

LARIMER COUNTY
ENGINEERING DEPARTMENT



FLOODPLAIN DEVELOPMENT GUIDE



SECTION 7:
HYDRAULIC STUDIES



7. HYDRAULIC STUDIES

Many forms of floodplain development will require the submittal of a hydraulic study prior to permitting. The following are examples of floodplain development for which a hydraulic study is required:

- Floodplain development and variance requests within a floodway zone including existing, unpermitted development or change of use applications,
- Floodplain development within 100' of a channel centerline in a Zone A floodplain or as determined by the County Engineer,
- Variance requests where hydraulic conditions need to be evaluated by Larimer County Flood Review Board (FRB) or at the discretion of the County Engineer,
- Floodplain Project Reviews, and
- Map Amendments

This section will summarize some of the main requirements for hydraulic studies in these cases. This section does not replace or remove any requirements for floodplain submittals to the Federal Emergency Management Agency (FEMA) or the Colorado Water Conservation Board (CWCB). Additional requirements from FEMA or CWCB must be met along with these standards.

No-Rise Analysis

If floodplain development is proposed or has occurred within a floodway zone, a hydraulic study is required to determine its impact on the base flood elevations (BFEs) and floodway elevations. The base flood elevation is the water surface elevation associated with the 1% Annual Chance Event (1% ACE, or 100-year flood) and the floodway elevation is the water surface elevation of the regulatory floodway after completing a floodplain encroachment analysis. The hydraulic study must be stamped and signed by a licensed Colorado Professional Engineer (PE) and demonstrate that the floodplain development has not resulted in an increase the BFEs or floodway elevations.

The following components must be included for a hydraulic study to be considered complete unless it is determined that a component is not necessary by the County Engineer:

Hydraulic Study Requirements for No-Rise Analyses

A No-Rise Hydraulic Study requires the submittal of a hydraulic report (PE Certified) and appendices as which include the following components:

Hydraulic Report

- Table of Contents: all sections, figures, tables, and appendices must be listed with page numbers.
- Project Description: provide a description regarding the purpose and nature of the work, the project location, location and condition of bridges and culvert crossings at or near the project site, location of any insurable structures at or near the project site, project participants, and any special hydraulic considerations.
- Background: provide the name of the flooding source (e.g. Big Thompson River) and the associated Flood Insurance Rate Map (FIRM) panel. The background must describe any previous hydraulic studies which have been completed for the project site and reference all map revisions (CLOMRs/LOMRs) which impact the project site.
- Location Maps: provide at least two maps showing the project location. One map must have a scale no smaller than what is required to show the extents of the project site (vicinity map) and the other must have a scale no larger than 1:12,000 to show the broader area surrounding the project site (location map). Both maps must be annotated to show the project site, study limits, roads (with road names labeled), bridges, culvert crossings, and access routes.
- Survey Information: provide the source of topographic and survey data along with the horizontal and vertical datums.
- Hydrology: identify the source of the discharge information used during the hydraulic analysis. Provide a table of discharge values for the 10-year, 50-year, and 100-year flood events resulting from the hydrologic study. If an independent hydrologic study was completed for the project, that study must be submitted separately from the hydraulic study.
- Hydraulic Modeling:
 - Hydraulic Model Description: describe the purpose of the study, the study limits, the location of bridges, roads, and culvert crossings, along with any other special hydraulic considerations.
 - Modeling Software: provide the name and version of the hydraulic modeling software used for the analysis.
 - Plan Description & Table: provide a description for, and table showing, all the hydraulic plans used in the analysis. The table should include the plan names along with the associated geometry and flow files used in the plan. Hydraulic plans typically include the effective, duplicate effective, corrected-effective,

existing, proposed, and post-project or as-built conditions. A separate floodway plan is also typically required to perform a floodway analysis.

- Cross-Sections: describe the location of the hydraulic cross-sections, cross-section spacing, Manning's roughness coefficients, bank stations, and contraction & expansion coefficients. If the project proposes to physically modify the geometry of any cross sections from the base condition, describe the nature of the changes and which cross-sections will be impacted. A table and cross-section plots for each cross-section are required as appendices to the report as described below.
 - Hydraulic Parameters: describe how the hydraulic parameters were determined and reasons for any changes from the base condition. The description should include, at minimum, discussion of Manning's roughness coefficients, bank stations, and contraction & expansion coefficients.
 - Ineffective Flow Areas: describe how the ineffective flow areas were determined and reasons for any changes from the base condition. Ineffective flow areas must be clearly shown on the cross-section plots in the appendices.
 - Base Flood Elevations (BFEs) & Flood Profile: describe the 1% ACE flood profile and flow conditions along the study reach. How do bridges and crossings impact the water surface elevations? How does the project impact the hydraulic characteristics? Explain any differences in the BFEs between the base condition and the other model conditions (e.g. existing, proposed, as-built).
 - Floodway Encroachment Analysis: describe the encroachment method and associated parameters used in the analysis. If the modeling software or version used for the floodway analysis varies from that used in the hydraulic analysis, state the software and version used for the floodway analysis and why it has been chosen.
 - Scour Analysis: describe the method used to estimate the anticipated scour depth(s) and the design for any protection measures which are needed to protect from scour. Scour protection measures must be shown in the construction plans.
- Results: provide a general discussion of the hydrologic and hydraulic modeling results. Discuss any changes in flood discharges, water surface elevations (BFE and floodway elevations), and floodplain/floodway boundaries. Discuss any adverse impacts due to the project on structures or lands, including scour impacts. Describe any mitigation measures that will be incorporated such as floodproofing or channel/bank stabilization.

