Storm Drainage Design and Technical Criteria

AURORA WATER

November 2023

CITY OF AURORA, COLORADO
STORM DRAINAGE DESIGN AND TECHNICAL CRITERIA

aka Storm Drainage Criteria

AURORA
WATER

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This manual sets forth rules and regulations to facilitate the proper administration of Aurora City Code Article VII of Chapter 138.

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CHAPTER 1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of the *Storm Drainage Design and Technical Criteria* Manual (Manual) is to present the design criteria and regulations governing drainage and stormwater management in the City of Aurora (CoA). This Manual constitutes “rules and regulations” as that term is used in the Aurora City Code (Aurora City Code Section 138-363). All planning and design must manage storm drainage with regard to quantity and quality to protect the health, safety, and welfare of current and future residents of the CoA. This Manual provides uniform criteria and procedures that apply to storm drainage systems across the CoA. These criteria incorporate much of Mile High Flood District's (MHFD’s) *Urban Storm Drainage Criteria Manual* (MHFD Manual) (Mile High Flood District, latest edition). For any criteria not included in this Manual, refer to Volumes 1 through 3 of the MHFD Manual for technical reference. See Chapter 3 for more detailed information on the hierarchy of criteria and guidance documents.

1.2 CITY CODE PROVISIONS

The Aurora City Code Sections 70-21, 138-363, and 138-438 delegate authority to the General Manager of Aurora Water (AW) to promulgate this Manual as rules and regulations (Aurora City Code Section 70-21(15); Aurora City Code Section 138-363; Aurora City Code Section 138-438). Additional information on municipal authority to regulate drainage improvements can be found in Volume 1, Chapter 2: Drainage Law of the MHFD Manual.

1.3 INTERPRETATION

In the interpretation and application of the provisions of this Manual, the following will govern:

1. This Manual provides the minimum requirements to protect the public health, safety, and welfare of the residents of the CoA, protect property, and minimize adverse impacts to the environment.

2. Whenever a provision of this Manual and any other provisions of the Aurora City Code, including the Unified Development Ordinance (UDO; i.e., Aurora City Code Chapter 146), ordinance, resolution, rule, or regulation of any kind contains any requirement(s) covering any of the same subject matter, the requirement(s) that are more restrictive or impose higher standards will govern.

3. This Manual does not abrogate or annul any easements, permits, drainage reports, or construction drawings recorded, issued, or accepted by the CoA prior to the Effective Date of this Manual.

The General Manager of AW has final authority to resolve any conflicting interpretations of this Manual.

1.4 APPLICABILITY OF UPDATED CRITERIA

The criteria contained in this Manual are applicable as of the Effective Date of the Manual. See Chapter 3 for information on grandfathering from the previous version of this Manual.

1.5 SIGNIFICANT UPDATES BY CHAPTER

Several changes have been made since the last version of this Manual (published October 2010) to update the criteria contained herein to reflect current best practices and CoA goals related to storm drainage. A summary of significant changes is provided below.

1. Chapter 1: Introduction
    - Provides an overview of major updates.
2. Chapter 2: Subdivision Planning and Submittal Requirements
    - Simplifies the requirements for all submittal types.
    - Incorporates standards previously included in the CoA's *Roadway Design and Construction Specifications* (RDCS) (City of Aurora, latest edition).
    - Describes certification of detention and water quality facilities.
    - Defines Structure Selection Reports (SSRs).
    - Describes Inspection and Maintenance (I&M) Plans.
    - Explains the procedure for variances.
3. Chapter 3: Storm Drainage Policy
    - Moves miscellaneous items previously included in this chapter to relevant chapters.
    - Elaborates on the foundational ideas used to create this Manual and employed during the drainage review process.
    - Lists and explains watersheds that have special requirements.
    - Clarifies when detention and water quality are required, with numerical thresholds.
    - Discusses submittal policies for various submittal types.
    - Explains policy for grandfathering.
    - Explains how variance requests are reviewed.
4. Chapter 4: Floodplain Regulations
    - Rewritten to match the floodplain ordinance adopted on November 25, 2013.
    - Explains submittal requirements, policies, and procedures related to floodplain management.

5. Chapter 5: Hydrologic Criteria

    - Incorporates current National Oceanic and Atmospheric Administration (NOAA) Precipitation Atlas 14 (NOAA Atlas 14) as basis for rainfall depth-duration-frequency and intensity-duration-frequency data. Rainfall depths are generally lower than those used previously.

    - Refers to MHFD Manual for Rational method and associated formulas including time of concentration.

    - Incorporates new analysis of imperviousness associated with different land uses and surface types. Additional guidance given on landscaping, gravel, and solar panels.

    - Method for determining runoff coefficients now uses percent imperviousness and hydrologic soil group to calculate coefficients, consistent with the approach in the MHFD Manual.

6. Chapter 6: Streets, Inlets, and Storm Drains

    - Updates the criteria related to allowable spread and depth for street flow capacity.

    - Provides additional guidance related to inlet clogging factors, inlet locations, and sump inlets in series.

    - Updates the criteria related to storm drain hydraulics, including, an updated requirement that storm drains convey the minor storm event while flowing at a maximum of 80% of full pipe capacity.

7. Chapter 7: Open Channels

    - References MHFD Manual for many applicable criteria.

    - Distinguishes between major drainageways, minor drainageways, and swales/ditches, and the corresponding design requirements for each.

    - Requires high-functioning lower-maintenance streams (HFLMS) in the design of major and minor drainageways.

    - References Stream Management Corridors (SMCs) for development boundaries.

8. Chapter 8: Hydraulic Structures

    - Provides guidance on when different types of grade control structures are applicable.

    - Stipulates criteria for soil riprap and void-filled riprap, referencing the MHFD Manual.

9. Chapter 9: Culverts and Bridges

- Adds requirement to submit a SSR for crossings of major drainageways with a span greater than 20 feet.

- Provides criteria for culvert inlets, outlets, safety grates, and emergency flow paths with reference to the MHFD Manual.

- Expands criteria for bridges, including freeboard, scour analysis, emergency overflow paths, and guidance for pedestrian bridges and low water crossings.

10. Chapter 10: Detention

- Establishes full spectrum detention (FSD) as the required approach for detention in the CoA.

- Eliminates the requirement of one foot of freeboard between the 100-year water surface elevation (WSEL) and the spillway invert. Freeboard is still required above the emergency overflow WSEL when the spillway is discharging.

- Adopts “nested” approach for water quality capture volume (WQCV), excess urban runoff volume (EURV), and 100-year storage volume (i.e., the WQCV is included as a part of the EURV, and both the WQCV and EURV are included as a part of the 100-year volume).

- Adds guidance for detention facilities near airports.

11. Chapter 11: Regulations on Stormwater Quality Control

- Updates terminology to match that used in the region and throughout the industry.

- Explains relationship between these criteria and MS4 permits.

- Clarifies what WQ treatment is required in which situations.

- Clearly defines the requirements for Cherry Creek Basin under Regulation 72.

- Provides updated information from Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual related to stormwater control measure (SCM) selection.

12. Chapter 12: Software and Design Tools

- Provides updated guidance on use of specific software packages and design tools, including when proprietary models may be used and what information must be submitted.

13. Appendices

- Removes obsolete technical appendices, such are nomographs.

- Removes I&M forms; I&M templates and information will be housed on the CoA's website.

1.6 REVISIONS

This Manual may be amended as needed. It is the responsibility of the Consultant/Contractor/Developer/Engineer to obtain the latest version of this Manual from the CoA. A list of revisions made after the Effective Date of this Manual will be located here.

