CHAPTER 6.0 RUNOFF

6.1 Introduction

This chapter provides design criteria and procedures to be used for determining runoff peaks and volumes for the design of stormwater drainage infrastructure in the County.

The selection of the appropriate criteria and procedures will be based on the project size, location and/or type. Many small projects can be completed using the Rational Method where only peak discharges are computed. Larger projects with complex routing and those that require detention design will need to use one of the methods that generate runoff hydrographs. The Colorado Urban Hydrograph Procedure (CUHP) and EPA Stormwater Management Model (SWMM) are most applicable for hydrologic modeling in urban areas. The Hydraulic Engineering Center – Hydrologic Modeling System (HEC-HMS) includes other methods that can be applied in both urban and rural watersheds. In some situations, it may be possible to use streamflow measurements or estimates from other sources. Table 6-1 is a summary of the methods discussed in this chapter and general guidelines for when each method can be used. The following sections discuss each method in more detail and provide additional criteria.

Table 6-1. Accepted Hydrologic Runoff Methods in Larimer County

Runoff Calculation Method	Application Criteria
Rational Method	● May be used in simple drainage basins of less than 90 acres. ● Should not be used when routing is required or parameters other than peak flow are warranted.
CUHP	● Urban areas only ● Required for basins greater than 90 acres, may be used for smaller basins ● Should be used in conjunction with SWMM when routing of the hydrograph is required.
SWMM	● Used for routing of runoff hydrographs generated from CUHP or HEC-HMS ● May be used for generating runoff hydrographs in Fort Collins Growth Management Area
HEC-HMS	● May be used for rural areas ● Includes multiple runoff hydrograph methods (including Soil Conservation Service Curve Number) ● Also includes routing methods
Streamflow Statistical Analysis	● Used for bridge/culvert design on streams with existing gages ● At least 30 years of annual maximum peak discharge data required
StreamStats	● Limited application for small, private projects such as culverts/bridges. Must be approved for use by County Engineer.

The percent impervious values that shall be used for different land uses and surfaces are provided in Table 6-2. If an appropriate land use or surface is not provided in Table 6-2, the engineer shall

use values from the MHFD Manual or another relevant source (subject to acceptance by the County Engineer).

Table 6-2: Percent imperviousness values to be used in hydrologic modeling

Land Use or Surface Characteristics	Percentage Imperviousness (%)
Business:	
Downtown Areas	95
Suburban Areas	75
Residential Lots (lot area only):	
Single-family	
2.5 acres or larger	12
0.75-2.49 acres	20
0.25-0.74 acres	30
0.24 acres or less	45
Apartments/Multi-Family	75
Industrial:	
Light Areas	80
Heavy Areas	90
Parks, cemeteries:	10
Schools:	55
Railroad yard areas:	50
Undeveloped Areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Offsite flow analysis (when land use not defined)	45
Streets/Roadways:	
Paved	100
Recycled Asphalt	100
Gravel (packed)	40
Driveways/Sidewalks:	90
Roofs:	90
Lawns:	2

6.2 Rational Method

The Rational Method may be used to compute peak flows for projects with a contributing area less than 90 acres and which do not have complex drainage systems (e.g., different flow paths for different flow rates). The overall contributing area should be subdivided into smaller subbasins so that hydrologic losses are homogeneous and uniform within each subbasin and to provide adequate resolution for design of drainage infrastructure. The user should read and understand the general applications, limitations and assumptions of the Rational Method as discussed in the *Runoff* chapter of the MHFD Manual.

Application of the Rational Method shall follow the design procedures provided in the *Runoff* chapter of the MHFD Manual. Use of the MHFD's UD-Rational software program is preferred, however, the use of other spreadsheet programs and/or well-organized written calculations are also acceptable.

6.3 Colorado Urban Hydrograph Procedure (CUHP)

The Colorado Urban Hydrograph Procedure (CUHP) is a unit hydrograph method developed for application in urban watersheds along the Front Range of Colorado. It generates a full runoff hydrograph from each subcatchment using design storm rainfall distributions and various watershed parameters. Routing of the subcatchment runoff hydrographs is performed using the EPA Stormwater Management Model (SWMM) discussed in the following section.

CUHP is available from the MHFD as a Microsoft Excel-based program. Application of CUHP, including selection of parameter values, shall follow the procedures provided in the *Runoff* chapter of the MHFD Manual and the CUHP User's Manual.

6.4 EPA Stormwater Management Model (SWMM)

SWMM is a computer program that simulates stormwater runoff and flow routing through urban watersheds. Runoff hydrographs are generated by a non-linear reservoir routing algorithm using design storm rainfall distributions and various watershed parameters. The County prefers that CUHP is used for generating runoff hydrographs for urban watersheds; however, exceptions may be necessary if the project is within the City of Fort Collins Growth Management Area.