- Errors: explain any modeling errors which impact the study limits and address how those errors have been resolved.
- Approval Criteria: list the applicable approval criteria from the LCLUC and address how each criteria has been adequately met by the project. Refer to LCLUC Section 12.1.4.E.3 for approval criteria.

Hydraulic Appendices

In addition to the report, several items must be submitted as appendices as described below:

- Hydraulic Model: provide a digital copy of the hydraulic model used for the analysis.
- FDP submittal requirements applicable to the request (see Floodplain Development Permit section above)
 - Floodplain Development Permit (FDP) Application
 - Construction Plans (PE Certified)
 - Certificates
 - Floodproofing Design
 - Repair or Improvement Submittals
 - Ownership Documentation
 - Other Permits & Approvals
- No-Rise Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No-Rise Certificate which certifies that the project will not increase the BFEs. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- No Adverse Impact Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No Adverse Impact Certificate which certifies that the project will not adversely impact a structure. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- Cross-Section Table: provide a table showing the river station, downstream reach lengths, Manning's roughness coefficients, bank stations, ineffective flow areas, and contraction & expansion coefficients for each cross-section affected by the project. If the project proposes to physically modify the geometry of any cross sections from the base condition, provide a column stating the nature of the changes for each modified cross-section. The table should include these values for each geometry file (e.g. existing,

proposed, as-built) and highlight values which have been modified from the base model (e.g. effective or existing).

- Base Flood Elevation (BFE) Comparison Table: provide a table showing the BFEs for all model conditions along with the differences between the model conditions.
- Cross-Section Plots: provide cross-section plots for each cross-section affected by the project. Plots should be submitted showing the ground elevation data, water surface elevation data, ineffective flow areas, flow obstructions, and floodway encroachments for each geometry and discharge frequency.
- Scour Calculations (PE Certified): provide detailed calculations for the estimated scour depth and protection which are stamped and signed by a licensed Colorado Professional Engineer (PE).
- Other requirement(s) as determined by the County Engineer to be necessary to allow the review criteria to be adequately evaluated.

All required submittal items must be provided in **three (3) hard copies** and **one (1) digital copy**.

Alternative Approaches to a No-Rise Analysis

A detailed hydraulic model may not be warranted to justify a no-rise in every circumstance where floodplain development is proposed in a floodway zone. In certain cases, alternative methods may be used as determined by the County Engineer. Such methods may include:

- **Maintain Existing Grade:** a no-rise condition may be justified by maintaining the existing ground elevations in the disturbed area. This method must be supported by pre-project and post-project ground surveys which are stamped by a licensed Colorado Professional Land Surveyor (PLS) and show no substantial deviations as determined by the County Engineer.
- **Conveyance Shadowing:** a no-rise condition may be justified by utilizing conveyance shadows in accordance with FEMA guidelines. This method must be supported by a figure showing the building footprint in relation to the conveyance shadow. The figure must show the floodplain development to be entirely within the conveyance shadow and be certified by a licensed Colorado Professional Engineer (PE).

Floodway Delineation

If floodplain development is proposed within 100 feet of a channel centerline in a Zone A floodplain, the applicant will be required to hire a licensed Colorado Professional Engineer (PE) to complete a floodway delineation showing the location of the floodway in relation to the development. A floodway delineation may also be required if deemed necessary by the County

Engineer. If the floodway delineation shows that a proposed structure is within a floodway, the structure will need to be relocated outside of the floodway before issuance of an FDP.

The following components must be included for a hydraulic study to be considered complete unless it is determined that a component is not necessary by the County Engineer:

Hydraulic Study Requirements for Floodway Delineations

A floodway delineation requires the submittal of a hydraulic report (PE Certified) and appendices which include the following components:

Hydraulic Report

- Table of Contents: all sections, figures, tables, and appendices must be listed with page numbers.
- Project Description: provide a description regarding the purpose and nature of the work, the project location, location and condition of bridges and culvert crossings at or near the project site, location of any insurable structures at or near the project site, project participants, and any special hydraulic considerations.
- Background: provide the name of the flooding source (e.g. Big Thompson River) and the associated Flood Insurance Rate Map (FIRM) panel. The background must describe any previous hydraulic studies which have been completed for the project site and reference all map revisions (CLOMRs/LOMRs) which impact the project site.
- Location Maps: provide at least two maps showing the project location. One map must have a scale no smaller than what is required to show the extents of the project site (vicinity map) and the other must have a scale no larger than 1:12,000 to show the broader area surrounding the project site (location map). Both maps must be annotated to show the project site, study limits, roads (with road names labeled), bridges, culvert crossings, and access routes.
- Survey Information: provide the source of topographic and survey data along with the horizontal and vertical datums.
- Hydrology: identify the source of the discharge information used during the hydraulic analysis. Provide a table of discharge values for the 10-year, 50-year, and 100-year flood events resulting from the hydrologic study. If an independent hydrologic study was completed for the project, that study must be submitted separately from the hydraulic study.
- Hydraulic Modeling:

- Hydraulic Model Description: describe the purpose of the study, the study limits, the location of bridges, roads, and culvert crossings, along with any other special hydraulic considerations.
- Modeling Software: provide the name and version of the hydraulic modeling software used for the analysis.
- Plan Description & Table: provide a description for, and table showing, the hydraulic plan(s) used in the analysis. The table should include the plan name(s) along with the associated geometry and flow files used in the plan. For a floodway delineation, hydraulic plans are typically developed for the 1% ACE and the floodway encroachment analysis.
- Cross-Sections: describe the location of the hydraulic cross-sections, cross-section spacing, Manning's roughness coefficients, bank stations, and contraction & expansion coefficients. A table and cross-section plots for each cross-section are required as appendices to the report as described below.
- Hydraulic Parameters: describe how the hydraulic parameters were determined. The description should include, at minimum, discussion of Manning's roughness coefficients, bank stations, and contraction & expansion coefficients.
- Ineffective Flow Areas: describe how the ineffective flow areas were determined. Ineffective flow areas must be clearly shown on the cross-section plots in the appendices.
- Base Flood Elevations (BFEs) & Flood Profile: describe the 1% ACE flood profile and flow conditions along the study reach. How do bridges and crossings impact the water surface elevations?
- Floodway Encroachment Analysis: describe the encroachment method and associated parameters used in the analysis. Floodway encroachments and elevations must be clearly shown on the cross-section plots and in the floodway data table in the appendices. Floodway surcharge may not exceed 0.5 feet.
- Results: describe the results for the floodway encroachment analysis. State whether the proposed structure is within the delineated floodway. Describe any mitigation measures that will be incorporated.
- Errors: explain any modeling errors which impact the study limits and address how those errors have been resolved.

- Approval Criteria: list the applicable approval criteria from the LCLUC and address how each criteria has been adequately met by the project. Refer to LCLUC Section 12.1.4.E.3 for approval criteria.

Hydraulic Appendices

In addition to the report, several items must be submitted as appendices as described below:

- Hydraulic Model: provide a digital copy of the hydraulic model used for the analysis.
- FDP submittal requirements applicable to the request (see Floodplain Development Permit section above)
 - Floodplain Development Permit (FDP) Application
 - Construction Plans (PE Certified)
 - Certificates
 - Floodproofing Design
 - Repair or Improvement Submittals
 - Ownership Documentation
 - Other Permits & Approvals
- Floodway Workmap (PE Certified): provide a workmap showing the floodway delineated by the study. The workmap must show the following components:
 - Floodplain and floodway boundaries for each model condition (1% ACE)
 - Study Limits
 - Hydraulic Cross-Sections
 - Base Flood Elevations
 - Ineffective Flow Areas
 - Stream Profile
 - Area(s) of Disturbance
 - Structures
 - Roads and Hydraulic Structure Alignments (Bridges, Culvert Crossings, etc.)
 - Property Boundaries
 - Horizontal and Vertical Datums (NAD83, NAVD88)
 - Date & Source of Aerial Photography

- Date and Source of Survey & Topographic Information
- Legend
- No-Rise Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No-Rise Certificate which certifies that the project will not increase the BFEs. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- No Adverse Impact Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No Adverse Impact Certificate which certifies that the project will not adversely impact a structure. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- Cross-Section Table: provide a table showing the river station, downstream reach lengths, Manning's roughness coefficients, bank stations, ineffective flow areas, and contraction & expansion coefficients for each cross-section included in the study.
- Floodway Data Table: provide a table showing each cross-section included in the study and its associated floodway width, cross-sectional area, mean velocity, and a water surface elevation comparison. The water surface elevation comparison should provide the base flood elevations, the floodway elevations, and the differences between the BFEs and floodway elevations for each cross-section. The differences between the BFEs and floodway elevations should not exceed 0.5 foot at any given cross-section.
- Cross-Section Plots: provide cross-section plots for each section affected by the project. Plots should be submitted showing the ground elevation data, water surface elevation data, ineffective flow areas, flow obstructions, and floodway encroachments.
- Spatial Data Files: provide digital copies of geographic data files (e.g. shapefiles) for the floodplain and floodway boundaries delineated by the study.
- Other requirement(s) as determined by the County Engineer to be necessary to allow the review criteria to be adequately evaluated.

All required submittal items must be provided in **three (3) hard copies** and **one (1) digital copy**.

Floodplain Project Reviews

Floodplain Project Reviews (FPRs) include the following:

- New or replacement bridges, roads, or other infrastructure which cross a stream channel, as determined by the County Engineer.
- New or replacement water control structures which are determined to be hydraulically significant by the County Engineer.

- New or replacement marinas, docks, piers, wharves, or other floodplain development determined by the County Engineer to require special consideration by the FRB.

