatching and can be seen in the Appendix.
LABEL	DOUBLE	Number format of Station (XX+00)

3.1.6 Cross Sections

The locations and orientation of all cross sections used in the hydraulic model are shown on the Flood Maps. The lines drawn should correspond to the actual sections studied and should span the largest floodplain studied (i.e. 500-year floodplain). Locations of cross section lines on the Flood Map along the stream alignment (or profile baseline) must correspond to the cross section location on the Flood Profiles.

Cross sections should be placed along the waterway in a manner that reflects the topography of the channel depicting changes in stream cross section geometry and changes in channel slope (FEMA, 2016b). In general for hydraulic flood models in urban areas, the distance between cross sections should not exceed 500 feet.

Distances between cross sections measured along the stream centerline, as defined in Section 3.1.5, must agree with corresponding distances shown on the water surface profiles to within the maximum tolerance specified on the UDFCD Agreement Table.

The required attributes for the cross section layer can be seen below:

Table 3-4. Cross Section Layer Attributes

S_XS Layer (Polyline)

Field Name	Field Type	Field Description
XSEC_ID	TEXT	Letter/Cross Section ID
DWAY_NAME	TEXT	Drainageway Name
DWAY_ID	TEXT	UDFCD 4 digit tributary number
WSEL	DOUBLE	Water surface at Cross Section

3.1.7 Structures

Structures that are evaluated or impacted by the DFHAD analysis shall be submitted as spatial data. The structure layer includes both hydraulic structures and insurable structures located in flood hazard area. Some examples of structures to include are listed in **Table 3-5**. This list is not exclusive and additional structure may be included depending on the location of the study. The required attributes for the structures layer can be seen below:

Table 3-5. Structure Layer Attributes

STRUCTURES Layer (Polygon)

Field Name	Field Type	Field Description
Building_Footprint	TEXT	Insurable Structure Type (Residential, Commercial)
S_Gen_Struct	TEXT	Structure Type (Bridge, Culvert, Levee, etc.)
DWAY_NAME	TEXT	Drainageway Name

3.1.8 Floodplain and Floodway Boundaries

The 100-year (and 500-year if required in the scope of work) floodplain boundaries shall be delineated to depict the flood elevations from the HEC-RAS analysis. The 100-year flood boundaries should be continuous through bridges with 100-year capacity, but not continuous through culverts that have 100-year capacity. Identify any overtopping with notes on the map.

Floodway boundaries for the 0.5-foot rise floodway (if required by the scope of work) shall be developed to reflect the results of the floodway analysis. There should be no additional encroachment for a floodway along stream reaches where:

- A 100-year channel has been constructed,
- There has already been fill in the floodplain up to a previously published floodway limit,
- A regional detention pond is located on-stream, or
- Floodplain preservation is being implemented.

This is especially the case along Maintenance Eligible stream reaches. In these areas the floodway is equal to the floodplain. Where this occurs, the condition shall be noted in the Floodplain and Floodway Data Table. If the floodway delineation will eliminate a flow split from the channel, thereby increasing the discharge carried by that channel reach, limited or no floodway encroachment may be warranted. **It is advisable to consult with District staff before beginning floodway analyses to verify areas of potential encroachment.**

If a reach is experiencing 100-year shallow flooding additional supporting calculations will be required to document the depth of flow and the shallow flooding area shall be included in the 100-year floodplain delineation. The average depth shall be included in the attribute table and the corresponding delineation must be distinguishable from the 100-year floodplain.

The GIS deliverables for floodplain and floodway hazard areas are listed below:

Table 3-6. Flood Hazard Layer Attributes

FLD_HAZ_AREA Layer (Polygon)

Field Name	Field Type	Field Description
Floodplain_100yr	TEXT	100-year Floodplain
Floodplain_500yr	TEXT	500-year Floodplain
Floodway	TEXT	Floodway
Shallow_Flooding	TEXT	Shallow Flooding

A boundary for each hazard layer shall be provided in the final spatial data deliverable. Each Special Flood Hazard Area (SFHA) shall have a boundary unique to that floodplain designation, with the exception of shallow flooding areas. These areas shall be included in the 100-year Floodplain boundary. Project study limits shall also be included on this layer. The GIS deliverables for the flood hazard boundary is listed below:

Table 3-7. Flood Hazard Layer Attributes

FLD_HAZ_LN Layer (Polyline)

Field Name	Field Type	Field Description
LN_TYPE	TEXT	Type of Boundary (Flood Hazard Area, Limit Lines)

Where there are existing on-site detention ponds adjacent to the channel, the HEC-RAS model top-width ("Top Width" value) reflects the top width of the wetted cross-section including the ineffective flow area within the detention pond. While the ineffective flow area covering the detention ponds is not accounted for in the Floodplain and Floodway Data Table, **the detention pond areas need to be shown as 100-year floodplain** at least up to the 100-yr WSEL in the adjacent cross-section along the channel.

Existing regional detention ponds that have been accounted for in the DFHAD hydrology must be clearly identified. Include the 100-yr WSEL, 100-yr volume, and peak 100-yr discharges (inflow and outflow) on the topographic work maps. Ensure that the topographic work map delineation of the flood pool for existing detention facilities coincides with the SWMM hydrology model results (i.e., ponding depth, surface area and/or volume, etc.). Documentation for all existing regional detention facilities incorporated into the DFHAD hydrology needs to include a sketch/drawing/description of the outlet structure for the existing facility, a corresponding stage versus discharge rating curve for that outlet structure (that is not exceeded in the SWMM model), and a stage versus volume rating curve for the pond (preferably with a grading plan). This information may be included in Appendix B (Hydrologic Analysis Support Documents).

3.1.9 Base Flood Elevations (BFEs)

Base Flood Elevations represent 100-year flood water surface elevations in feet and are shown by contours drawn normal to the direction of flow of floodwater. BFEs must cross perpendicular to the stream alignment, and extend completely across the 100-year floodplain. BFEs should tie into the intersection of the floodplain boundary with the corresponding topographic contour. BFEs should never

cross over a cross section line.

The BFE objects must each be a continuous line/polyline with the minimum number of vertices to correctly represent the feature. BFEs on the Flood Map are to be shown as solid red lines (see **Table 3-9**).

Table 3-8. Base Flood Elevation Layer Attributes

BFE Layer (Polyline)

Field Name	Field Type	Field Description
ELEV	DOUBLE	Rounded, whole foot elevation for 1 percent chance flood

Each BFE must be recorded with its elevation on NAVD88 datum. In GIS, the BFE features are to be attributed with their elevation. In CAD, the BFE lines/polylines are to be assigned their appropriate elevation.

All BFEs must be labeled with an elevation value that is located above, below, or on the end of the line where it meets the 100-year floodplain. If the BFE label cannot be placed within 0.1 inch of the BFE line, a leader line must be used to connect the BFE label to the BFE line.

The following are guidelines recommended by FEMA's *Guidance for Flood Risk Analysis and Mapping – Mapping Base Flood Elevations on Flood Insurance Rate Maps* dated November 2014 for help in determining the spacing of BFEs.

- BFEs shall be placed at inflection points not already captured by cross sections, or as needed in areas of backwater, ponding, complex flow areas, overflow areas off the profile baseline, or other areas needed per engineering judgment.
- BFEs must be shown at appropriate locations to allow map users to accurately interpolate flood elevations both horizontally and vertically.
- Minimize overcrowding of BFEs.

3.1.10 Feature Appearance and Layer Conventions

Flood Map features should be formatted in accordance with **Table 3-9** Flood Map Feature Appearance and Layer Conventions. Line styles (patterns, dashes, etc.) should be applied to the feature objects, and not drawn in. Annotation and leader lines must be on separate layers from geographic data.

3.1.11 Additional Flood Map Components

Flood Maps should include the following information:

- DFHAD study name (consistent with the Flood Profile drawings title; typically, "Flood Hazard Area Delineation, [Name of Drainageway]";
- Date of DFHAD (month and year);
- North arrow and scale (See Section 3.1.4 for more information);

- Legend including symbology for cross sections, floodplain and floodway boundaries, BFEs, stream centerline, hydraulic structure symbols, and contours;
- Information about mapping source including the date, horizontal datum, and vertical datum;
- Consultant's information;
- Match lines and key map if more than one Flood Map is produced;
- The following instructions for printing portions of Flood Map PDF to scale:

    1. Using the "Snapshot" tool, select the desired area to print.
    2. Click File>Print...
    3. Select your printer from the printer dropdown menu.
    4. Set the desired paper size using the printer "Properties" menu.
    5. Choose the "Selected graphic" option under "Print Range".
    6. Select "None" from the "Page Scaling" dropdown menu.
    7. Unselect "Choose paper source by PDF page size".
    8. Click "OK" to print selection.