1.7 REFERENCES

City of Aurora. (n.d.). Aurora City Code Section 138-363. In *Aurora City Code.* Retrieved from https://aurora.municipal.codes/Code/138-363

City of Aurora. (n.d.). Aurora City Code Section 138-438. In *Aurora City Code.* Retrieved from https://aurora.municipal.codes/Code/138-438

City of Aurora. (n.d.). Aurora City Code Section 70-21(15). In *Aurora City Code.* Retrieved from https://aurora.municipal.codes/Code/70-21(15)

City of Aurora. (latest edition). *Roadway Design & Construction Specifications.* Aurora, Colorado. Retrieved from https://www.auroragov.org/business_services/development_center/codes_rules/design_standards/engineering_design_standards

Mile High Flood District. (latest edition). *Urban Storm Drainage Criteria Manual.* Denver, Colorado. Retrieved from https://mhfd.org/resources/criteria-manual

CHAPTER 2.0 SUBMITTAL REQUIREMENTS

2.1 INTRODUCTION

This chapter describes the process and requirements for drainage submittals to the City of Aurora (CoA). It also explains the requirements for pond certifications, Structure Selection Reports (SSRs), and Inspection and Maintenance (I&M) Plans, as well as the process for obtaining a variance.

2.2 OUTLINE OF SUBMITTAL AND REVIEW PROCESS

2.2.1 General

The CoA's development process is described on the Office of Development Assistance's webpage and in the Development Handbook linked thereon. Drainage reports generally follow the same requirements and processes as civil plans (CPs), as outlined in the CoA's *Roadway Design & Construction Specifications* (RDCS). All submittals are made electronically, via a web portal.

Note that for any of the documents described in Sections 2.2.2 through 2.2.6 below, if the submitted drainage report/letter and plans cannot be approved with the third submittal, the review of the documents will start over, and a new review fee will be required. It is important that quality plans meeting all CoA standards and criteria are submitted at each step of the review cycle, and that any comments are fully and thoroughly addressed before resubmitting. This will save time for all involved.

2.2.2 Master Drainage Reports

Master Drainage Reports (MDRs) are submitted concurrently with the Master Plan (MP) to the web portal set up by the Planning Department. Three separate Portable Document Format (PDF) documents should be uploaded: a narrative report with appendices (i.e., MDR), plan sheets for the MDR, and the MDR Checklist. Aurora Water (AW) staff will review the submittal for completeness and will provide instructions for the submittal of electronic modeling files. When the drainage submittal is complete, these materials will be transferred to a separate folder on the web portal, where subsequent submittals will be made.

Specific requirements for MDR submittals are described in Section 2.3 below.

2.2.3 Preliminary Drainage Reports

Preliminary Drainage Reports (PDRs) are submitted concurrently with the Site Plan to the web portal set up by the Planning Department. Three separate PDF documents should be uploaded: a narrative report with appendices (i.e., PDR), plan sheets (i.e., Preliminary Drainage Plan [PDP]), and the PDR Checklist. AW staff will review the submittal for completeness and will provide instructions for the submittal of electronic modeling files. When the drainage submittal is complete, these materials will be transferred to a separate folder on the web portal, where subsequent submittals will be made.

Specific requirements for PDR submittals are described in Section 2.4 below.

2.2.4 Preliminary Drainage Letters

Preliminary Drainage Letters (PDLs) are submitted concurrently with the Site Plan to the web portal set up by the Planning Department. Two separate PDF documents should be uploaded: a letter with supporting documents (i.e., PDL) and the PDR Checklist.[1] Pre-application notes will outline specific items to be addressed in a PDL. AW staff will review the submittal for completeness and will provide instructions for the submittal of electronic modeling files. When the drainage submittal is complete, these materials will be transferred to a separate folder on the web portal, where subsequent submittals will be made.

Specific requirements for PDL submittals are described in Section 2.4.5 below.

2.2.5 Final Drainage Reports

Final Drainage Reports (FDRs) are submitted as part of the CPs to the folder created by Public Works. The FDR, with appendices and supporting documents, should be uploaded as a single PDF document. The Final Drainage Plan (FDP) and other sheets described in Section 2.5.3 below should be incorporated into the CP sheets. The CP checklist includes drainage requirements and should be included in the overall submittal.

Specific requirements for FDR submittals are described in Section 2.5 below.

2.2.6 Final Drainage Letters

Final Drainage Letters (FDLs) are submitted as part of the CPs to the folder created by Public Works. Two separate PDF documents should be uploaded: a letter with supporting documents (i.e., FDL) and the CP checklist. AW staff will review the submittal for completeness and will provide instructions for the submittal of electronic modeling files.

Specific requirements for FDL submittals are described in Section 2.5.4 below.

2.2.7 Submittal Summary Table

The Submittal Summary Table outlines and compares the requirements of the MDR, PDR, and FDR. The Submittal Summary Table is located here.

2.3 MASTER DRAINAGE REPORT

2.3.1 General

The MDR is the over-arching drainage guidance document required for sites over 80 acres or phased commercial/industrial development in excess of 10 acres. This document provides the framework for all subsequent documents within the area (i.e., PDRs, site plans, FDRs, CPs, etc.). The MDR must be consistent with the information provided in the Aurora Planning Department's MP. The MDR will identify the areas which must be dedicated to drainage infrastructure and inform the overall site design. It is recommended that a drainage engineer be consulted early in the land planning process to ensure drainage needs are accounted for in the

[1] There is no PDL-specific checklist, as every PDL addresses unique circumstances. The PDR checklist should be used, selecting "Not Applicable" as appropriate.

overall site plan and business model. **The MDR must be approved by the AW Drainage Division prior to the MP approval.**

The MDR must provide a conceptual level analysis of the drainage system, including:

- Stream corridor location(s) and widths;
- Detention locations and approximate sizing (volume and area);
- Emergency overflow directions;
- Locations of flow to and from neighboring properties;
- Perpetual maintenance obligations;
- Water quality approach; and
- Compliance with basin-wide regional master plans.

The MDR must be structured in accordance with Section 2.3.4, and the accompanying MDR plans must be in accordance with Section 2.3.5. The MDR and MDR plans must contain all applicable information listed in each section. The MDR must be prepared by a qualified Professional Engineer licensed in the State of Colorado, or under their direct supervision, whose seal and signature must be affixed to the report and all plan sheets at signature set. The engineer must also complete, sign, and submit the MDR Review Checklist to ensure all applicable elements are included prior to formal review. The MDR checklist can be found at this location and all requirements listed therein are considered part of this Manual by reference.

2.3.2 Master Drainage Kick-off Meeting

A drainage kick-off meeting is required for all MDR submittals that include regional infrastructure. This meeting will be used to discuss maintenance eligibility and stream management corridors (SMCs), and to identify relevant reference documents and coordinate unique circumstances for the site. The requirement to hold a drainage kick-off meeting will be identified in the pre-application notes, or by direct communication with AW drainage staff.

The meeting shall be limited to one hour and be held with Mile High Flood District (MHFD) and AW drainage staff prior to submittal of the MDR. The meeting must take place prior to submittal of the MDR to the Planning portal. Meeting minutes shall be prepared by the applicant, reviewed by all attendees, and included in the appendix of the MDR. Contact aurorawaterdrainage@auroragov.org to schedule this meeting.

2.3.3 Crossing Coordination Meeting

A crossing coordination meeting is required for all MDR submittals where a wide drainageway (width of 20 feet or greater, measured along roadway/trail centerline) intersects an arterial roadway and/or a regional trail.[2] The meeting shall be held with the AW Drainage Division, the CoA's Parks, Recreation, and Open Space (PROS) Department, and the CoA's Public Works

[2] As defined by the CoA's Parks, Recreation, and Open Space (PROS) Department's *Dedication and Development Criteria Manual* (City of Aurora, latest edition).