The following components must be included for a hydraulic study to be considered complete unless it is determined that a component is not necessary by the County Engineer:

Hydraulic Study Requirements for Floodplain Project Reviews

A Floodplain Project Review requires the submittal of a hydraulic report (PE Certified) and appendices which include the following components:

Hydraulic Report

- Table of Contents: all sections, figures, tables, and appendices must be listed with page numbers.
- Project Description: provide a description regarding the purpose and nature of the work, the project location, location and condition of bridges and culvert crossings at or near the project site, location of any insurable structures at or near the project site, project participants, and any special hydraulic considerations.
- Background: provide the name of the flooding source (e.g. Big Thompson River) and the associated Flood Insurance Rate Map (FIRM) panel. The background must describe any previous hydraulic studies which have been completed for the project site and reference all map revisions (CLOMRs/LOMRs) which impact the project site.
- Location Maps: provide at least two maps showing the project location. One map must have a scale no smaller than what is required to show the extents of the project site (vicinity map) and the other must have a scale no larger than 1:12,000 to show the broader area surrounding the project site (location map). Both maps must be annotated to show the project site, study limits, roads (with road names labeled), bridges, culvert crossings, and access routes.
- Survey Information: provide the source of topographic and survey data along with the horizontal and vertical datums.
- Hydrology: identify the source of the discharge information used during the hydraulic analysis. Provide a table of discharge values for the 10-year, 50-year, and 100-year flood events resulting from the hydrologic study. If an independent hydrologic study was completed for the project, that study must be submitted separately from the hydraulic study.
- Hydraulic Modeling:

- Hydraulic Model Description: describe the purpose of the study, the study limits, the location of bridges, roads, and culvert crossings, along with any other special hydraulic considerations.
- Modeling Software: provide the name and version of the hydraulic modeling software used for the analysis.
- Plan Description & Table: provide a description for, and table showing, all the hydraulic plans used in the analysis. The table should include the plan names along with the associated geometry and flow files used in the plan. Hydraulic plans typically include the effective, duplicate effective, corrected-effective, existing, proposed, and post-project or as-built conditions. A separate floodway plan is also typically required to perform a floodway analysis.
- Cross-Sections: describe the location of the hydraulic cross-sections, cross-section spacing, Manning's roughness coefficients, bank stations, and contraction & expansion coefficients. If the project proposes to physically modify the geometry of any cross sections or structures from the base condition, describe the nature of the changes and which cross-sections will be impacted. A table and cross-section plots for each cross-section are required as appendices to the report as described below.
- Hydraulic Parameters: describe how the hydraulic parameters were determined and reasons for any changes from the base condition. The description should include, at minimum, discussion of Manning's roughness coefficients, bank stations, and contraction & expansion coefficients.
- Ineffective Flow Areas: describe how the ineffective flow areas were determined and reasons for any changes from the base condition. Ineffective flow areas must be clearly shown on the cross-section plots in the appendices.
- Base Flood Elevations (BFEs) & Flood Profile: describe the 1% ACE flood profile and flow conditions along the study reach. How do bridges and crossings impact the water surface elevations? How does the project impact the hydraulic characteristics? Explain any differences in the BFEs between the base condition and the other model conditions (e.g. existing, proposed, as-built).
- Floodway Encroachment Analysis: describe the encroachment method and associated parameters used in the analysis. If the modeling software or version used for the floodway analysis varies from that used in the hydraulic analysis, state the software and version used for the floodway analysis and why it has been chosen.

- Scour Analysis: describe the method used to estimate the anticipated scour depth(s) and the design for any protection measures which are needed to protect from scour. Scour protection measures must be shown in the construction plans.
- Results: provide a general discussion of the hydrologic and hydraulic modeling results. Discuss any changes in flood discharges, water surface elevations (BFE and floodway elevations), and floodplain/floodway boundaries. Discuss any adverse impacts due to the project on structures or lands, including scour impacts. Describe any mitigation measures that will be incorporated such as floodproofing or channel/bank stabilization.
- Errors: explain any modeling errors which impact the study limits and address how those errors have been resolved.
- Approval Criteria: list the applicable approval criteria from the LCLUC and address how each criteria has been adequately met by the project. Refer to LCLUC Section 12.1.6.H.2 for approval criteria.

Hydraulic Appendices

In addition to the report, several items must be submitted as appendices as described below:

- Hydraulic Model: provide a digital copy of the hydraulic model used for the analysis.
- FDP submittal requirements applicable to the request (see Floodplain Development Permit section above)
 - Floodplain Development Permit (FDP) Application
 - Construction Plans (PE Certified)
 - Certificates
 - Floodproofing Design
 - Repair or Improvement Submittals
 - Ownership Documentation
 - Other Permits & Approvals
- No-Rise Certificate (PE Certified): unless FEMA has approved a CLOMR for the project, the engineer must provide a signed and stamped copy of a No-Rise Certificate which certifies that the project will not increase the BFEs. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).