Table 3-9. Flood Hazard Layer Attributes

FEATURE	FEATURE TYPE	LAYER NAME	APPEARANCE (RGB Values)	
100-Year Floodplain	Polygon	Floodplain_100yr	Blue (0, 230, 255), 70% transparency	
500-Year Floodplain (if specified by contract)	Polygon	Floodplain_500yr	Orange (255, 128, 0), 70% transparency	
Floodways (if specified by contract)	Polygon	Floodway	1 – Line Weight 5 Pt., Red (255, 0, 0), Angle 45; Offset 5, Separation 10, 70% transparency 2 – Line Weight 5 Pt., Blue (0, 230, 255), Angle 45; Offset 0, Separation 10, 70% transparency	
Shallow_Flooding	Polygon	Shallow Flooding	Blue (0, 230, 255), Grey, Angle 45;Offset 0, Separation 6 70% transparency	
Floodplain Boundaries	Line	S_FLD_HAZ_LN	Black, solid line	
Study Limits	Line	S_FLD_HAZ_LN	Black, solid line	
Cross-Sections	Line	S_XS	Black, solid line	
BFE	Line	BFE	Red(255, 0, 0), solid line	
Study Limits	Polygon	STUDY_AREA	Thick Black outline, no Fill Color	
Stream Centerline	Line	STREAM_CENTERLINE	Blue (0, 77, 168), solid line	
Centerline Stationing	Line	STATIONING		
Insurable Structures	Polygon	Building_Footprints	Red outline, 45 degree hatch fill	
Culverts, Bridges, Other Structures	Polygon	S_Gen_Struct	Black outline, 45 degree hatch fill	
Areas Revised by Previous LOMRs, limits should match LOMR Reference	Polygon	S_LOMR	Black, Line Weight 2 Pt., solid line	
BASE MAP ELEMENTS				
Roads	Label	--		
Railroads	Label	--		
Major Contours	Line	Contours	Brown(168, 112, 0), solid line	
Minor Contours	Line	Contours	Brown solid line, less prominent than Major Contours	

Water Bodies (Lakes, Ponds, etc.)	Line/Polygon	--	Thin Gray Outline	

3.2 Flood Profiles

Flood Profiles should be developed for the flood frequencies specified in the scope of work. The profiles depict the flood elevation at each cross section. The digital profiles should be one continuous profile. Flood Profiles should be oriented with increasing stationing from left to right.

3.2.1 Units

Units for all distances and elevations are in feet.

3.2.2 Grid and Scale

The digital profiles shall be plotted on a grid. Note that Flood Profiles must be oriented with the downstream end on the left side of the sheet regardless of the Flood Map orientation. The horizontal scale of the profile should match the horizontal scale of the Flood Maps. The minimum vertical scale is 1"= 10'. Horizontal grid lines should be spaced every 0.5 inch on the printed Flood Profile. Major vertical grid lines should be spaced every 0.5 inch on the printed Flood Profile with minor vertical grid lines representing every 1-foot of vertical elevation. For exceptionally steep drainageways, consult with UDFCD on reducing the vertical scale.

Label the horizontal grid lines with the stations that correspond to the stations along the stream centerline in the Flood Maps at every major horizontal grid line. Label the vertical grid with elevations at 10' intervals. Elevation labels should be repeated at least every 10 inches on the printed Flood Profile.

The Flood Profile layouts are to be created to minimize the number of sheets. The printed map size is not to exceed 36" x 120", but no smaller than 11" x 17". If multiple sheets are necessary because the maximum map size would be exceeded, clearly indicate match lines between the multiple sheets to indicate breaks and provide a key map on each sheet.

3.2.3 Profile Lines

Flood Profiles are to include lines for the thalweg (typically stream bed, or profile baseline) and water surface elevations for the flood frequencies specified in the scope of work. Different line types should be used to differentiate the profiles. Flood Profiles should be checked to ensure that the Flood Profile lines do not intersect or cross each other. Drawdowns are typically eliminated from the Flood Profiles. See **Table 3-10** for specific formatting requirements (FEMA, 2016a).

3.2.4 Cross Sections

Each cross section should be represented by a symbol (consistent with the symbol on the Flood Map) and the cross section number at the station that matches the cross sections location on stream centerline alignment. Cross section symbols should be a consistent distance from the Flood Profile lines to facilitate capturing pertinent data when printing a select area of the profiles.

3.2.5 Structures

Bridges, culverts, and other hydraulic structures should be illustrated on the profile to depict the open area

and length of the structure along the profile. For bridges, the top of road (TOR) and low chord (LC) are to be represented by the conventional symbol (I), where TOR is represented by the upper horizontal bar, LC by the lower bar, and the center of the structure by the vertical bar. For culverts use the overburden culvert symbol typically shown by HEC-RAS.

3.2.6 Feature Appearance and Layer Conventions

Flood Profile features should be formatted in accordance with **Table 3-10**. Line styles (patterns, dashes, etc.) should be applied to the feature objects, and not drawn in. Annotation and leader lines must be on separate layers from geographic data.

3.2.7 Labels

Label the flood elevation lines and the stream alignment line on the profile. Label structures with the street name or other identifier with vertical text near the appropriate station. Label jurisdictional boundaries with vertical text near the appropriate station. Vertical labels are typically placed above the Flood Profile, but may be placed below the stream alignment if space requires it. Label the peak discharges (10-year and 100-year minimum) at appropriate locations along the profile. Also label the study limits.

3.2.8 Additional Flood Profile Components

Flood Profiles should include the following information:

- DFHAD study name (consistent with the Flood Map drawings title; typically, "Flood Hazard Area Delineation, Name of Drainageway");
- Date of DFHAD (month and year);
- Horizontal and vertical scale (See Section 3.2.2, for more information);
- Legend including symbology for Flood Profile lines and cross section symbols;
- Consultant's information;
- Vertical Datum; and
- Also include the same instructions in Section 3.1.11 for printing smaller portions of the Flood Profile PDF to scale.

Table 3-10. Flood Profile Feature Appearance and Layer Conventions (AutoCAD)

Feature	Layer Name	Appearance	Other
100-Year Flood Profile	100-PROFILE	Blue, thick solid line	Label
Other Flood Profiles (if specified by contract)	[YEAR]-PROFILE	Black, broken line different from 100-year	Label
Stream Alignment (Stream Bed)	PROF_BASLN	Black, solid line, ground hatch below line	Label
Cross Section Text	XSTXT	Black	
Cross Section Symbol	XS-HEX	Black, closed polygon	

Structures	STRUCTURES	Bridges: Conventional I-symbol with upper bar TOR, and lower bar LC, and vertical bar center of structure; Culverts: overburden culvert symbol typical in HEC-RAS	
Grid Lines	GRID	Thin black or gray line	
Text (Stationing, elevations, hydraulic structures; pertinent peak discharges)	TXT-PROFILE	Black	
Limit of Study	STUDYLIMIT	Thick black solid line	

3.3 Floodplain and Floodway Data Tables

The UDFCD Floodplain and Floodway Data Tables list information at each cross section for the floodplains and floodways studied. Floodway data is required even when the design flows are confined within a well-defined channel. Floodway data values reported in the table will be taken from the floodway hydraulic model. A notation in the Comments column of the Floodplain and Floodway Data Table should be added whenever the floodway is equal to the floodplain. **Table 3-11** Error! Reference source not found.lists the required and optional information that should be included in the table. An example is shown in the Appendix. Please limit values within the Floodplain and Floodway Data Table to reasonable significant digits (i.e., discharges to nearest cubic foot per second, elevations to nearest 0.01 foot, distances and top widths to nearest foot, areas to nearest square foot, and velocities to the nearest 0.1 foot per second).

Table 3-11. Floodplain and Floodway Data Table Contents

ITEM	LOCATION	CONTENT
Title	Top Center	Table #, FHAD Study Name, Floodplain and Floodway Data Table
Reach	Row Heading	River/Reach
Reference Location	Column 1	Location or other identifier like streets, structures, or other physical features
River Station	Column 2	Station along stream alignment
Cross Section	Column 3	Cross section number/identification from hydraulic model
Profile Baseline Elevation (ft.)	Column 4	Profile Baseline Elevation
Peak Flow (cfs) 10-, 50-, 100- & 500-Year (specified by contract)	Columns 5-8	Peak Flow data from hydraulic model for 10-, 50-, 100-, & 500 year storm events
Water Surface Elevation (ft.) 10-, 50-, 100- & 500- Year (specified by contract)	Columns 9-12	Flood water surface elevation from hydraulic model for storm frequencies specified by contract

100-Year Floodplain Width (ft.) Energy Grade Line	Columns 13-14	Total floodplain width including high ground and ineffective flow area, and the energy grade line for the 100-year storm event
100-Year Floodway (0.5 ft. rise in EGL) Floodway Elev (ft.) Width (ft.) Area (sq. ft.) Velocity (ft./s)	Columns 15-18	100 year 0.5 feet floodway water surface elevation, total width of flood including high ground and ineffective flow area, flow area of the entire cross section including ineffective flow area (Area), and the average velocity of flow in the total cross section (Vel Total)
Comments	Last Column	Use to note specific details or how the values may differ from hydraulic model and reason for the difference (See Table 4 below)
Footnotes	Below table	Additional notes or a way to note specific details for particular cross sections

Examples of some typical notations that might appear in the Comments column are provided in **Table 3-12**.