(PW) Department; the goal of the meeting is to define the concept of the crossing of the drainageway. The crossing concept must be included in the MDR, Planning Department's MP, and Master Traffic Impact Study. Meeting minutes shall be prepared by the applicant, reviewed by all attendees, and included in the appendix of the MDR. Contact aurorawaterdrainage@auroragov.org to schedule this meeting.

2.3.4 Master Drainage Report Format and Required Information

The following MDR outline is a structured format to provide consistency in drainage reports and to expedite the review. The applicant must structure the report in this format, label each heading as shown, and address all of the items identified. Sections that are not applicable should be shown but noted as "N/A." Additional information may be requested based on site conditions.

All reports must be submitted digitally as PDF documents and be legible. The cover must include: the title of the project (subdivision name consistent with the Planning Department MP); the Owner's name, address, phone number, email, and point of contact; the Engineer's name, address, phone number, email, and point of contact; and approval block (see Section 2.6 below). The MDR must be prepared by a qualified Professional Engineer licensed in the State of Colorado, or under their direct supervision, whose seal and signature must be affixed to the report at signature set.

Note that certain elements of drainage design are neither reviewed nor approved with MDRs. If an item is not listed as a requirement in the sections below, in the Submittal Summary Table (see Section 2.2.7 above), or in the MDR Review Checklist, do not include it as a part of the MDR submittal. Under certain circumstances, data and/or analysis typically reserved for later in the drainage review process may be required for a MDR submittal.

MDR OUTLINE

TABLE OF CONTENTS

A. INTRODUCTION

1. Location

a. Include a vicinity map. Label adjacent arterial and collector streets, surrounding developments and associated subdivision names, major drainageways, etc.

b. Note major drainageways and facilities within or adjacent to the development.

2. Proposed Development

a. Describe the proposed development and land use. Discuss if site grading will follow existing flow paths or if there will be a transfer of flow from one basin to another.

Drainage Mapping Resources

The CoA maintains a robust database of Geographic Information Systems (GIS) files. These data may be useful for a variety of mapping products required with drainage submittals. These data may be accessed at *https://www.auroragov.org/city_hall/maps.*

3. Variances

    a. If variances are requested, see Section 2.10 for guidance. If there are no variances requested, state “No variances requested.”

B. HISTORIC DRAINAGE

1. Description of Property and Drainage Basin

    a. Provide a description of the existing/historic condition of the overall drainage basin and property that is analyzed in the MDR including: area in acres, soils and hydrologic soil groups, existing land uses and imperviousness, and other characteristics related to land use and hydrology.

    b. Identify any major drainageways adjacent to or within the proposed development and indicate if they have Federal Emergency Management Agency (FEMA) regulated floodplains or MHFD Flood Hazard Area Delineations (FHADs).

    c. Identify any existing irrigation facilities (i.e., canals/ditches) within or within 100 feet of the proposed development. Note if the identified irrigation facilities will influence or be influenced by local drainage.

    d. Identify any off-site basins and describe their impacts to the existing property.

    e. Identify all outfalls from the property.

    f. Reference all relevant major drainageway planning studies, including (but not limited to): FEMA Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs), MHFD FHAD Reports, MHFD Major Drainageway Plans (MDPs), major watershed planning reports, Outfall System Plans (OSPs), SMCs, Fluvial Hazard Zone (FHZ) studies, existing MDRs and associated plan sheets, etc. Note relevant reference information (e.g., Engineering Drawing Number [EDN] or Record Sequence Number [RSN], panel number, etc.) where applicable.

Record Sequence Numbers & Engineering Drawing Numbers

When a plan and/or report is submitted to the CoA’s electronic review system, it is issued a seven-digit Record Sequence Number (RSN). When the plan and/or report is approved, it is issued a six-digit Engineering Drawing Number (EDN). The RSN or EDN should be noted for all relevant documents to assist CoA staff in locating related plans and reports.

C. DESIGN CRITERIA

1. Hydrologic Criteria

a. Identify the minor and major design storm frequencies that will be used per the criteria in Chapter 6.

b. List the one-hour point precipitation depths for the minor and major storm events per the criteria in Chapter 5.

c. Identify proposed land uses and associated imperviousness (percent). Land uses **must** match those proposed in Planning MP documents.

d. Identify the calculation method or methods used in the hydrologic analysis (e.g., Rational Method, CUHP[3]).

e. Identify the detention volume computation method (e.g., CUHP/SWMM[4], MHFD-Detention workbook, etc.), the preliminary pond footprint calculation method (see Chapter 10), and any other equations used in the hydrologic analysis.

f. Note any other design criteria referenced aside from Manual or the MHFD Manual. See Chapter 3.

2. Hydraulic Criteria

a. Identify the calculation methods used to perform the hydraulic analysis, if applicable. Identify the version/release date for the models employed in development of the MDR.

b. Describe the criteria and methodology for establishing the drainageway corridor widths. Note that open channel, high-functioning, lower-maintenance streams (HFLMS) are required unless otherwise approved by a variance. Drainageway corridor widths can be established quickly and easily by utilizing the existing MHFD Stream Corridor Mapping or by performing additional analysis as further described in Chapter 7.

c. Identify regulatory FEMA, FHAD, or other delineated floodplains and any anticipated Letters of Map Change (LOMCs, including Conditional Letters of Map Revision [CLOMRs or CLOMR-Fs]) that will be required for the development.

d. Note any other sources referenced aside from this Manual or the MHFD Manual. See Chapter 3.

D. DRAINAGE CONCEPT

1. General Concept

a. Discuss the proposed drainage concept and typical drainage patterns.

b. Discuss coordination and compliance with other existing MDRs, MHFD MDPs, etc. Describe any proposed changes or departures from approved reports.

c. Discuss compliance with the Public Improvement Plan and Planning Department MP.

d. Discuss the impacts of off-site basins on the proposed development, including coordination requirements with surrounding developments. Note locations where off-site runoff enters the proposed development and discuss how off-site runoff is conveyed through or around the proposed development.

[3] Colorado Urban Hydrograph Procedure (Urban Drainage and Flood Control District (now Mile High Flood District), latest edition).

[4] Storm Water Management Model (United States Environmental Protection Agency, latest edition).

e. Discuss any conveyance elements required to pass the major flows to a major drainageway.

f. Discuss the structure concept for arterial and/or regional trail crossings of wide drainageways (see Section 2.3.3 above).

g. Describe the proposed outfall(s). Discuss downstream capacity and note any off-site infrastructure upon which the proposed drainage concept relies.

h. Describe areas where bank stabilization may be required to protect the site development.

i. If drainageway corridor widths differ from those established by MHFD Stream Corridor Mapping, confirm that the proposed corridor width and basin design will have acceptable hydraulic characteristics (shear, velocity, depth, etc.).

j. Incorporate a table of detention facilities which notes the pond tributary area in acres, the pond function (e.g., water quality capture volume [WQCV], excess urban runoff volume [EURV], etc.), the 100-year storage volume, total pond volume, estimated pond footprint (see Chapter 10), peak inflows, required release rates for design events, and required pond drain times for each detention facility. Note that detailed pond hydraulic calculations and final pond outlet sizing calculations are neither reviewed nor approved with MDRs.

k. Describe how perimeter roadway drainage will be addressed.

l. Discuss the overall approach to water quality. Indicate whether the Stormwater Control Measures (SCMs) provided are regional water quality SCMs identified in an OSP or intended to be subregional for future site plan areas. Identify if any SCMs are intended as multi-use facilities. For any regional SCMs, identify the location of the facility. Note that preliminary sizing calculations (volume and area) are required for any regional SCM.

m. Discuss if any of the drainage infrastructure is intended to be maintained by the CoA and why. Only major, regional infrastructure (as defined in Chapter 3) is eligible for public maintenance. See Chapter 3 for more information. Note that regional facilities and/or facilities which qualify for the MHFD's Maintenance Eligibility Program (MEP) should be identified during the Drainage Kick-off Meeting (see Section 2.3.2).

n. Discuss the impacts of runoff from the proposed development on downstream, upstream, and adjacent sites under both existing and future buildout conditions.

o. Identify the measures taken to ensure compliance with special watershed requirements as applicable. See Chapter 3 for more information on special watershed requirements.