- No Adverse Impact Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No Adverse Impact Certificate which certifies that the project will not adversely impact a structure. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- Cross-Section Table: provide a table showing the river station, downstream reach lengths, Manning's roughness coefficients, bank stations, ineffective flow areas, and contraction & expansion coefficients for each cross-section affected by the project. If the project proposes to physically modify the geometry of any cross sections from the base condition, provide a column stating the nature of the changes for each modified cross-section. The table should include these values for each geometry file (e.g. existing, proposed, as-built) and highlight values which have been modified from the base model (e.g. effective or existing).
- Base Flood Elevation (BFE) Comparison Table: provide a table showing the BFEs for all model conditions along with the differences between the model conditions.
- Cross-Section Plots: provide cross-section plots for each cross-section affected by the project. Plots should be submitted showing the ground elevation data, water surface elevation data, ineffective flow areas, flow obstructions, and floodway encroachments for each geometry and discharge frequency.
- Scour Calculations (PE Certified): provide detailed calculations for the estimated scour depth and protection which are stamped and signed by a licensed Colorado Professional Engineer (PE).
- Other requirement(s) as determined by the County Engineer to be necessary to allow the review criteria to be adequately evaluated.

All required submittal items must be provided in **three (3) hard copies** and **one (1) digital copy**.

Map Amendments

Map amendments are proposals to revise the regulatory floodplain boundaries or associated floodplain data (such as base flood elevations) within the FPO District. Under the National Flood Insurance Program (NFIP), Larimer County requires that map amendments are submitted under the following circumstances:

- A Conditional Letter of Map Revision (CLOMR) must be submitted if floodplain development is proposed within the FPO District that would, upon construction, affect the hydrologic and hydraulic characteristics of a flooding source and result in the modification of the floodway zone, the Base Flood Elevations (BFEs), or FEMA's Special Flood Hazard Areas (SFHAs, a.k.a. FEMA Floodplain).

- A Letter of Map Revision (LOMR) must be submitted if development has occurred which:
 - Received a Conditional Letter of Map Revision (CLOMR) from FEMA before the start of construction,
 - Results in an increase in the 1% annual chance (100-year) water surface elevation,
 - Results in a decrease in the 1% annual chance (100-year) water surface elevation greater than 0.3 foot, or
 - Involves alteration(s) of a watercourse which will relocate the channel.

The County Engineer may also require that a CLOMR and/or LOMR be submitted for projects at his or her discretion. CLOMRs and LOMRs must be reviewed by the Flood Review Board (FRB) prior to County approval.

The process for CLOMR/LOMR submittals is shown in Figure 4. Typically, a project which will modify the regulatory floodplain boundaries or elevations will require the submittal of both a CLOMR and a LOMR. These will need to be reviewed by the Larimer County Flood Review Board (FRB) and FEMA before and after construction. In the case of a locally administered floodplain (such as those established by the City of Fort Collins), the local authority will review the map amendment instead of FEMA.

Hydraulic Report

A map amendment requires the submittal of a hydraulic report (PE Certified) and appendices which include the following components:

- Table of Contents: all sections, figures, tables, and appendices must be listed with page numbers.
- Project Description: provide a description regarding the purpose and nature of the work and map amendment proposal, the project location, condition of bridges and culvert crossings at or near the project site, location of any insurable structures at or near the project site, project participants, and any special hydraulic considerations.
- Background & Study Limits: describe the proposed revision reach and provide the name of the flooding source (e.g. Big Thompson River), the impacted Flood Insurance Rate Map (FIRM) panels, effective FIRM dates, and the river stations of the cross-sections that will tie into the effective study. The background must describe any previous hydraulic studies which have been completed for the project site and reference all map revisions (CLOMRs/LOMRs) which impact the project site.
- Location Maps: provide at least two maps showing the project location. One map must have a scale no smaller than what is required to show the extents of the project site

(vicinity map) and the other must have a scale no larger than 1:12,000 to show the broader area surrounding the project site (location map). Both maps must be annotated to show the project site, study limits, roads (with road names labeled), bridges, culvert crossings, and access routes.

- Mapping & Survey Information: describe the source of the survey data and topographic mapping used for the project including the survey or mapping company, collection date, scale, contour interval, vertical datum using the North American Vertical Data of 1988 (NAVD88), and control point data. This section should also reference the horizontal datum (North American Datum of 1983, or NAD 83) and mapping projection (Colorado State Plane North) used for the base mapping. If the mapping uses ground coordinates, please provide the conversion factor to grid coordinates or a table showing XY values for several known points in both grid and ground coordinates.
- Hydrology: identify the source of the discharge information used during the hydraulic analysis. Provide a table of discharge values for the 10-year, 50-year, and 100-year flood events resulting from the hydrologic study. If an independent hydrologic study was completed for the project, that study must be submitted separately from the hydraulic study.
- Hydraulic Modeling:
 - Hydraulic Model Description: describe the purpose of the study, methodology, study limits, the location of bridges, roads, and culvert crossings, along with any other special hydraulic considerations.
 - Modeling Software: provide the name and version of the hydraulic modeling software used for the analysis.
 - Plan Description & Table: provide a description for, and table showing, all the hydraulic plans used in the analysis. The table should include the plan names along with the associated geometry and flow files used in the plan. Hydraulic plans typically include the effective, duplicate effective, corrected-effective, existing, proposed, and post-project or as-built conditions. A separate floodway plan is also typically required to perform a floodway analysis.
 - Cross-Sections: describe the location of the hydraulic cross-sections, cross-section spacing, Manning's roughness coefficients, bank stations, and contraction & expansion coefficients. If the project proposes to physically modify the geometry of any cross sections or structures from the base condition, describe the nature of the changes and which cross-sections will be impacted. A

table and cross-section plots for each cross-section are required as appendices to the report as described below.