Table 3-12 – Example Comments for the Floodplain and Floodway Data Table and Agreement Table

Floodway equal to floodplain.
Floodplain and floodway top width includes high ground or obstruction, and ineffective flow area.
Floodway top width includes high ground or obstruction.
Floodplain top width includes ineffective flow area.
Floodway top width includes ineffective flow area.
Adjacent on-site detention pond.
Island located within 100-yr floodplain not shown because it falls within the floodway.
Roadway overtopping of 'Street Name', top width adjusted for Flood Map delineations.
Floodplain delineation includes ineffective flow area not reflected in the hydraulic model.

3.3.1 Additional Data Descriptions and Information

Profile Baseline (ft) - Defined as the minimum channel elevation. In HEC-RAS 4.1, "MinCh El" is the minimum channel elevation.

Peak Flow (cfs) - Defined as the peak flood flow (future conditions) for the given storm event. In HEC-RAS 4.1, "Q Total" is the total flow in the cross section.

Water Surface Elevation (ft) - Defined as the flood water surface elevation for the given storm event. In HEC-RAS 4.1, "W.S. Elev" is the calculated water surface from the energy equation.

100-Year Floodplain Width (ft.) - Defined as the total width of the floodplain as shown on the Flood Maps, regardless of islands (whether mapped or not) and other obstructions. When this value is different from results in the hydraulic model, note it in the Comments column and state why. In HEC-RAS 4.1,

"Top Width" is the top width of the wetted cross section, but does not include islands or obstructions. "Top Width Act" is the top width of the wetted cross section, not including ineffective flow. In most cases, for DFHAD studies, the floodplain and floodway boundaries need to reflect the total top width value for both the floodplain and floodway that includes ineffective flow areas and high ground. Other HEC-RAS top width variables (such as "Top Width Act" or "Top Width" can be the same value as the total top width if no high ground or ineffective flow areas are present.

When the cross section indicates islands or obstructions in the floodplain, the top widths reported in HEC-RAS will not produce the proper total top width to list in the Floodplain and Floodway Data Table. The total top width from left to right floodplain lines can be calculated by using HEC-RAS's "Sta W.S. Lft" and "Sta W.S. Rgt" fields which list the left and right station where water intersects the ground. Tables can be defined in HEC-RAS that include a column that will calculate the difference between them. Define the table with "Sta W.S. Rgt", "Sta W.S. Lft", and "Diff' and the total top width will be displayed in the "Diff' column. Since the floodplain and floodway values in the UDFCD DFHAD typically reflect the total width of the floodplain/floodway regardless of ineffective flow, islands, and other obstructions, a note should be added to the Comments column of the table to indicate what is included (i.e., standard Flood Insurance Study (FIS) Floodway Data Tables have historically included only the "Top Width Act" values). These notations will be helpful in explaining discrepancies when the DFHAD data is incorporated into future FIS updates. See the Top Width examples in the Appendix.

For areas where existing on-site detention ponds are located adjacent to the main channel, the floodplain top width shown in the Floodplain and Floodway Data Table adjacent to the detention ponds needs to reflect the top width for actual conveyance without the ineffective flow area (this would typically be the "Top Width Act" value) for these areas.

Note that for DFHAD studies, islands are not typically mapped (shown as high ground) in the floodway. Also note that islands within a floodplain or floodway must be treated on a case-by- case basis and the Engineer should consult with UDFCD when islands occur within the floodplain or floodway limits for further guidance.

Floodway Elev (ft) - Defined as the floodway water surface elevation with encroachments that cause the energy grade line to rise up to 0.5-foot.

Floodway Width (ft) - Defined as the total floodway width (regardless of islands and other obstructions, or ineffective flow area) with encroachments that cause the energy grade line to rise up to 0.5-foot. Refer to the definition of 100-Year Floodplain Width for additional information on reporting widths. When the cross section indicates high ground or other obstructions, follow the process in the "100-Year Floodplain Width (ft.)" section described above to obtain the total floodway width.

Floodway Area (sq ft) - Defined as the flow area of the entire cross section including ineffective flow. In HEC-RAS 4.0, this is the "Area" variable. When different from results in the hydraulic model, note it in the Comments column and state why. For cross sections with adjacent detention ponds this value may end up being the "Area Channel" or "Flow Area" value.

Floodway Velocity (fps) - Defined as the average velocity of the flow in the total cross section. In HEC-RAS 4.0, this is the "Vel Total" variable. For cross sections with adjacent detention ponds this value may end up being the "Vel Chnl" value.

3.3.2 Discrepancies between Table Values and HEC-RAS Model

The values published in the Floodplain and Floodway Data Table must match the Flood Maps (within acceptable tolerances), but there may be situations where floodplain/floodway does not match the

geometry of the HEC-RAS output. For instance, a rapid change in geometry, such as the downstream side of an overtopped roadway, may result in the floodplain delineation differing from the HEC-RAS output. Or a floodplain delineation line around a small island may be omitted to simplify the floodplain limits. In these situations, it is imperative that the discrepancy be well documented. Record the reason for the discrepancy in the Comments column and further describe it in the text of the DFHAD Report.

Table 3-12 lists several examples of standard comments used to describe or explain discrepancies between the hydraulic model, water surface profile, and topographic work map values that can be used in the Floodplain and Floodway Data Table and Agreement Tables (Section 5.2). In addition, other comments may be more appropriate to describe the situation occurring at a given cross section.

3.3.3 Final HEC-RAS Floodway Model - Method 1

It is important that the floodway encroachments, floodway elevations, and floodway widths agree between the Flood Map, Flood Profile, and the HEC-RAS hydraulic model. The final HEC- RAS model submitted to the District must be saved as a Method 1 floodway, where the exact location of the encroachment stations is specified for each individual cross section.

3.4 Additional Information

3.4.1 Drainage Structures Cross-Sections

Cross sections of each of the drainage structures (culverts and bridges) shall be included in FHAD Report in Appendix C (Hydraulic Analysis Supporting Documents). This information should include the structure's location, station, dimensions, material, and elevations of the invert, low chord, and overtopping weir (road low point elevation).

3.4.2 Cross Sections

For the FHAD Report Appendix C (Hydraulic Analysis Supporting Documents) cross sections from the HEC-RAS model illustrating the 100-year storm event water surface elevations shall be included. Create a PDF file from HEC-RAS formatted for multiple cross sections per 11" x 17" page at a scale that can be easily read. Cross sections shall be in color and include the 100-year water surface elevation, reach name, and river station. It is recommended that each page contain 9-12 cross sections and that the pages are numbered.

4.0 Submittal Requirements

All formal submittals will require evidence of Quality Control (QC) and Error Checking (see Section 5.0**Error! Reference source not found.**), or will be returned without detailed review of the submittal. These rejected submittals may be re-submitted once quality control has been performed by the consultant. All submittals need to include a comment response letter addressing items of concern raised in previous review comments (when applicable).

Five separate submittal phases are required:

1. Model Review;
2. 100-year Floodplain Delineation;
3. Floodway Model, 500-year Floodplain Delineation;
4. Full Draft Submittal; and
5. Final Submittal.

Requirements for each separate submittal phase are listed in the FHAD Submittal Form in the **Appendix**. The FHAD Submittal Form highlights the items that will be reviewed with each submittal. Each submittal is intended to build on the superseding submittal. As necessary, the required items for each review shall be provided in digital format including the spatial GIS data, PDFs and referenced .mxd file. If necessary, a CD containing the electronic files may be submitted to UDFCD. Please coordinate with the UDFCD Project Manager prior to submittal. A brief discussion regarding the review process is described in subsequent sections.

4.1 Model Review

The Model Review is provided only to the UDFCD, and is used for technical review of the floodplain analysis methods, specifically the hydraulic model. **Approval of the HEC-RAS Floodplain model (excluding floodway) must be received prior to the 100-year Floodplain Delineation submittal.**

The following items shall be provided with the Model Review:

- Technical memorandum documenting hydraulic analysis, assumptions made, and discussion of any decisions made by the Engineer;
- A PDF workmap that adheres to the these guidelines (Section 3.1) documenting the required items in the Model Review step on the FHAD Submittal Form in the **Appendix;** and
- Electronic submittal of all items documented on the FHAD Submittal Form in the **Appendix**.

Once UDFCD has completed the Model Review it may be necessary to conduct an in-person meeting to review the comments that require discussion.