E. LIST OF REFERENCES

a. List all criteria, existing drainage reports, MDR(s), City MP(s), floodplain studies, MHFD MDPs, etc. used in the report. Provide citation information, including the

author and date of each reference. Note the EDN or RSN for CoA-approved documents.

F. APPENDIX

1. Soil, Precipitation, Floodplain, and Airport Pond Buffer Information

    a. Natural Resources Conservation Service (NRCS) Soils Report with the site boundaries delineated and the hydrologic soil groups identified.

    b. One-hour point precipitation depths for all design events per NOAA Atlas 14.

    c. FEMA FIRM or FiRMette with the site boundaries delineated.

    d. Airport Detention Pond Buffer Zone with the site boundaries delineated.

2. Hydrologic Computations

    a. Land use assumptions for historic and proposed conditions.

    b. Runoff coefficient, percent imperviousness, time of concentration, intensity, peak flow, and routed flow calculations for each drainage basin under historic and proposed conditions if using Rational Method. Include copies of the equations and tables from this Manual used in the calculations.

    c. CUHP printouts of inputs and outputs for modeled design storms under historic and proposed conditions.

    d. SWMM printouts of inputs and outputs for modeled design storms under historic and proposed conditions. Include a model schematic. The model schematic must depict all drainage basins, conveyance elements, storage elements, and junctions.

    e. Inputs and outputs for modeled design storms under historic and proposed conditions using other modeling software. Include additional relevant information as applicable.

3. Hydraulic Computations

    a. Preliminary detention pond sizing calculations. Include the tributary area in acres, calculations of the area-weighted imperviousness for the tributary area, WQCV, EURV, 100-year storage volume, total pond volume, estimated pond footprint (see Chapter 10), allowable release rates, emergency overflow routing, etc. Provide the preliminary stage-storage and stage-discharge rating curves, derived from the pond calculations and entered into SWMM, if applicable.

    b. Other preliminary regional SCM sizing, as applicable.

    c. Preliminary sizing calculations for proposed culverts.

d. SMC analyses (if being established or modified from MHFD SMC width). See Chapter 7 for more information.

4. Supporting Documentation

    a. Copies of graphs, tables, etc., referenced or used in the report or calculations.

    b. Excerpts from previously approved reports, plans, etc. Annotate/highlight relevant information. Note the EDN or RSN where applicable.

    c. Master Drainage Kick-Off Meeting Minutes (see Section 2.3.2 above) and Crossing Coordination Meeting Minutes (see Section 2.3.3 above).

5. Digital Data

    a. Electronic copies of models used in above analysis. Provide all input and output files and ensure all submitted models are executable.

2.3.5 MDR Plan Sheets

The MDR plan sheets are the maps which accompany the MDR and show the proposed drainage improvements. The MDR plan sheets must be prepared on 24" x 36" or 22" x 34" PDF plan sheets and be provided as a separate PDF from the MDR. The MDR plan sheets must be prepared in compliance with the drafting standards denoted in the RDCS. The plan must include all items noted below and in the MDR checklist (see Section 2.3.1). Each plan sheet of the signature set shall be stamped by the Professional Engineer who prepared the MDR and MDR plan sheets. The MDR plan sheets shall include the following:

A. Cover sheet with CoA Approval block, General Conformance and Adjacent Property Owner Coordination notes (see Section 2.6 below), and reference to a CoA NAVD 88 benchmark.

B. If drainage concept relies on an existing facility for detention or water quality, include the Pond Recertification note (see Sections 2.6 and 2.7 below).

C. Formal subdivision name in title block of each sheet.

D. Legend showing all symbols, linetypes, and fills/hatches used on the plan. Exclude any symbols, linetypes, and/or fills/hatches not used on the plan.

E. Vicinity Map (minimum scale 1" = 2,000') showing the location and name of all arterial and collector roadways within one mile of the proposed development, as well as all other roadways in the vicinity of the proposed development. The project area shall be indicated by shading. Label adjacent developments with the associated subdivision name and RSN/EDN, if applicable. Label any other significant features (e.g., major drainageways, ditches/canals, etc.). This may be combined with item A above.

F. Overview plan sheet depicting and labeling all drainage basins (on-site and off-site).

G. Sheet index for entire MDR area where site cannot fit on a single sheet at the required scale. This may be combined with Item F above.

H. Plan sheets with scales as small as 1" = 200'; scales of 1" = 100' or larger are preferred. Off-site drainage basins may use a scale as small as 1" = 500'.

I. Existing topography at a 2-foot contour interval minimum. Contours must provide sufficient coverage to completely encompass all drainage basins (on-site and off-site). Contours will be extended a minimum of 50 feet beyond the property lines or as necessary to clearly identify off-site drainage patterns.

J. Flow direction arrows with slope in percent.

K. Drainage basin boundaries and design points. Off-site basins may be shown on 8-1/2" x 11" or 11" x 17" topographic maps included within the MDR; if so, note the location of the off-site drainage basin delineations on the drainage plans. Note that drainage basins shall incorporate required roadway improvements, including perimeter street sections.

L. Table with the basin identifier, basin area (acres), percent imperviousness, and major and minor design flows for all basins and design points; include runoff coefficients for the design storms as well if Rational Method is used. The table must include the direct runoff for each basin and the accumulated (routed) flows for each design point, with tributary basins to a design point identified. Note that design points should not have an imperviousness or runoff coefficient value associated with them in the table row (separate tables for the basin information and design point flows may be provided if so desired).

M. Floodplain information, including the 1% annual chance (1PAC; i.e., 100-year) floodplain and floodway limits and Base Flood Elevations (BFEs), if available, from FIRMs, FISs, FHADs, or other Best Available Information (see Chapter 4). Identify the map panel and effective date as applicable on any sheet depicting the floodplain. Identify any LOMCs (i.e., CLOMRs and LOMRs) along with their case numbers and effective dates as applicable.

N. If any work is planned within the floodplain, include the Floodplain Development Permit note (see Section 2.6 below).

O. SMCs. Label corridor widths and identify conceptual locations for grade control and bank revetment structures. SMCs shall be per MHFD SMC map unless stream corridor width is revised by accompanying geomorphic analysis (see Chapter 7). Include flow direction arrows.

P. FHZ mapping, if applicable.

Q. Identification of reaches where bank stabilization is required.

R. Existing and proposed detention pond locations. Include the pond tributary area, pond function (e.g., WQCV, EURV, etc.), 100-year storage volume, total pond volume, estimated pond footprint (see Chapter 10), and required release rates for design events. Clearly identify the pond emergency overflow locations and flow directions.

S. Existing and proposed culvert crossings of arterial and collector roadways. Label the culvert size, emergency overflow location, and flow direction.

T. Existing and proposed outfall location(s).

U. Labeling of all infrastructure as either CoA or private maintenance. Note party responsible for private maintenance (e.g., Metro District, HOA, etc.). The note in Section 2.6 below may be used in lieu of individually labeling each facility.

V. Identify MEP infrastructure.

W. Labeling of all adjacent properties, subdivisions, developments, existing and proposed off-site infrastructure, connected MDRs, etc. Note the EDN or RSN where applicable.