- Hydraulic Parameters: describe how the hydraulic parameters were determined and reasons for any changes from the base condition. The description should include, at minimum, discussion of Manning's roughness coefficients, bank stations, and contraction & expansion coefficients.
 - Ineffective Flow Areas: describe how the ineffective flow areas were determined and reasons for any changes from the base condition. Ineffective flow areas must be clearly shown on the cross-section plots in the appendices.
 - Base Flood Elevations (BFEs) & Flood Profile: describe the 1% ACE flood profile and flow conditions along the study reach. How do bridges and crossings impact the water surface elevations? How does the project impact the hydraulic characteristics? Explain any differences in the BFEs between the base condition and the other model conditions (e.g. existing, proposed, as-built).
 - Floodway Encroachment Analysis: describe the encroachment method and associated parameters used in the analysis. If the modeling software or version used for the floodway analysis varies from that used in the hydraulic analysis, state the software and version used for the floodway analysis and why it has been chosen.
 - Tie-Ins: describe the boundary conditions, horizontal tie-ins, and vertical tie-ins to the effective study. Provide the magnitude of any deviations from the effective data at the tie-in locations.
 - Scour Analysis: describe the method used to estimate the anticipated scour depth(s) and the design for any protection measures which are needed to protect from scour. Scour protection measures must be shown in the construction plans.
- Results: provide a general discussion of the hydrologic and hydraulic modeling results. Discuss any changes in flood discharges, water surface elevations (BFE and floodway elevations), and floodplain/floodway boundaries. Discuss any adverse impacts due to the project on structures or lands, including scour impacts. Describe any mitigation measures that will be incorporated such as floodproofing or channel/bank stabilization.
- Errors: explain any modeling errors which impact the study limits and address how those errors have been resolved.

- Approval Criteria: list the approval criteria for map amendments from the LCLUC and describe how each criteria or requirement has been adequately met by the project. Refer to LCLUC Section 12.1.6.G.2 for approval criteria.
- References: list all references used during the preparation of the hydraulic study along with the modeling software programs and version(s).

Hydraulic Appendices

In addition to the report, several items must be submitted as appendices as described below:

- Hydraulic Model: provide a digital copy of the hydraulic model used for the analysis.
- FDP submittal requirements applicable to the request (see Floodplain Development Permit section above)
 - Floodplain Development Permit (FDP) Application
 - Construction Plans (PE Certified)
 - Certificates
 - Floodproofing Design
 - Repair or Improvement Submittals
 - Ownership Documentation
 - Other Permits & Approvals
- Floodplain Workmaps (PE Certified): provide floodplain workmaps showing the following comparisons as applicable:
 - Effective Condition vs. Corrected-Effective Condition
 - Corrected-Effective Condition vs. Existing Condition
 - Effective and Existing Conditions vs. Proposed Condition
 - Effective and Existing Conditions vs. As-Built Condition
 - Proposed Condition vs. As-Built Condition

The floodplain workmaps must show the following components:

- Floodplain and floodway boundaries for each model condition (1% ACE and 0.2% ACE)
- Topographic contours (up to 2' contour interval)
- Study Limits

- Hydraulic Cross-Sections
- Base Flood Elevations
- Ineffective Flow Areas
- Stream Profile
- Area(s) of Disturbance
- Structures
- Roads and Hydraulic Structure Alignments (Bridges, Culvert Crossings, etc.)
- Property Boundaries
- Horizontal and Vertical Datums (NAD83, NAVD88)
- Date & Source of Aerial Photography
- Date and Source of Survey & Topographic Information
- Legend

Floodplain information should follow a logical naming and appearance convention to identify the flood hazard features from the geographic or background data. Additionally, a map legend or labels for the pertinent floodplain information should be included. Recommended symbology and naming conventions are presented in Figure 2.

- Cross-Section Table: provide a table showing the river station, downstream reach lengths, Manning's roughness coefficients, bank stations, ineffective flow areas, and contraction & expansion coefficients for each cross-section affected by the project. If the project proposes to physically modify the geometry of any cross sections from the base condition, provide a column stating the nature of the changes for each modified cross-section. The table should include these values for each geometry file (e.g. existing, proposed, as-built) and highlight values which have been modified from the base model (e.g. effective or existing).
- Base Flood Elevation (BFE) Comparison Table: provide a table showing the BFEs for all model conditions along with the differences between the model conditions.
- Annotated Flood Profiles: provide a comparison profile in FEMA FIS format to identify changes in BFEs. Comparison profiles should contain the effective and proposed/post-project condition profile, as well as a box noting the area of revision. There are any number of ways to generate and present this comparison profile, however, the profile should utilize a common stationing system, like what is shown in the comparison table and effective FIS profile (if applicable). HEC-RAS profile plots will not be accepted. Free

software is available for download from FEMA's website to generate FIS formatted profiles from HEC-RAS. These programs can be found at the following link:

FEMA Flood Mapping Software:

<https://www.fema.gov/flood-maps/software>

- Annotated Floodway Data Table: provide an annotated floodway data table indicating which effective cross-sections are being revised as part of the submittal and display the revised floodway data for the revised cross-sections. Since the annotated floodway data table references the stream stationing, some sort of correlation must also be provided when cross-section labels are different than the corresponding stream stationing. FEMA FIS format must be used for all annotated floodway data tables.
- Annotated FIRM Panels: annotated FIRM exhibits are required for all impacted FIRM panels. The annotated FIRM must show the boundaries of the modified floodplain and floodway within the revised reach and how they tie into the effective information at the upstream and downstream tie-in locations. For requests within a Municipal Floodplain, an annotated floodplain map for the affected floodplain should be prepared in place of the FIRM exhibit and included as part of the submittal.
- Agreement Tables: provide an agreement table which correlates the following information in the hydraulic model, floodplain work map, and floodway data:
 - Distance between hydraulic cross-sections along channel centerline
 - Cumulative channel distance along channel centerline
 - 1% annual-chance (100-year) floodplain top width
 - Regulatory floodway top width (if applicable)

The acceptable tolerance is plus or minus 5% between the model and map data. For detailed 1% ACE floodplain areas, the revised BFEs plotted on the work maps should also correlate with the profile in the hydraulic model. The revised BFEs shown on the work maps should adhere to the following guidelines:

- BFEs should be placed and labeled in the correct location along the channel centerline as compared to the adjacent hydraulic cross-sections,
- BFEs should intersect the location where the proposed floodplain crosses the whole foot contour value indicated by the BFE,
- Shape and orientation of BFEs should follow the shape and orientation of nearby hydraulic cross-sections and the general flow patterns, and
- BFEs should not cross nearby hydraulic cross-sections.

- Cross-Section Plots: provide cross-section plots for each cross-section affected by the project. Plots should be submitted showing the ground elevation data, water surface elevation data, ineffective flow areas, flow obstructions, and floodway encroachments for each geometry and discharge frequency.
- Scour Calculations (PE Certified): provide detailed calculations for the estimated scour depth and protection which are stamped and signed by a licensed Colorado Professional Engineer (PE).
- Notifications: notifications of the forthcoming map amendment are required (1) before advertisement of the FRB meeting and (2) during the FEMA review process.
 - Initial Notifications: at least three (3) weeks prior to the FRB meeting, the engineer must submit individual notification letters to the County for each property impacted by the map revision. These letters must be written in layman's terms so that they are easily understandable by the public. After review and approval by the County, the engineer and/or applicant must send these notification letters to each impacted property owner and provide written confirmation to the County that they have been sent and received. If there is not adequate information available to notify certain property owners (e.g. address information is not available), the engineer must send written confirmation to the County that due diligence has been taken to notify these property owners before a determination was made that they cannot be reached.
 - FEMA Notifications: following County approval of the map amendment, the engineer must send individual notifications and/or publish a newspaper notification per FEMA's requirements as indicated during their review process. The County must review and approve these notifications prior to sending or publishing. The engineer and/or applicant, not the County, shall send and/or publish these notifications at their expense.
- Spatial Data Files: provide digital copies of geographic data files (e.g. shapefiles) for the floodplain and floodway boundaries delineated by the study. Recommended symbology and naming conventions are presented in .
- Model Error Report or Table: provide a report or table showing all errors indicated by the error assessment tool in the modeling software (e.g. cHECK-RAS) which impact the study limits and provide a short description of how the errors have been resolved.
- FEMA MT-2 Form: provide one copy of the required FEMA MT-2 form. The form must be filled out and submitted with all required signatures including the requester and a licensed Colorado Professional Engineer (PE). Upon approval of the map amendment,

the County Engineer or his designee will sign the form. The signed forms will then be returned to the applicant and/or engineer for submittal to FEMA.

- No Adverse Impact Certificate (PE Certified): the engineer must provide a signed and stamped copy of a No Adverse Impact Certificate which certifies that the project will not adversely impact a structure. A copy of this form can be downloaded through the Larimer County Floodplains website (<https://www.larimer.org/engineering/floodplains>).
- Other requirement(s) as determined by the County Engineer to be necessary to allow the review criteria to be adequately evaluated. These may include:
 - Additional calculations or figures
 - Copies of previous studies or reports
 - Correspondence

All required submittal items must be provided in **three (3) hard copies** and **one (1) digital copy**.