4.2 100-Year Floodplain Delineation

The 100-year Floodplain Delineation submittal is provided only to the UDFCD and shall include all approved items from the previous submittal, Model Review. **Approval of the 100-year floodplain, BFE placement and corresponding Agreement Table shall be received prior to the development of the**

floodway model.

The following items shall be provided with the 100-year Floodplain Delineation:

- Response letter from the Model Review submittal;
- All revised items from the previous submittal;
- A PDF workmap that adheres to Section 3.1 documenting the required items in the 100-year Floodplain Delineation step on the FHAD Submittal Form in the **Appendix;** and
- Electronic submittal of all items documented on the FHAD Submittal Form in the **Appendix**.

4.3 Floodway Model, 500-year Floodplain Delineation

The Floodway Model, 500-year Floodplain Delineation submittal is provided to all Sponsors electronically and shall include all approved items from the previous submittals outlined in Section 4.1 and 4.2. **Approval of the Floodway Model, 500-year Floodplain, Floodway Delineation and corresponding Agreement Table shall be received prior to the development of subsequent submittals.**

The following items shall be provided with the Floodway Model, 500-year Floodplain Delineation:

- Response letter from the 100-year Floodplain Delineation submittal;
- All revised items from the previous submittal;
- A PDF workmap that adheres to Section 3.1 documenting the required items in the Floodway Model, 500-year Floodplain Delineation step on the FHAD Submittal Form in the **Appendix;** and
- Electronic submittal of all items documented on the FHAD Submittal Form in the **Appendix**.

Once UDFCD has completed the Floodway Model Review it may be necessary to conduct an in-person meeting to review the comments that require discussion.

4.4 Full Review

Once the hydraulic models and mapping have been approved the full DFHAD submittal (Full Review) shall be provided to UDFCD and the Sponsors. The following items shall be submitted electronically per the FHAD Submittal Form in the **Appendix**:

- Response letter from the Floodway Model, 500-year Floodplain Delineation;
- All revised items from previous submittals;
- Flood Profiles as described in Section 3.2;
- Agreement Table and Floodplain and Floodway Data Table per Sections 3.3 and 5.2;
- A PDF Flood Map that adheres to Section 3.1 and the associated .mxd file; and
- The FHAD Report as described in Section 3.0.

4.5 Final Review

The Final Review submittal will take place once all items from the previous submittals have been adequately addressed. The submittal will include final electronic versions of all products previously requested for the Full Review Submittal, and be accompanied by both completed DFHAD Report and Technical Appendix Checklists.

4.5.1 Technical Appendix

All supporting technical documentation shall be compiled in a Technical Appendix. A completed Technical Appendix Checklist must accompany this submittal.

5.0 Quality Control and Error Checking

5.1 Checklists

The DFHAD Report Checklist identifies the information that is required for DFHAD reports. A copy of the DFHAD Report Checklist should accompany the Full Review and Final Review Submittals to ensure all pertinent materials have been included in the DFHAD report.

The completed Technical Appendix Checklist shall be included with the Full and Final Submittal. The FHAD Submittal Form shall be included with all submittals to document what needs to be submitted and what has been approved.

5.2 Agreement Table

The Agreement Tables serve as an error checking device to ensure that data and results for the Flood Maps, Flood Profiles, Floodplain and Floodway Data Tables, and HEC-RAS models agree. If discrepancies exist, the reasons for any valid discrepancies can be noted in the Comments column. **Table 5-1** lists the required and optional information that should be included in the table. Each submission for technical review is to be accompanied by completed Agreement Tables. The Agreement Table will not be included in the Report, but will be included in the Technical Appendix to accompany the final hydraulic model files.

The Agreement Table lists every cross section and compares the distances between cross sections, the cumulative distance, floodplain and floodway top widths, water surface elevations, and an indication of whether the BFE lines have been located correctly relative to the adjacent cross sections and water surface profile (this is typically an 'ok' or 'yes' once verified by the Consultant). The allowable differences between the map, profile, and table are listed at the bottom of the Agreement Table.

Table 5-1 – Agreement Table Contents

Column	Contents
1	Reference Location - A location or other identifier like streets, structures, or other physical features
2	Cross Section - The cross section number/identifier used in the hydraulic model (that can sometime differ from the actual river station). If the cross section identification is consistent with the actual river station along the stream alignment then this could also be used to reference previous FHAD cross section identifications or FIS cross sections. Start at the downstream cross section and work upstream
3	River Station - Actual station along the stream alignment that corresponds to the current cross section
4 - 6	Distance between RS, ft. - Relative distance from current cross section to the next downstream cross section in feet.
7 - 9	Cumulative Distance, ft. - Relative distance from current cross section to the next downstream cross section in feet.

10 - 11	FP Width, ft. - The total floodplain top width at the current cross section including high ground and/or ineffective flow areas in feet; however when an on-site detention pond exists adjacent to the main channel, this value will only reflect the top width for actual conveyance without the ineffective flow area (this would typically be the Top Width Act value in HEC-RAS)
12 - 13	FW Width, ft. - The total floodway top width at the current cross section in feet. This can include high ground and ineffective flow areas.
14 - 15	BFE, ft. - The 100-year water surface elevation for the current cross-section in feet.
16	BFE Loc - This is a verification that the BFE line plotted on the topographic work map is located correctly based on the corresponding water surface profile near the cross-section
17	Comments and/or Explanations - A description and/or reasoning for any discrepancies between values from the model/map/profile that occur at the current cross section (see Table 4 Example Comments for the Floodplain and Floodway Data Table, Section 3.3)

The data and results in the Floodplain and Floodway Data Table, Flood Maps, Flood Profiles, and HEC-RAS model must agree within the tolerances specified at the bottom of the Agreement Table. **Note that the allowable tolerance for Floodplain and Floodway Widths is within either 25 feet or 5% of the map scale for a 1:500 ft Flood Insurance Rate Map.**

5.3 Quality Assurance

There are a number of items to check for prior to making a submittal to UDFCD. Several of these items have been listed in **Table 5-2**. Please ensure that quality assurance has been performed prior to submitting products for review.

Table 5-1 - DFHAD Quality Assurance Items

Floodplain delineation is based on subcritical hydraulic analysis results.
Cross section orientation is left to right facing downstream.
Make sure that relative top widths make sense (i.e., the floodway top widths are not greater than the floodplain top width at a given location).
Consistent significant digits for the values in the Floodplain and Floodway Data Tables and Agreement Tables.
Note differences in floodplain or floodway top widths between the hydraulic model results and the topographic work map delineations in the Floodplain/Floodway Data Table (FP/FWDT).
Existing online detention ponds that were accounted for in the hydrologic analysis are to remain un-encroached to the flood pool elevations.
Make sure the cross section orientations are perpendicular to the flow, stream centerline (or baseline

profile), and contours.
Clearly identify both the upstream and downstream study limits on the topographic work map.
Verify for a given cross section that the WSEL is the same on both sides of the plotted floodplain, and that it has been tied-off to the correct contour data based on the topographic work map.
Make sure that the BFE lines: 1. Are oriented perpendicular to the stream centerline, flow and contours; 2. Cross the stream centerline at the same location as shown on the water surface profiles; 3. Are approximately placed with regard to the BFEs for the adjacent cross sections; 4. Tie-off to the correct contour; 5. Extend across the floodplain width, and do not stop short or extend past the floodplain limits; 6. Do not cross/extend across cross sections; and 7. Are pertinent and are shown adequately to replicate slope changes along the water surface profile.
Make sure that an existing regional detention pond has been accounted for in the hydraulic model to produce consistent results for all storm frequencies modeled (i.e., actual geometry for outlet structure, rating curve, boundary condition, known WSEL, etc.). Verify that the existing detention pond is reflected in the resulting water surface profile from the hydraulic model results.
Verify whether over-topping occurs at roadways or railroad crossings along the drainageway, and make sure the water surface profile and topographic work map clearly indicate if over-topping occurs.
Make sure that floodplain delineations downstream of over-topped crossings are representative of the hydraulic conditions (especially since the hydraulic model will not reflect the impacts of over-topping at downstream cross sections).
Make sure that the energy grade lines and/or WSELs between any two split flow segments are within 0.5 foot at the upstream end (breakout point).
Even though the 500-yr floodplain is not the official regulatory floodplain, the delineations for this floodplain need to be mapped to a reasonable accuracy (i.e., the 500-yr delineation on the topographic work map needs to reflect the hydraulic model results).
Verify that the cross section identifications and locations used in the hydraulic model are consistent with those shown on the topographic work map and water surface profile.
Eliminate crossing water surface profiles between the multiple frequencies used along a given drainageway (or provide a logical explanation of what was attempted and why this was not possible, or how it was resolved).
No future detention facilities are to be shown on the topographic work maps for the DFHAD. These proposed facilities are to be shown in the relative master planning documents for the drainageway.
All data and hydraulic models provided shall be spatially referenced.