X. Labeling and dimensioning of existing and proposed right-of-way (ROW) where available. Label adjacent arterial or collector roadways (existing or proposed).

Y. CoA jurisdictional boundaries as applicable.

Z. SWMM model schematic diagram depicting all drainage basins, conveyance elements, storage elements, junctions, etc. The schematic may also be included in the MDR as long as all elements are clearly identifiable.

AA. Any other information deemed necessary to the project.

BB. Ensure that no copyright notes are included on the MDR plan sheets.

CC. For drafting standards, scales, and other standard requirements, see the RDCS.

2.3.6 Master Drainage Amendment

A Master Drainage Amendment (MDA) is required when there are any modifications to a City Planning MP and/or CoA-approved MDR that could affect stormwater infrastructure sizing, including one or more of the following:

- There is a change in land use or density producing an increase in impervious area greater than 5%.
- There is a change in the proposed sizing or location of ponds and/or channels.
- Additional tributary area is added to the area considered by the MDR, or the tributary area is otherwise revised.
- There are changes in the basin boundaries used in the MDR.
- There are changes in the arterial and/or collector roadway corridor widths or locations.
- There are major grading changes that impact stream corridor routing or major drainage facilities.
- There are changes in the basin-wide master drainage study.

In these instances, a MDA submittal explaining the changes and providing applicable updated report calculations is required. MDA submittals shall include a separate file with revised MDR plan sheets. Revisions shall be shown in clouded annotations on the MDR plan sheets, MDR text, model sheets, etc. Where computer models are used, executable input and output files must be provided in digital format. In some instances, where many of the original MDR concepts have changed, it may be advantageous to develop a new MDR to ensure the subsequent processes can be completed in a timely manner.

Where modifications to the features listed above are minor in nature, a MDA letter may be required to ensure the proper function of the drainage infrastructure.

2.4 PRELIMINARY DRAINAGE REPORT

2.4.1 General

The purpose of the PDR is to establish the preliminary location and design flows of drainage infrastructure. The PDR must thoroughly assess both the effects of the proposed development on off-site properties and the effect of off-site drainage on the proposed development. Existing off-site flows must be accepted and perpetuated through the site. The PDR must address the entire property as shown on the plat and/or site plan. The PDR shall not incorporate multiple subdivisions. The PDR and PDP must be consistent with the Planning site plan.

Approval of the PDR relates to other CoA submittals in the following manner:

- For developments that require an MDR, the MDR must be approved prior to submittal of the PDR.
- A PDR must be approved prior to approval of any Subdivision Plat or Site Plan.
- The PDR must be approved prior to any CP submittal.

The PDR must be structured in accordance with Sections 2.4.3, and the accompanying PDP must be in accordance with Section 2.4.4. The PDR and PDP must contain all applicable information listed in each section. The PDR must be prepared by a qualified Professional Engineer licensed in the State of Colorado, or under their direct supervision, whose seal and signature must be affixed to the report and all plan sheets at signature set. The Engineer must also complete, sign, and submit the PDR Review Checklist to ensure all applicable elements are included prior to formal review. The PDR checklist can be found at this location and all requirements listed therein are considered part of this Manual by reference.

Multi-Use Facilities

Multiple uses (i.e., multi-uses) of detention facilities is encouraged; however, it is critical to coordinate the design of these facilities with various CoA departments to ensure that all relevant criteria are met. Coordination between the engineer, AW, and PROS prior to the PDR submittal is encouraged to achieve understanding and consensus on the design of a multi-use facility.

2.4.2 Preliminary Drainage Kick-off Meeting

A drainage kick-off meeting is required for all PDR submittals that contain regional infrastructure. This meeting will be used to discuss maintenance eligibility and SMCs, and to

identify relevant reference documents and coordinate unique circumstances for the site. The requirement to hold a drainage kick-off meeting will be identified in the pre-application notes, or by direct communication with AW drainage staff.

The meeting shall be limited to one hour and be held with MHFD and AW drainage staff prior to submittal of the PDR. The meeting must take place prior to submittal of the PDR to the Planning portal. Meeting minutes shall be prepared by the applicant, reviewed by all attendees, and included in the appendix of the PDR. Contact aurorawaterdrainage@auroragov.org to schedule this meeting.

2.4.3 Preliminary Drainage Report Format and Required Information

The following PDR outline is a structured format to provide consistency in drainage reports and to expedite the review. The applicant must structure the report in this format, label each heading as shown, and address all of the items identified. Sections that are not applicable should be shown but noted as "N/A."

Preliminary Drainage Report and Plan Name

The name of the PDR and plan set shall be the full platted subdivision name. If a replat is proposed with the site plan, the name shall be the proposed re-platted subdivision name. The platted subdivision name shall be noted on the cover page of the PDR and included in the title block on each sheet of the plan set.

All reports shall be submitted digitally in a PDF and be legible. The cover must include: the title of the project (platted subdivision name); the Owner's name, address, phone number, email, and point of contact; the Engineer's name, address, phone number, email, and point of contact; and approval block (see Section 2.6 below).

Note that certain elements of drainage design are neither reviewed nor approved with PDRs. If an item is not listed as a requirement in the sections below or in the PDR Review Checklist, please do not include it as a part of the PDR submittal. Under certain circumstances, data and/or analysis typically reserved for later in the drainage review process may be requested for a PDR submittal.

PDR OUTLINE

TABLE OF CONTENTS

A. INTRODUCTION

1. Location

   a. Include a vicinity map. Label adjacent arterial and collector streets, surrounding developments and associated subdivision names, major drainageways, etc.

   b. Note major drainageways and facilities within or adjacent to the development.

2. Proposed Development

   a. Describe the proposed development. Include a general project description, the proposed land use, and the proposed density.

3. Changes to MDR

    a. Discuss any changes made to the approved MDR.

    b. Address any conditional approval comments on the approved MDR or MDR plan sheets.

4. Variances

    a. If variances are requested, see Section 2.10 for guidance. If there are no variances requested, state “No variances requested.”

B. HISTORIC DRAINAGE

1. Description of Property and Drainage Basin

    a. Provide a description of the existing/historic condition of the overall drainage basin and property that is analyzed in the PDR including: area in acres, soils and hydrologic soil groups, existing land uses and imperviousness, and other characteristics related to land use and hydrology.

    b. Identify any major drainageways adjacent to or within the proposed development, and indicate they have FEMA regulated floodplains or MHFD FHADs.

    c. Identify any existing irrigation facilities (i.e., canals/ditches) within or within 100 feet of the proposed development. Note if the identified irrigation facilities will influence or be influenced by local drainage.

    d. Identify any off-site basins and describe their impacts to the existing property.

    e. Identify all outfalls from the property.

    f. Reference all relevant major drainageway planning studies, including (but not limited to): FEMA FISs and FIRMs, MHFD FHAD Reports, MHFD MDPs, major watershed planning reports, OSPs, SMCs, FHZ studies, existing MDRs, etc. Note relevant reference information (e.g., EDN or RSN, panel number, etc.) where applicable.

C. DESIGN CRITERIA

1. Hydrologic Criteria

    a. Identify the minor and major design storm frequencies that will be used per the criteria in Chapter 6.

    b. List the one-hour point precipitation depths for the minor and major storm events per the criteria in Chapter 5.

    c. Identify the calculation method or methods used in the hydrologic analysis (e.g., Rational Method, CUHP, etc.).

d. Identify the detention volume computation method (e.g., CUHP/SWMM, MHFD-Detention workbook, etc.; CUHP/SWMM preferred) and any other equations used in the hydrologic analysis.

e. Note any other design criteria referenced aside from Manual or the MHFD Manual. See Chapter 3.