SWMM's hydraulic routing features include open channels, storm pipes, culverts, and detention basins. When used in conjunction with CUHP, SWMM imports runoff hydrographs directly from the CUHP/SWMM interface file and applies them to the corresponding SWMM routing node. SWMM models should be run using the kinematic wave routing method. Use of the dynamic wave routing method may be approved by the County Engineer if the applicant can demonstrate the need for doing so. The steady-state routing method is not allowed under any circumstances. The SWMM model can be downloaded from the EPA Stormwater Management Model website.

https://www.epa.gov/water-research/storm-water-management-model-swmm

6.5 Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS)

The HEC-Hydrologic Modeling System (HMS) is a computer program with several different methods for generating runoff hydrographs and routing hydrographs through various conveyance elements. Although the County will accept any of the rainfall-runoff methods included in HEC-HMS, the Soil Conservation Service (SCS) Curve Number Loss Method and SCS Unit Hydrograph Method are commonly used and familiar to most engineers. The appropriate

routing method must be selected by the user based on conditions being modeled. It is recommended that the user discuss which methods to use with the County Engineer prior to proceeding with the modeling work.

https://www.hec.usace.army.mil/software/hec-hms/

6.6 Streamflow Statistical Analysis

If a project is located on a gaged stream, it may be appropriate to use the recorded stream flow data to determine peak flow estimates for various return intervals. The period of record for the stream gage should extend at least 30 years if the 100-year return interval is to be estimated. The user is responsible for determining the reasonableness of the gage data considering the location of the project compared to the gage and changes in land use or other watershed characteristics that have occurred over time or are projected to occur. The USGS Guidelines for Determining Flood Flow Frequency Bulletin 17C (USGS, 2019) includes a variety of methods that may be applicable for this type of analysis.

https://pubs.usgs.gov/tm/04/b05/tm4b5.pdf

6.7 StreamStats

StreamStats is an online tool provided by the United States Geological Survey (USGS) to estimate peak flows for various return intervals at a given design point. While relatively easy to use, the estimates provided by StreamStats can have large margins of error that exceed those of more detailed hydrologic analyses. When using StreamStats results, the user should review the reported margin of error and consider applying a safety factor (i.e., increasing the design flow) to provide a level of conservativeness. The County Engineer will generally only approve StreamStats estimates for relatively small, low-risk projects on private property and must be approved by the County Engineer prior to submittal.

https://streamstats.usgs.gov/ss/

6.8 Offsite Flows (Upstream)

Hydrologic analysis is required to quantify upstream, offsite flows that drain through a proposed project area. Offsite flows shall be based on fully developed conditions as defined by existing drainage master plans or other planning documents. If such plans do not exist, then existing conditions may be used. Additionally, the County may require that a drainage easement be acquired for the areas where offsite flows are conveyed. The engineer shall consult with the County Engineer to determine the project-specific requirements of the hydrologic analysis and easement.

6.9 Post-Fire Runoff Considerations

The hydrologic response of watersheds impacted by wildfire can be significantly greater than natural conditions. Burned vegetation and soil result in a reduction of interception/infiltration losses and shorter overland flow paths that ultimately increase runoff volumes and peak flows. Experience in Colorado has shown that a 2-year rainfall event can produce post-fire runoff peaks and volumes exceeding the pre-fire 10/25-year peaks and volumes. These conditions are typically most significant in the first 5 years after a wildfire and can last for over 10 years depending on various factors.

The design engineer should make appropriate considerations for these changes when working on any project in/near recent wildfire-impacted watersheds. For example, various hydrologic modeling parameters may have to be modified from their typical values to appropriately account for the increased hydrologic response. Several publications are available online that provide guidance for post-fire hydrologic modeling, including the Natural Resource Conservation Service (NRCS) publication, *Hydrologic Analyses of Post-Wildfire Conditions, Hydrology Technical Note No. 4* (NRCS, 2016). The design engineer is encouraged to discuss appropriate modeling methods with the County Engineer prior to developing submittals.

6.10 Submittal Requirements

Drainage Reports shall include the following information (at a minimum) to document runoff calculations:

- Discussion of hydrologic method(s) used, including assumptions and references used for parameter selection,
- Plans showing delineation, area and runoff coefficients/imperviousness of subbasins,
- Spreadsheets showing all Rational Method calculations, including references for equations used for different spreadsheet columns and calculations, and
- Print outs of modeling input files and summary tables/figures of model outputs at critical design points.

6.11 References

Natural Resource Conservation Service (NRCS), 2016. Hydrologic Analysis of Post-Wildfire Conditions – Hydrology Technical Note No. 4. August 2016.

United States Geological Survey (USGS), 2019. Guidelines for Determining Flood Flow Frequency – Bulletin 17C, Version 1.1. May 2019.