6.0 References

CH2M HILL (CH2M). 2006. *Specification for Electronic Submittal of FHAD and Master Plan Documents in PDF Format*. (2nd ed.). August.

Federal Emergency Management Agency (FEMA). 2016a. *Guidance for Flood Risk Analysis and Mapping, Hydraulics: Flood Profiles.* November. Available at https://www.fema.gov/media-library-data/1485269649213-8f3f5dd54ab7c3ded7d5bcecaff61eab/Flood_Profiles_Guidance_Nov_2016.pdf

Federal Emergency Management Agency (FEMA). 2016b. *Guidance for Flood Risk Analysis and Mapping, Hydraulics: One-Dimensional Analysis.* November. Available at https://www.fema.gov/media-library-data/1484864685338-42d21ccf2d87c2aac95ea1d7ab6798eb/Hydraulics_OneDimensionalAnalyses_Nov_2016.pdf

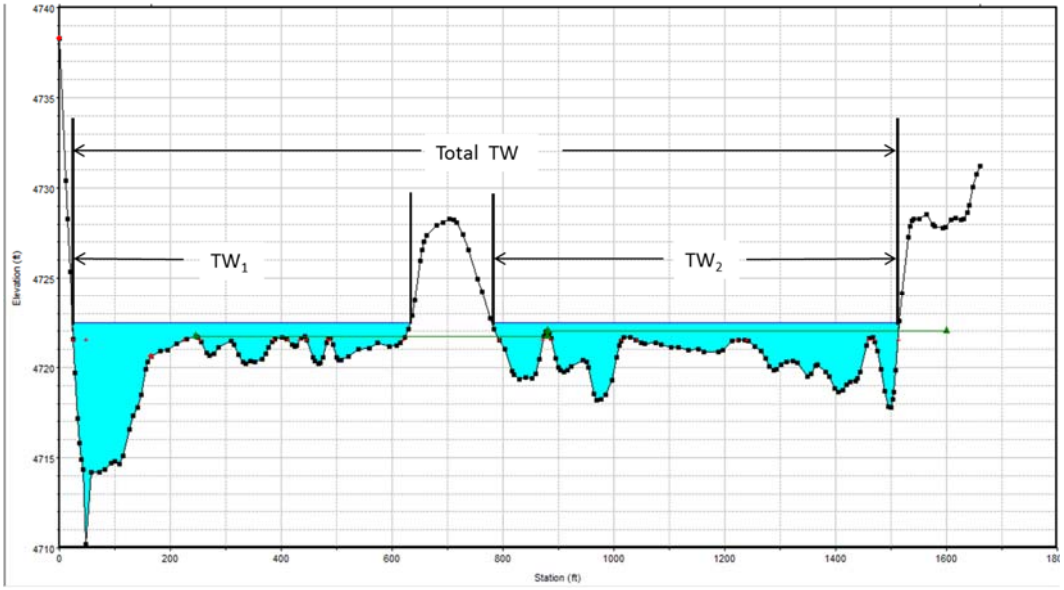
Federal Emergency Management Agency (FEMA). 2014. *Guidance for Flood Risk Analysis and Mapping, Hydraulics: Mapping Base Flood Elevations on Flood Insurance Rate Maps.* November. Available at https://www.fema.gov/media-library-data/1420661867979-3be27a7290574e2ab8d95be793d10175/BFE_Mapping_Guidance_Nov_2014.pdf

Appendix

TOP WIDTH EXAMPLES

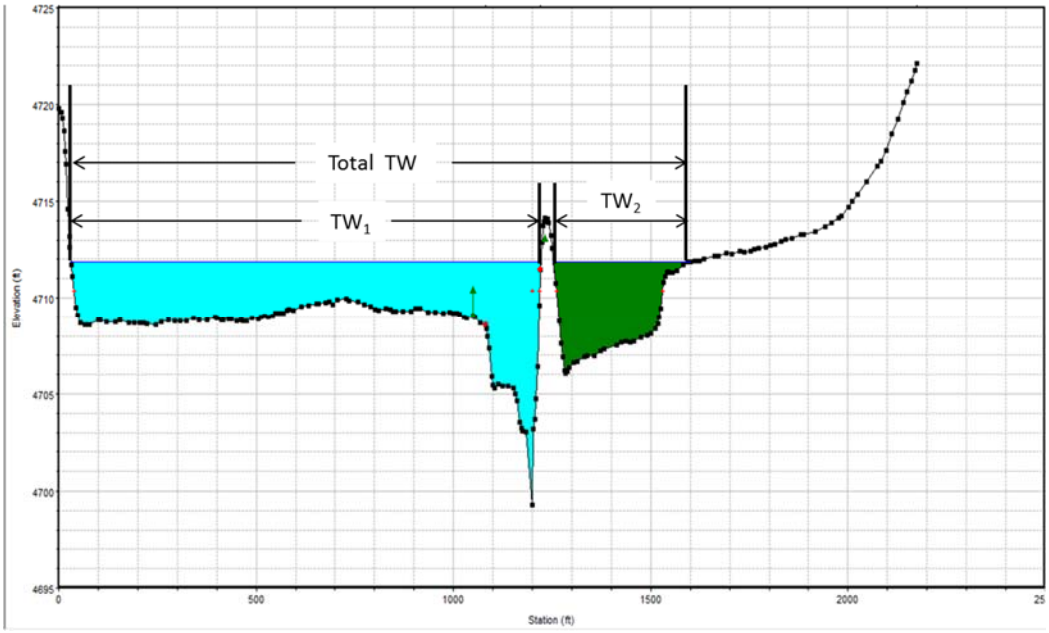
Effective Flow Area: Ineffective Flow Area:

Example 1:



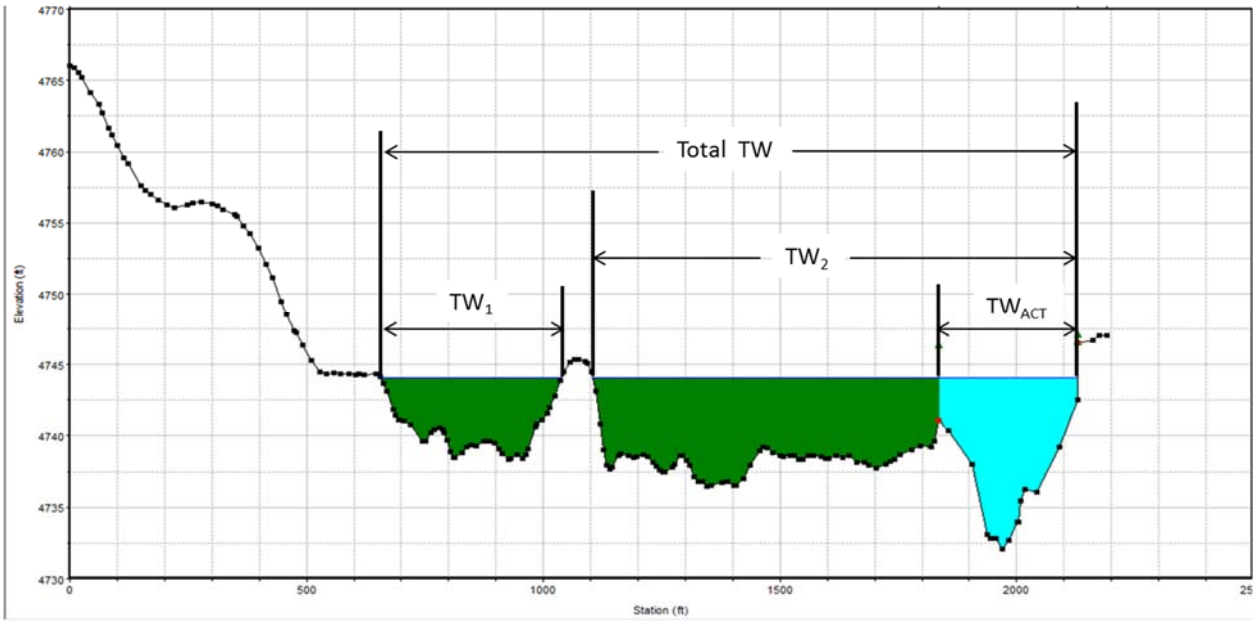
Total Top Width includes high ground (islands)
Actual Top Width = TW_1 +TW_2

Example 2:



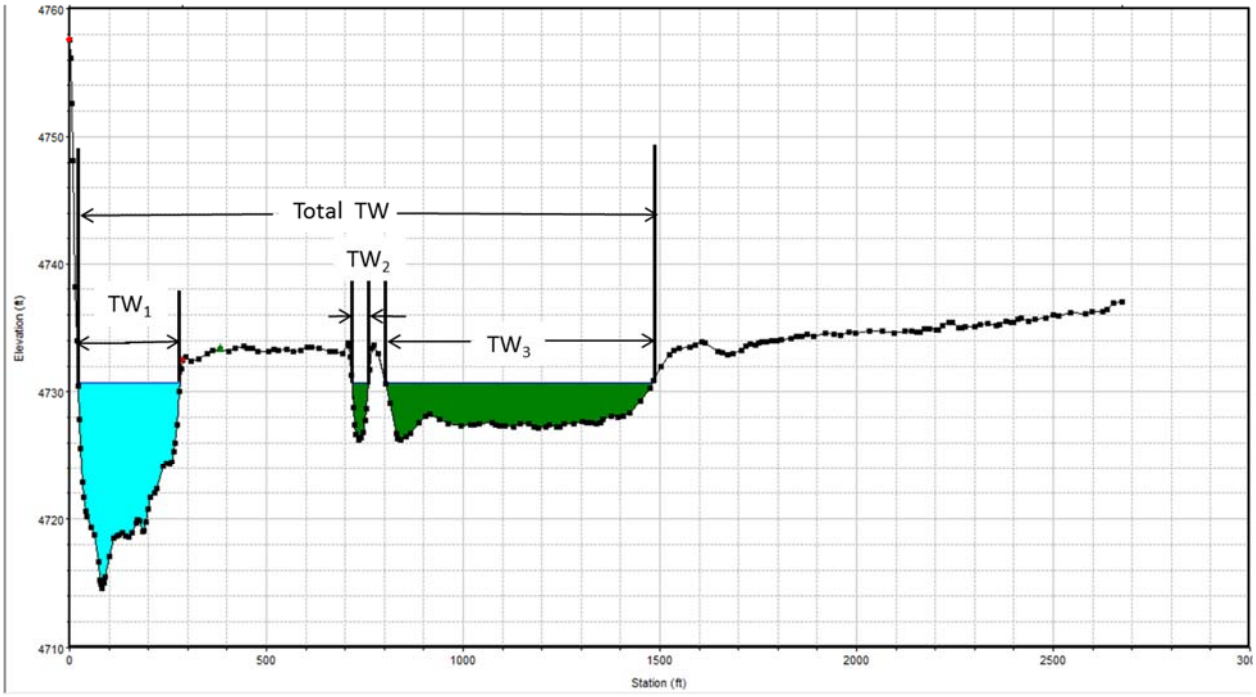
Total Top Width includes high ground and ineffective flow area (TW_2)
Actual Top Width = TW_1

Example 3:



Total Top Width includes high ground and ineffective flow areas. TW_1 could be an adjacent on-site detention pond. TW_2 includes the Actual Top Width and an ineffective flow area.

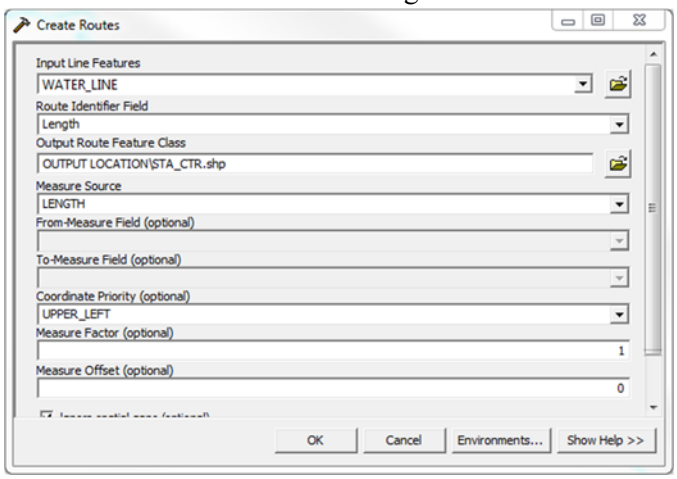
Example 4:



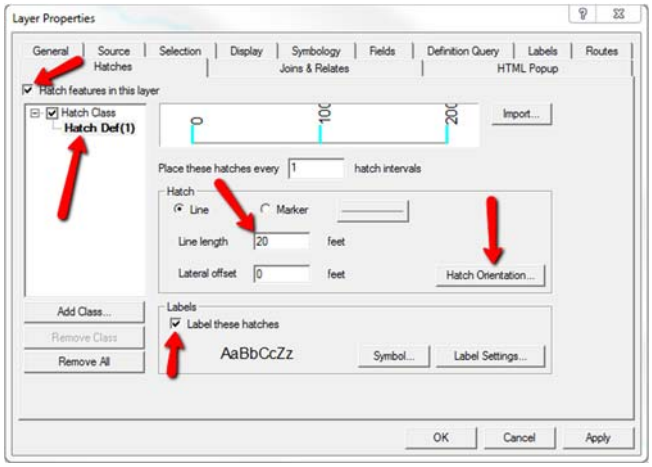
Total Top Width includes ineffective flow areas and high ground
Top Width = TW1 + TW2 + TW3

How to Create Station Labels in ArcGIS (Version 9.3)

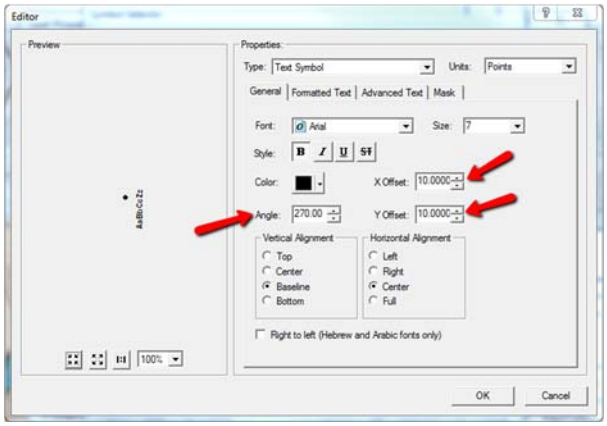
1. ArcToolbox → Linear Referencing Tools → Create Routes



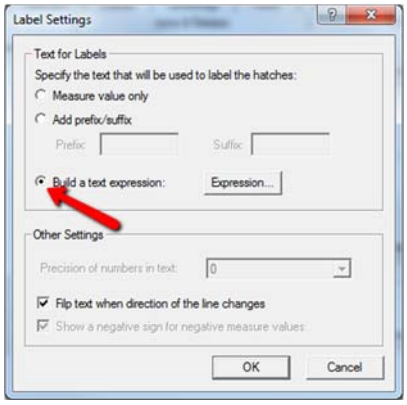
2. Open Properties Dialog of the routes .shp just created STA_CTR.shp → Click on Hatches tab
    a. Hatch Interval = 100 for stationing label every 100 feet
3. Click on Hatch Def and entered desired length for stationing mark. Click checkbox to "Hatch features in this layer" and "Label these hatches" then click Hatch Orientation.



4. Under the Hatch Orientation tab, choose "Center" and click OK
5. Click the "Symbol" button to adjust the text size, and direction



6. Click the “Label Settings” to format the text
7. Click the “Build a text expression” button.



8. Click Advanced check box, and paste the following code into the expression editor.

```
Function FindLabel (esri_measure)
        if(esri_measure = 0)  then
        FindLabel = 0 & ("+00")
        end if
      if (esri_measure > 0) then
        FindLabel = Left (esri_measure, Len(esri_measure)-2 )&("+00")
   end if
End Function
```

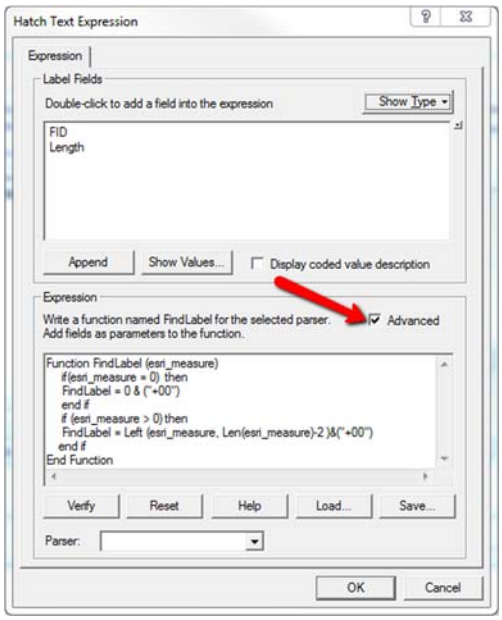


EXHIBIT D – DIGITAL FLOOD HAZARD AREA DELINEATION STUDIES REPORT CHECKLIST

Instructions:

1. Engineer shall submit a completed copy of this checklist with all draft and final reports.
2. For deviations from checklist, include a separate sheet with numbered comments and write the corresponding number in the "Note #" column.
3. Clearly label Sections and Subsections (bold items in checklist) in report.
4. Provide both links from Table of Contents and bookmarks.