2. Hydraulic Criteria

a. Identify design storm frequencies for culverts, swales, channels, detention basins, street flow, inlets, and storm drain pipes (note that inlet and pipe sizing is not required). See Chapter 6.

b. Describe the criteria and methodology for sizing proposed water quality and detention facilities. Identify the calculation method used to determine preliminary sizing for proposed detention facilities (e.g., CUHP/SWMM, MHFD-Detention workbook, etc.).

c. Describe the criteria and methodology for establishing the drainageway corridor widths. Note that open channel, HFLMS are required unless otherwise approved by a variance. Drainageway corridor widths can be established quickly and easily by utilizing the existing MHFD Stream Corridor Mapping or by performing additional analysis as further described in Chapter 7.

d. Identify regulatory FEMA or FHAD floodplains and any anticipated LOMCs (i.e., CLOMRs and/or CLOMR-Fs) that will be required for the development.

e. Indicate whether proposed infrastructure is public (i.e., maintained by CoA) or private (i.e., maintained by a metropolitan district, homeowner's association, owner, etc.); if private, note agency responsible for maintenance. Note that regional facilities and/or facilities which qualify for the MHFD's MEP should be identified during the Drainage Kick-off Meeting (see Sections 2.3.2); any deviations from the MDR must be approved by AW.

f. Note any temporary proposed stormwater infrastructure.

g. Identify the design calculation method(s) and software used in the hydraulic analysis (e.g., MHFD-Detention workbook, HY-8, etc.).

h. Note any other sources referenced aside from this Manual or the MHFD Manual.

D. DRAINAGE PLAN

1. General Concept

a. Discuss the proposed drainage concept and typical drainage patterns.

b. Discuss conformance with the MDR(s) or other previously approved documents with respect to imperviousness, basins, channels, ponds, etc. Note any changes or departures from applicable MDR(s), City MP, floodplain studies, and/or MHFD

MDPs. Changes to a MDR may require a MDR Amendment to be approved prior to PDR approval (see Section 2.3.6).

c. Discuss conformance with the Public Improvement Plan, if applicable.

d. Discuss conformance with the Site Plan.

e. Describe the conveyance of off-site drainage. Note locations where off-site emergency overflows are both received by and sent from the subject property.

f. Discuss coordination with surrounding developments and indicate whether the proposed PDR, plans, and a copy of the *Stormwater Conveyance – Notification of Adjacent Property Owners* memorandum have been provided to the off-site owners.

Coordination with Adjacent Property Owners

It is often necessary for a developer to coordinate with adjacent property owners to achieve a responsible stormwater management design. For example, collaboration between adjacent property owners is necessary when: off-site construction is necessary to connect to an existing storm drain system; emergency overflows are directed to a downstream property; historic sheet flow will be concentrated off-site; the historic flow path changes; and/or when the headwaters or drainage basin area change. The CoA has a *Stormwater Conveyance – Notification of Adjacent Property Owners* memorandum to aid in coordination of stormwater management between adjacent property owners (Aurora Water, latest edition). This memorandum should be reviewed and included in the PDR if applicable (see Item F.4 in Section 2.4.3). This memorandum can be accessed here.

g. Describe the proposed downstream outfall(s). Discuss downstream capacity and note any off-site infrastructure upon which the proposed drainage concept relies.

h. Discuss the effects of the proposed development on downstream, upstream, and adjacent sites under both existing and future buildout conditions.

i. Discuss the water quality SCMs and detention plan. Identify ownership and maintenance responsibilities. If the site relies on an off-site SCM, such as a detention pond or water quality device, state the project platted subdivision name and EDN.

2. Specific Details

a. Discuss project phasing as applicable. Describe the interim condition(s) and ultimate condition. Include discussion of both project phasing and phasing/coordination with ongoing surrounding developments as applicable. Note that separate hydrologic/hydraulic analyses of each phase may be required. If there is no project phasing, state the project will not be phased.

b. Discuss each basin or sub-basin (in words). Include descriptions of land use, basin outfall, design points, proposed internal stormwater infrastructure, upstream drainage areas, and minor and major storm flow patterns through the basin.

c. Provide a table summarizing the percent impervious, runoff coefficient values for minor and major storms, and corresponding discharges for each sub-basin. Show routed flows where appropriate.

d. Describe detention pond location(s) and outfall(s). Include the tributary area in acres, the composite percent imperviousness, and the required WQCV, EURV, and 100-year storage volume. Note whether pond(s) will be publicly or privately maintained and the party responsible for maintenance.

e. Discuss any off-site water quality SCMs or detention facilities utilized by the project. Include the RSN or EDN and demonstrate that this project complies with the off-site facility's design. Include a figure showing the location of the off-site facility with respect to the project; alternatively, include a sheet in the PDP showing the off-site facility's location with respect to the project.

f. Provide a table summarizing proposed culverts. Include a designation to locate each culvert on the PDP, culvert dimensions, major and minor design discharges, emergency overflow discharge, number of barrels and material, and the headwater-to-culvert-depth (HW/D) ratio during the major storm. If a SSR was prepared, reference said report as applicable (see Section 2.8 below).

g. Discuss bridge[5] concepts. Include the location; type (steel arch, beam, etc.), material, length, and width; number of spans; number and shape of piers; abutments and wingwalls; major and minor discharges; emergency overflow discharge, if applicable (see Chapter 9); and freeboard. If a SSR was prepared, reference said report as applicable (see Section 2.8 below).

h. Describe emergency overflow paths for sump inlets, culverts, bridges (if applicable, see Chapter 9), and detention ponds. Sump inlet, culvert, bridge, and detention pond emergency overflow path descriptions may be included with the individual discussions of each of those elements above. Indicate where the accompanying overflow calculations are located in the appendix and where the overflow cross sections are provided in the PDP.

i. Discuss swale, ditch, and open channel concepts. Identify the location, cross section shape, longitudinal slope, major and minor design discharge, velocity, depth, and freeboard. This information may be presented in table form. Include a discussion of the Manning's n-value values used in the hydraulic analysis (see Chapter 7).

j. Provide a conceptual geomorphic analysis for any regional channel. If the SMC width is being revised, provide a detailed geomorphic analysis with channel and corridor sizing calculations and descriptions of erosion protection and bank stabilization measures. Note the party responsible for maintenance.

[5] Note that the Federal Highway Administration (FHWA) defines bridges categorically as any crossing with a span greater than 20 feet. This Manual does not define bridges in this manner, and instead uses the more colloquial definition of the term "bridge."

k. Provide a table of street, drive, and alley flow capacities. Note the flow depth and street spread for the major and minor storms (see Chapter 6).

l. Discuss the proposed permanent SCMs. See Chapter 11 for more information on permanent SCMs. Do not provide discussion on construction control measures (CMs) or temporary SCMs.

m. Discuss how the requirements set forth in the approved MHFD MDP or OSP have been met, if applicable.

n. Include any other information deemed necessary to the project and solutions to problems encountered.

E. LIST OF REFERENCES

a. List all criteria, existing drainage reports, MDR(s), City MP(s), floodplain studies, MHFD MDPs, etc. used in the report. Provide citation information including author and date of each reference. Note the EDN or RSN for CoA-approved documents.

F. APPENDICES

1. Soil, Precipitation, Floodplain, and Airport Pond Buffer Information

a. NRCS Soils Report with the site boundaries delineated and the hydrologic soil groups identified.

b. One-hour point precipitation depths for all design events per NOAA Atlas 14.

c. FEMA FIRM or FiRMette with the site boundaries delineated.

d. Airport Detention Pond Buffer Zone with the site boundaries delineated.