Figure 1. Map Amendment Flowchart

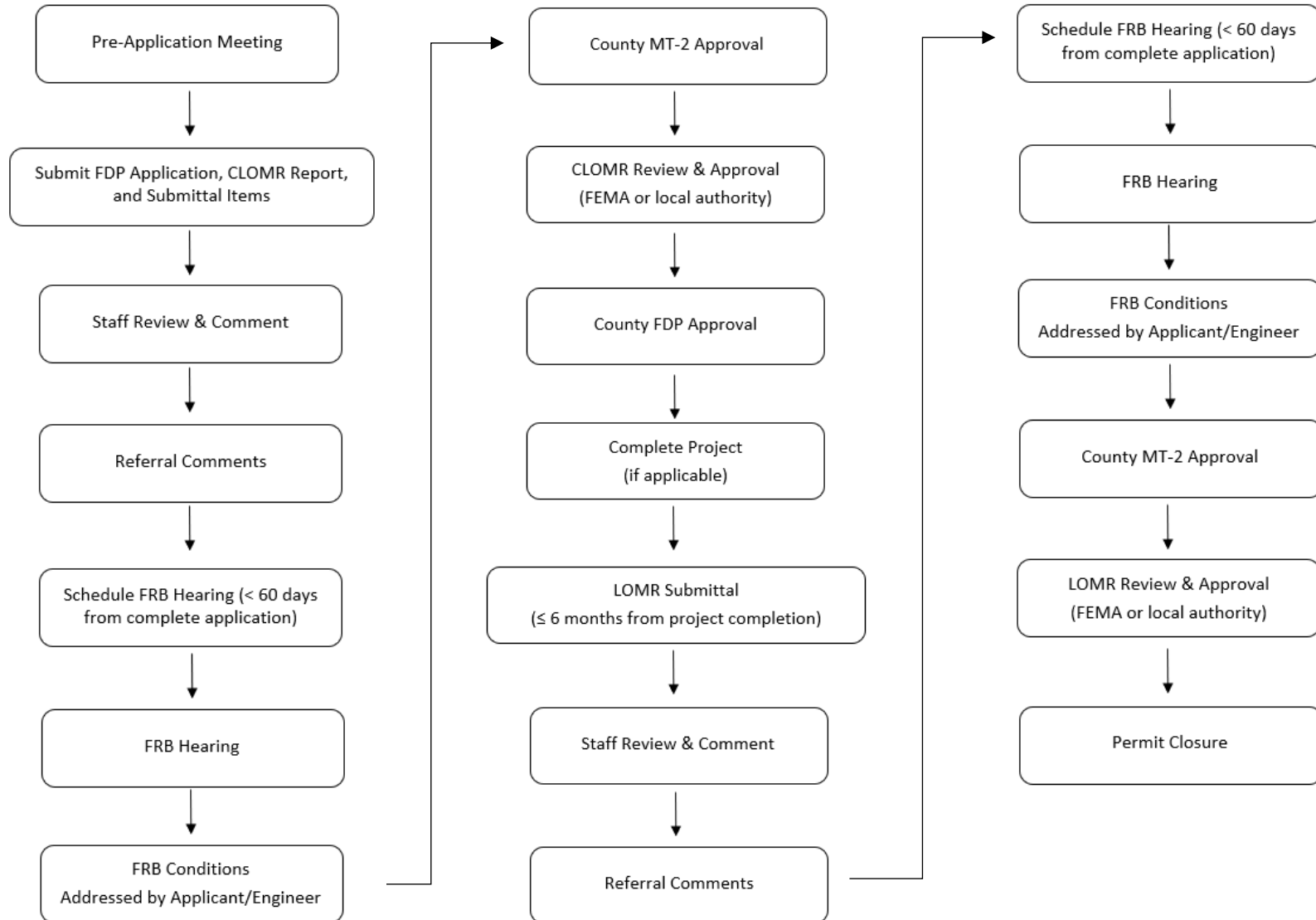


Figure 2. Floodplain Layer Symbology & Naming Conventions

Feature	Layer/Shape Name	Color	Line Type
Effective 100-YR Floodplain	100-YEAR-EFF	Light Blue	Continuous
Corrected Effective 100-YR Floodplain	100-YEAR-CE	Light Orange	Continuous
Existing 100-YR Floodplain	100-YEAR-EX	Green	Continuous
Proposed 100-YR Floodplain	100-YEAR-PP	Dark Blue	Continuous
Effective 500-YR Floodplain	500-YEAR-EFF	Light Blue	Dashed
Corrected Effective 500-YR Floodplain	500-YEAR-CE	Light Orange	Dashed
Existing 500-YR Floodplain	500-YEAR-EX	Green	Dashed
Proposed 500-YR Floodplain	500-YEAR-PP	Dark Blue	Dashed
Effective Regulatory 0.5-ft Floodway	HALF-FT-FLDWY-EFF	Light Blue	Hidden
Corr. Eff. Regulatory 0.5-ft Floodway	HALF-FT-FLDWY-CE	Light Orange	Hidden
Existing Regulatory 0.5-ft Floodway	HALF-FT-FLDWY-EX	Green	Hidden
Proposed Regulatory 0.5-FT Floodway	HALF-FT-FLDWY-PP	Dark Blue	Hidden
Hydraulic Cross-Section	XSECTION	Black	Continuous
Effective Base Flood Elevation (BFE)	BFE-EFF	Black	Zigzag
Corr. Eff. Base Flood Elevation (BFE)	BFE-CE	Light Grey	Zigzag
Existing Base Flood Elevation (BFE)	BFE-EX	Dark Grey	Zigzag
Proposed Base Flood Elevation (BFE)	BFE-PR	Red	Zigzag
Stream Centerline	CHANNEL	Black	Center
Culvert	CULVERT	Black	Continuous
Bridge	BRIDGE	Black	Continuous
Footbridge	FOOTBRIDGE	Black	Continuous
Community Boundaries	BNDRY-COMMUN	Thick Black	Phantom
Property Boundaries	BNDRY-PROP	Grey	Phantom