REPORT SECTIONS		DRAFT REPORT	FINAL REPORT	NOTE #
PRELIMINARIES	**Cover Sheet**	☐	☐	
	Project Title "Flood Hazard Area Delineation, (Drainageway Name)"	☐	☐	
	Project Sponsors List, including logos	☐	☐	
	Engineer's Name/Address	☐	☐	
	Date (Month & Year)	☐	☐	
	"DRAFT" stamp (on all except Final Report)	☐	☐	
	Transmittal Letter	☐	☐	
	Signed and sealed by Engineer transmitting report to District	☐	☐	
	Table of Contents	☐	☐	
	Section titles and page numbers	☐	☐	
	List of Table (number, title, and location in report)	☐	☐	
	List of Figures (number, title, and location in report)	☐	☐	
	List of Appendices	☐	☐	
SECTION 1 - INTRODUCTION	**Authorization**	☐	☐	
	Identify District and Engineer as contracting parties and identify other sponsors	☐	☐	
	Agreement number	☐	☐	
	Notice to Proceed date	☐	☐	
	Purpose and Scope	☐	☐	
	Describe original scope of Project	☐	☐	
	Include all actions taken by District and Sponsors that modified, limited, or expanded the scope	☐	☐	
	Describe the amendments to the scope with reference to agreement number	☐	☐	
	Planning Process	☐	☐	
	Describe how the Project evolved	☐	☐	
	Describe specific goals and objectives for the FHAD	☐	☐	
	Provide summary of project website progress meetings and other coordination with District, sponsors, and attendance roster (reference material in Appendix A)	☐	☐	
	Mapping and Surveys	☐	☐	
	Describe mapping source (i.e. mapping firm, USGS, local governments, other)	☐	☐	
	Scale	☐	☐	
	Contour interval	☐	☐	
	Datum (horizontal and vertical)	☐	☐	
	Date of mapping	☐	☐	
	Data Collection	☐	☐	
	Discuss maps, plans, reports, and other information obtained from District, Sponsors, and other agencies (reference Data Collected table in narrative)	☐	☐	
SE CT	**Acknowledgements**	☐	☐	
	Acknowledge participants and their rose in the Project (reference Project	☐	☐	

	Participants table in narrative)			
	Tables	☐	☐	
	List of Data Collected; maps, plans, or reports used for Project including title, date, and author	☐	☐	
	List of Project Participants and their affiliations	☐	☐	
	Figures (none)	☐	☐	
SECTION 2 – STUDY AREA DESCRIPTION	**Project Area**	☐	☐	
	Describe Project limits (reference Watershed Map in narrative)	☐	☐	
	Describe Project's watershed size	☐	☐	
	Describe jurisdictions and major landmarks	☐	☐	
	List Project Reuse watershed number(s)	☐	☐	
	Describe changes to the Project Area and why; if none, state this	☐	☐	
	Describe hydrologic features	☐	☐	
	Describe NRCS hydrologic soil classification (reference Soils Map in Appendix B)	☐	☐	
	Describe percent of watershed currently developed	☐	☐	
	List highest and lowest watershed elevation, average slope and watershed shape	☐	☐	
	Land Use	☐	☐	
	Describe existing land use types (reference Existing Land Use Map in Appendix B) and how information was obtained	☐	☐	
	Describe future land use types (reference Future Land Use Map in Appendix B) and how information was obtained	☐	☐	
	Discuss how imperviousness values were determined based on land use types (reference Land Use table in narrative)	☐	☐	
	Discuss overall existing watershed imperviousness (reference Existing Imperviousness Map)	☐	☐	
	Discuss overall future watershed imperviousness (reference Future Imperviousness Map)	☐	☐	
	Reach Description	☐	☐	
	Describe drainageway by FHAD reach (reference FHAD Reach figure) with reference to typical channel cross sections and photographs	☐	☐	
	Describe problem areas as discovered by observation or anecdotal information, hydrologic and hydraulic calculations, with reference to tables and figures	☐	☐	
	Identify all major crossings including street name, street type and structure type and size (reference Major Crossing Structure Inventory table)	☐	☐	
	Flood History	☐	☐	
	Provide information on past flooding event, bridge scour or stream stability, including stream gage data, literature citations, newspaper articles, anecdotal information	☐	☐	
	Environmental Assessment	☐	☐	
	Describe potential wetland and riparian zones within the Project area (reference Wetland and Riparian Inventory in Appendix E)	☐	☐	
	Describe flora, fauna and threatened or endangered species identified within the Project Area	☐	☐	
	Tables	☐	☐	
	Land Uses with assigned impervious values	☐	☐	
	Describe soil associations and their NRCS hydrologic classification	☐	☐	
	Major Crossing Structure Inventory	☐	☐	
	Include inventory of known flora, fauna, threatened/endangered species (if applicable)	☐	☐	
	Figures	☐	☐	
	Vicinity Map showing watershed location within District boundaries	☐	☐	
	FHAD Reach Figure	☐	☐	
	Watershed Map including jurisdictional boundaries; Identify major public and private facilities, (transportation corridors, golf courses, fairgrounds, existing detention ponds	☐	☐	

	And irrigation facilities)	☐	☐	
	All other Tables and Figures to be included in Appendix B	☐	☐	
SECTION 3 – HYDROLOGIC ANALYSIS	**Overview**	☐	☐	
	Describe general process for developing and routing hydrographs through Project Area	☐	☐	
	Describe CUHP and/or SWMM models used, including version number	☐	☐	
	Describe all calculations, references, and modeling used to develop the hydrology	☐	☐	
	Provide date hydrologic calculations approved by UDFCD	☐	☐	
	Design Rainfall	☐	☐	
	Describe the design rainfall used and source of point rainfall values and distributions (reference Point Rainfall table in narrative and Rainfall Distribution table in Appendix B)	☐	☐	
	Describe any area corrections used (reference Rainfall Area Correction Factors table in narrative)	☐	☐	
	Subwatershed Characteristics	☐	☐	
	Describe subwatershed characteristics and how they were determined (reference CUHP Input table and Subwatershed figure in Appendix B)	☐	☐	
	Discuss number of subwatersheds, range and average size of subwatershed	☐	☐	
	Hydrograph Routing	☐	☐	
	Describe flow-routing element types and geometrics for existing and future land use, existing infrastructure conditions (reference SWMM Routing Map and SWMM Schematic figures in Appendix B)	☐	☐	
	Describe all existing detention facilities modeled, including stage-storage-discharge relationships (reference Detention Rating Curve tables in Appendix B)	☐	☐	
	Describe flow diversion relationships for all diversions (reference Flow Diversions table in Appendix B)	☐	☐	
	Describe potential effects of drainageway improvements (channel modifications, inadvertent detention, water quality facilities, etc.) and how addressed.	☐	☐	
	Previous Studies	☐	☐	
	Discuss hydrologic results presented in previous studies and regulatory models	☐	☐	
	Results of Analysis	☐	☐	
	Comparison of future and existing 100-year hydrology to determine if DFIRM required	☐	☐	
	Discuss results of hydrologic analysis; reconcile any deviations from flows presented in previous studies to within 10% (reference Previous Studies Reconciliation table in narrative)	☐	☐	
	Provide results of hydrologic analysis presenting peak flows and volumes (reference Peak Flow table and Runoff Volume table in Appendix B)	☐	☐	
	Provide hydrographs at key locations representing peak flows for both existing and future conditions (reference Hydrograph figures in Appendix B)	☐	☐	
	Provide peak flow profiles along the drainageway centerline for both existing and future conditions (reference Peak Flow Profile figures in Appendix B)	☐	☐	
	Provide typical samples of hydrologic model (reference sample SWMM table in Appendix B)	☐	☐	
	Tables	☐	☐	
	Point Rainfall for each flood return period	☐	☐	
	Rainfall Area Correction Factors	☐	☐	
	Comparison of Existing versus Future Conditions 100-Year Peak Flows	☐	☐	
	Previous Studies Hydrology Reconciliation showing peak flows at key locations from all studies and percent difference	☐	☐	
	Figures (none in narrative)	☐	☐	
	All other Tables and Figures to be included in Appendix B	☐	☐	
SECTION 4 –	**Evaluation of Existing Facilities**	☐	☐	
	Describe procedures used to evaluate capacity of existing road crossings, channels, storm sewers and detention	☐	☐	