2. Hydrologic Computations

a. Identify all equations used in the hydrologic analysis (e.g., time of concentration equation, rainfall intensity equation, detention volume computation method, etc.). Use standard MHFD workbooks where applicable to standardize submittals and help with review timelines. Include copies of the equations and tables from this Manual used in the calculations.

b. Land use assumptions for existing and proposed conditions.

c. Runoff coefficient and percent imperviousness calculations for each drainage basin under historic and developed conditions.

d. Time of concentration calculations for each drainage basin under existing and proposed conditions.

e. Model printouts for any CUHP and/or SWMM modeling, as applicable. Include the inputs and outputs for modeled design storms under historic and proposed

conditions. Include a model schematic for any SWMM modeling which depicts all drainage basins, conveyance elements, storage elements, junctions, and outfalls.

f. Minor and major storm runoff computations for historic and developed runoff conditions for all drainage basins and design points. Include flow routing.

g. Required WQCV, EURV, and 100-year runoff detention volumes, water surface elevations (WSELs), 100-year allowable release rate, and detention pond capacity with supporting calculations.

h. Sizing calculations for grass buffer, grass swale, rain garden, and/or sand filter SCMs, using the latest MHFD calculation workbooks, if applicable. For infiltration-based SCMs, geotechnical analysis confirming the suitability of the infiltration-based water quality technique must be provided. Note that it is the responsibility of the developer to ensure that any infiltration-based water quality approach is appropriate and functional.

i. Updates to MDR and/or MHFD MDP modeling (e.g., CUHP, SWMM) which reflect the proposed drainage concept, if applicable. Include model schematic as applicable. Model schematic must depict all drainage basins, conveyance elements, storage elements, and junctions. Include all CUHP/SWMM model calculations, MHFD-Detention workbooks, etc., in both hardcopy (i.e., PDF) and digital executable formats. Note that changes to the MDR may require a MDA (see Section 2.3.6 above).

3. Hydraulic Computations

a. Swale, ditch, and/or open channel design calculations (normal depth calculations are appropriate; note that HEC-RAS[6] modeling is neither reviewed nor approved with PDRs). Calculations should be provided for each channel section and longitudinal slope. Alternatively, calculations may be provided for only the flattest and steepest slopes for each channel section, to demonstrate compliance with freeboard and velocity criteria under the worst-case conditions. The normal depth calculations must include the design flow, channel invert, depth of flow, velocity, and Froude number. Provide all calculations in both hardcopy (i.e., PDF) and digital executable formats, where appropriate.

b. Conceptual geomorphic calculations and analysis for regional channels. If the SMC width is being revised, provide detailed geomorphic calculations and analysis instead, including channel sizing and channel/bank stabilization calculations.

c. Culvert design calculations.

d. Scour calculations for bridges.

e. Street, drive, and alley capacity calculations.

[6] Hydrologic Engineering Center River Analysis System (United States Army Corps of Engineers, latest edition).

f. Emergency overflow calculations for sump inlets, culverts, bridges (if applicable, see Chapter 9), and detention pond spillways. Note the emergency WSELs. Include drainage tract sizing as necessary.

4. Supporting Documentation

   a. Copies of graphs, tables, nomographs, etc., referenced or used in report or calculations.

   b. Excerpts from previously approved reports, plans, etc. Annotate/highlight relevant information. Note the EDN or RSN where applicable.

   c. SSR justifying the selection of each bridge or culvert with a span greater than 20 feet for each applicable site. See Section 2.8 below.

   d. A copy of the *Stormwater Conveyance – Notification of Adjacent Property Owners* memorandum, if applicable.

   e. Preliminary Drainage Kick-Off Meeting Minutes (see Section 2.4.2 above).

5. Digital Data

   a. Electronic copies of models used in above analysis. Provide all input and output files and ensure all submitted models are executable.

2.4.4 Preliminary Drainage Plan

The PDP is the map which accompanies the PDR and shows the details of the proposed drainage plan. The PDP should be prepared on 24" x 36" or 22" x 34" plan sheets and be provided as a separate PDF from the PDR. The PDP must be prepared in compliance with the drafting standards denoted in the RDCS. The plan must include all items noted below and in the PDR checklist (see Section 2.4.1). Each plan sheet of the signature set shall be stamped by the Professional Engineer who prepared the PDR and PDP. In some cases, land development may occur in phases. When this is the case, the PDR and PDP (and eventual FDR and FDP) must include analyses of the interim and ultimate conditions. The PDP shall include the following:

A. Cover sheet with CoA Approval block, General Conformance and Adjacent Property Owner Coordination notes (see Section 2.6 below), and reference to a CoA NAVD 88 benchmark.

B. If drainage concept relies on an existing facility for detention or water quality, include the Pond Recertification note (see Sections 2.6 and 2.7 below).

C. Platted subdivision name in title block of each sheet (see Section 2.4.3 above).

D. Legend showing all symbols, linetypes, and fills/hatches used on the plan. Exclude any symbols, linetypes, and/or fills/hatches not used on the plan.

E. Vicinity Map (minimum scale 1" = 2,000') showing the location and name of all arterial and collector roadways within one mile of the proposed development, as well as all other roadways in the vicinity of the proposed development. The project area shall be

indicated by shading. Label adjacent developments with the associated subdivision name and RSN/EDN, if applicable. Label any other significant features (e.g., major drainageways, ditches/canals, etc.). This may be combined with A above.

F. Overview plan sheet depicting and labeling all drainage basins (on-site and off-site).

G. Sheet index for entire PDP area where site cannot fit on a single sheet at the required scale. This may be combined with Item F above.

H. Plan sheets with minimum scales as follows:

1. Single family detached: 1" = 50'

2. Multifamily: 1" = 30'

3. Commercial and Industrial:

- Building footprint less than 500,000 ft^2: 1" = 30'

- Building footprint greater than 500,000 ft^2: 1" = 50'

I. Existing topography at a 2-foot contour interval minimum. Proposed grading at 2-foot contour interval minimum. Contours must provide sufficient coverage to completely encompass all existing and proposed drainage basins (on-site and off-site). Contours must be extended a minimum of 50-feet beyond the property lines or further as necessary to clearly identify off-site drainage patterns and show the tie-in between the proposed grading and existing topography.

J. Flow direction arrows with slope in percent for proposed on-site grading and off-site areas.

K. Drainage basin boundaries and design points. Off-site basins may be shown on 8-1/2" x 11" or 11" x 17" topographic maps included within the PDR; if so, note the location of the off-site drainage basin delineations on the drainage plans. Note that drainage basins shall incorporate required roadway improvements, including perimeter street sections.

L. Table with basin identifier, basin area (acres), major and minor runoff coefficients, percent imperviousness, and minor and major runoff for all basins and design points. The table must include the direct runoff for each basin and the accumulated (routed) flows for each design point, with tributary basins to a design point identified. Note that design points should not have an imperviousness or runoff coefficient value associated with them in the table row (separate tables for the basin information and design point flows may be provided if so desired).

M. Floodplain information, including the 1PAC floodplain and floodway limits and BFEs, if available, from FIRMs, FISs, FHADs, or other Best Available Information (see Chapter 4). Identify the map panel and effective date as applicable on any sheet depicting the floodplain. Identify any LOMCs (i.e., CLOMRs and LOMRs) along with their case number and effective date as applicable.

N. If any work is planned within the floodplain, include the Floodplain Development Permit note (see Section 2.6 below).

O. SMCs. Label corridor widths and identify conceptual locations for grade control and bank revetment structures. SMCs shall be per MHFD SMC map unless stream corridor width is revised by accompanying geomorphic analysis (see Chapter 7). Include flow direction arrows.

P. FHZ mapping, if applicable.

Q. Identification of reaches where bank stabilization is required.

R. Location of all existing drainage facilities and public improvements. Include the size and EDN or RSN for each existing facility.