	Discuss development of HEC-RAS models used to delineate existing infrastructure and future land use conditions floodplain (reference HEC-RAS Cross Sections in Appendix C); final electronic files for models included in Technical Appendix.	☐	☐	
	Discuss how Manning's n-values were determined; include photographs of typical channel sections used to determine values	☐	☐	
	Describe Floodway Analysis	☐	☐	
	Discuss results of hydraulic model, including any split flow conditions, types and number of structures in the future conditions floodplain (reference Flood Maps in Appendix C)	☐	☐	
	Discuss existing drainage facilities, providing a brief description of physical condition and estimated capacity related to future hydrology discharges (reference Existing Facilities table in narrative)	☐	☐	
	Flood Hazards	☐	☐	
	Describe existing and potential future drainage, erosion, water quality and flood hazard problems by reach and/or problem area (with reference to Tables and/or Figures)	☐	☐	
	Previous Analysis	☐	☐	
	Explain difference from previous hydraulic analyses of existing facilities and floodplain delineation	☐	☐	
	Tables	☐	☐	
	Existing Facilities table showing estimated capacity relative to future conditions discharges (reference survey crossing number)	☐	☐	
	Figures (none in narrative)	☐	☐	
	All other Tables and Figures to be included in Appendix C	☐	☐	
SECTION 5 – REFERENCES	**List of all references used for report**	☐	☐	
APPENDICES	**Appendix A – Project Correspondence**	☐	☐	
	Minutes of progress meetings and public meetings	☐	☐	
	Summary of comments from Sponsors for each submittal and response of how each comment was addressed	☐	☐	
	Any other pertinent correspondence documenting flood hazard area determination process	☐	☐	
	Figures showing website content	☐	☐	
	Appendix B – Hydrologic Analysis Support Documents	☐	☐	
	Reach map	☐	☐	
	Soils Conditions map	☐	☐	
	Land Use maps (existing and future)	☐	☐	
	Design Rainfall Distribution table for each flood return period	☐	☐	
	CUHP Input table (subwatershed hydrologic characteristics, including area, length, centroid length, existing and future percent impervious, time of concentration, pervious and impervious storage, and initial, final and decay rate for infiltration)	☐	☐	

APPENDICES (CONTINUED)	Subwatershed figure showing boundaries, ID, area, existing and future percent subwatershed imperviousness for each subwatershed	☐	☐	
	EPS SWMM Input Table (routing conveyance elements and their parameters detention pond and rating curves and all diversions and their flow diversion relationships)	☐	☐	
	SWMM Routing Map with aerial image in background (show subwatersheds, conveyance elements, design points, diversions, and detention routing elements	☐	☐	
	SWMM Schematic with major crossings labeled	☐	☐	
	Detention Rating Curve tables showing stage-storage-discharge relationships for all detention facilities (please include pond layout, description of outlet works and any supporting calculations)	☐	☐	
	Flow-diversion tables for all flow diversions	☐	☐	
	Peak flows along drainageway for future land use conditions (all return periods) including station, routing element, channel reach, and landmark	☐	☐	
	Runoff volumes and accumulated drainage areas at same locations as for peak flow	☐	☐	
	Hydrographs at key locations for existing infrastructure and future land use conditions	☐	☐	
	Peak flow Profiles along drainageway centerline for existing infrastructure and future land use	☐	☐	
	Sample SWMM (100-yr) output report with full input included	☐	☐	
	Any other hydrology tables and figures not included in Section 3	☐	☐	
	Appendix C – Hydraulic Analysis Support Documents	☐	☐	
	Existing hydraulic structures sections	☐	☐	
	Existing hydraulic structures photographs	☐	☐	
	HEC-RAS sections illustrating design storm flood elevations	☐	☐	
	Any other hydraulic calculations tables and figures not included in Section 4	☐	☐	
	Appendix D – Floodplain and Floodway Data Table	☐	☐	
	Appendix G – Flood Maps	☐	☐	
	Appendix H – Flood Profiles	☐	☐	

TECHNICAL APPENDIX CHECKLIST FOR FLOOD HAZARD AREA DELINEATION STUDIES

Instructions:

1. Engineer shall submit a completed copy of this checklist with the technical appendix submittal.
2. For deviations from checklist, include a separate sheet with numbered comments and write the corresponding number in the "Note #" column.

Notes:

1. Bold text represents the technical appendix folders.
2. Italicized text represents individual files.
3. Indentations represent folders of files within folders.
4. Folder and file naming shall match those shown in this checklist.
5. Text included in parenthesis is for information only and should not be included in folder of file name.

	FOLDER AND FILE NAMES		NOTE #
FHAD	**FHAD and/or DFIRM (if required)**	☐	
	FHAD (Drainageway Name) (entire final report PDF)	☐	
	FHAD	☐	
	GIS Files	☐	
	Floodmap Elements	☐	
	Referenced .mxd Files	☐	
	Existing Contours	☐	
	FLD_HAZ_AREA Layer	☐	
	FHAD 100-Year FloodplainFLD	☐	
	FHAD 500-Year Floodplain	☐	
	FHAD Floodway	☐	
	FHAD Shallow Flooding	☐	
	FHAD Floodplain Boundaries	☐	
	FHAD Study Limits	☐	
	S_XS	☐	
	BFE	☐	
	STREAM_CENTERLINE	☐	
	STATIONING	☐	
	STRUCTURES Layer	☐	
	Building_Footprint (insurable structures)	☐	
	S_Gen_Struct (Bridge, Culverts, etc)	☐	
	S_LOMR	☐	
	A_LEVEE	☐	
	AutoCAD Files	☐	
	FHAD Flood Profiles	☐	
	FHAD 100-Year Flood Profile (existing infrastructure and future land use conditions)	☐	
	Other Flood Profiles (typically 10-year, 25-year,,50-year, and 500-year) (existing infrastructure and future land use conditions)	☐	
	Stream Alignment (stream bed) profile	☐	
	Cross Section Text	☐	
	Cross Section Symbol	☐	
	Structures	☐	
	Axis labels (provide datum reference for elevations)	☐	
	Grid Lines	☐	
	Text (Stationing, elevations, hydraulic structures, pertinent peak discharges)	☐	
	Match lines	☐	
	Any other figures included in the FHAD report, clearly labeled with the figure title	☐	
	FHAD Supplemental Information	☐	
	Models	☐	
	Include all additional models used in the FHAD (other than models included in the "Hydrology" and "Hydraulics" folders). Clearly label modes with "FHAD…"	☐	
	Spreadsheets	☐	

	FHAD Submittal Form	☐	
	Agreement Table	☐	
	Floodplain and Floodway Data Table	☐	
	Include any other spreadsheets used for the FHAD. Spreadsheets may include tables used for final report, UDFCD worksheets, etc. Remove extraneous information from spreadsheets and clearly label spreadsheets with "FHAD…"	☐	
	Other	☐	
	Include any other information used in the FHAD. Additional folders may be added, or files with clearly marked names may be added to an "Other" folder.	☐	
	Hydraulics	☐	
	HEC-RAS v. XXX (i.e. HEC-RAS v. 4.1.0)	☐	
	HEC-RAS Cross Sections	☐	
	Include final FHAD HEC-RAS model with FHAD files only, labeled as such. Include (for HEC-RAS) the Project (.prj) file, with each Plan clearly identified (multiple-profile and floodway at a minimum); and all input data files used to analyze pertinent Plans [plan files (.p0#) with corresponding geometry (.g0#) and flow (.f0#) files (complete with file dates)]. Include a description for the FHAD model Plans that states the conditions (existing infrastructure, future land use hydrology, multiple-profile, floodway, etc.).	☐	
	Other	☐	
	Include any other information used in the FHAD hydraulic analysis (special culvert hydraulics, all rating curve calculations, etc.) Additional folders may be added, or files with clearly marked names may be added to an "Other" folder.	☐	
	(If no MDP/OSP with FHAD; include same items listed for Baseline hydrology from Major Drainageway Planning checklist (but only 10-year, 25-year, 50-year, 100-year, and 500-year Hydrology information required); otherwise, include only if 500-year models are different than Baseline hydrology models).	☐	
	CUHP XXXX – v. XXX (i.e. CUHP 2005 – v 1.3.3)	☐	
	Input Files	☐	
	(Drainageway Name) FHAD 500-Year CUHP Input	☐	
	Output Files	☐	
	(Drainageway Name) FHAD 500-Year CUHP Output	☐	
	Input Files	☐	
	(Drainageway Name) FHAD 500-Year EPA SWMM Input	☐	
	Output Files	☐	
	(Drainageway Name) FHAD 500-Year EPA SWMM Output	☐	
	Spreadsheets	☐	
	Include any spreadsheets used for FHAD 500-year hydrology. Spreadsheets may include tables used for	☐	
	Other	☐	
	Include sketches/description of outlet works/supporting calculations for any Regional Detention Facility included in the FHAD (or DFIRM) hydrology. Require rating curves for stage versus volume and stage versus discharge.	☐	
	Include any other information used in the FHAD 500-year hydrology. Additional folders may be added, or files with clearly marked names may be added to an "Other" folder.	☐	
	Report Documents	☐	
	(Drainageway Name) FHAD (in Word Format)	☐	
	Include any other final report documents not included in another section	☐	