S. Labeling of all proposed drainage facilities (e.g., culverts, inlets, pipes, swales, tracts, etc.). The design storm frequency and maintenance responsibility (CoA or private) for each proposed drainage facility must be indicated (e.g., "private storm drain, 5-year storm capacity"); if privately maintained, note party responsible for maintenance (e.g., Metro District, HOA, etc.). A general note covering the above can be placed on all plans in lieu of labeling all facilities (see Section 2.6 below). Note that sizing of proposed storm drain inlets and pipes is neither reviewed nor approved for PDRs; the location and asset type should be noted, but do not include sizing for storm drain pipes and inlets.

T. Existing and proposed detention pond locations. For each pond, label the WQCV, EURV, and 100-year storage volumes and WSELs. Note the allowable release rates, maximum depths, ponding limits, and any other water quality SCM data as needed for the proposed SCM. Label pond side slopes, bottom slopes, trickle channel slopes, etc. as applicable. Label maintenance access, material, and turn radius as applicable. Define maintenance responsibilities if not included as a general note (see Item S above).

U. Location and direction of all emergency overflows for sump inlets, culverts, bridges, and detention ponds. Emergency overflow arrows shall be unique and included in legend (see D above). Label all inlets in sump.

   For each emergency overflow location, include a cross section with the emergency overflow discharge, WSEL, dimensioned freeboard, and adjacent building lowest point of entry[7] (LPE) if applicable.

V. Preliminary plan and profiles for open channels. Note the longitudinal slope on both the plan and profiles. Include a typical cross section for each channel section which notes the major and minor design storm discharges, WSELs, dimensioned freeboard, and adjacent building lowest floor elevation (LFE). Define maintenance responsibilities if not included as general note (see Item S above). Note schematically (i.e., no sizing)

[7] The lowest point of entry (LPE) is the lowest elevation at which surface water may enter a structure, such as the elevation of the bottom of a door frame, or the elevation of the top of a basement window well. The LPE is distinct from the lowest floor elevation (LFE), though in some cases the elevations of each may be identical. See Chapter 3 for definitions of the LPE and LFE.

the location of any erosion protection and bank stabilization measures. Include as-built profiles of any existing utilities, culverts, etc., crossing the channel.

W. Typical cross sections for each swale and/or ditch. Note the major and minor design storm discharges, WSELs or flow depth, dimensioned freeboard, and adjacent building LPE. Include a note identifying all swales and/or ditches as privately maintained.

X. Existing and proposed outfall location(s). Include reference label to applicable report/plan denoting projected received flows.

Y. Labeling of any interim infrastructure. Do not include Stormwater Master Plan (SWMP) CMs.

Z. Project phasing as applicable. If necessary, include plan sheets for both interim and ultimate conditions, with relevant hydrologic and hydraulic information adjusted to match each condition.

AA. Proposed buildings and LFEs for commercial and multi-family sites. Note the LPE for structures near emergency overflow paths and swales/ditches.

BB. Labeling of proposed retaining walls. Include preliminary cross section with maximum height and ROW/property lines.

CC. Existing and proposed easements (drainage, utility, fire lane, etc.), property lines, and ROW. Dimension all easements and ROWs and label all roadways. Identify any necessary license agreements.

DD. Labeling of all adjacent properties, subdivisions, developments, etc. Include the platted subdivision names where applicable. Note the EDN or RSN where applicable. Provide CoA jurisdictional boundaries as applicable.

EE. SWMM model schematic diagram depicting all drainage basins, conveyance elements, storage elements, junctions etc., if applicable. The schematic may also be included in the PDR as long as all elements are clearly identifiable.

FF. Any other information deemed necessary to the project.

GG. Ensure that no copyright notes are included on the PDP sheets.

HH. For drafting standards, scales, and other standard requirements, see the RDCS.

2.4.5 Preliminary Drainage Letters

A PDL (or letter) is a simplified drainage submittal that can be used to document conformance with a previously approved PDR and PDP when a site meets all of the following qualifying criteria:

1. Prior approval to submit a PDL in lieu of a PDR must be obtained from AW. If a pre-application meeting with the Office of Development Assistance (ODA) was held, the

meeting notes from that meeting should be consulted to determine if a PDL will be allowed in lieu of a PDR.

2. The property must be included in a previously approved PDR and PDP where the site conditions and site plans have not significantly changed. The PDL must reference the previously approved plan and any subsequently approved PDL(s), and must also include the EDN or RSN where applicable.

3. The development must not alter flow or drainage patterns which affect other properties from those previously established in approved PDRs or CPs which included the property.

4. The site must currently discharge to an improved drainage channel or existing storm drain system. The adjacent surface drainage system must have the hydraulic capacity for post-development runoff, and additional storm drains are not required for development of the site.

5. The development must not require additional on-site detention or water quality treatment. Water quality, EURV, and detention are provided for the site from an off-site facility.

A PDL may also be required when there are changes to a CoA-approved PDR. A PDL submittal to amend an approved PDR is required when any of the following conditions apply:

1. A site plan amendment is required by the CoA Planning Department. If there are no changes to the drainage plans, the PDL will simply be a conformance letter stating that there are no changes to the drainage plan of the approved PDR.

2. The PDR includes more than one development or covers a commercial or industrial site with one or more lots to be developed at different times, where changes to the drainage design may impact the other portions of the development.

3. There are any changes to the drainage design from the approved PDR, including (but not limited to):

    a. Changes in land use or density that increase the imperviousness and/or area contributing to a drainage facility such that the sizing or design of the facility requires modification.

    b. Changes in pond or channel sizing or location.

    c. Changes to drainage basin or subbasin boundaries.

    d. Changes to roadway locations or widths.

    e. Changes in grading that affect drainage infrastructure.

If no additional water quality, detention, or channel facilities are required, a PDL revising an approved PDR may be waived provided that a FDL and CP revision is submitted concurrently with the site plan amendment.

PDLs are primarily applicable to development of pad sites within previously approved commercial developments or for minor changes to existing properties. The letter must be addressed to the AW Drainage Supervisor. The letter must be submitted as a PDF and must be signed and sealed by a qualified Professional Engineer licensed in the State of Colorado.

The letter must identify the platted subdivision name, location, project land use, and any minor drainage changes to the previously approved drainage study. The letter must include information that demonstrates that the design of the site is in general conformance with the previously approved drainage study. Updated calculations may need to be provided to document changes to basin areas, impervious values, runoff coefficient values, flows, volumes, or other drainage characteristics established in a previously approved drainage report.

A general location map must accompany the letter, and a site map (8-1/2” x 11” or 11” x 17”) is required that shows at a minimum:

1. Property boundaries.

2. Existing and proposed site features (buildings, parking areas, drive lanes, and other impervious surfaces).

3. Arrows showing existing and proposed drainage patterns. Include existing and proposed contours.

4. Labels identifying relevant drainage infrastructure.

5. Labels identifying existing and proposed peak flow rates at any points where concentrated runoff leaves the property.

Design drawings are not required for a PDL but may be included by the applicant if they are needed to explain how the project conforms to the previously approved drainage plan; these typically take the form of revised plan sheets from the PDP, updated to reflect proposed changes. If design drawings or details are provided, they must be an 8-1/2” x 11” or 11” x 17” size attached to the letter. Revisions shall be shown in clouded annotations on the PDP sheets, PDR text, model sheets, etc. Where computer models are used, executable input and output files must be provided in digital format.

2.5 FINAL DRAINAGE REPORT

2.5.1 General

The Final Drainage Report (FDR) is a detailed drainage study and analysis of the proposed development. It must include calculations for all runoff and for all drainage structures or facilities within the proposed development.

The FDR must be structured and accordance with Section 2.5.2 below. The report must also be accompanied by the CPs as described in Section 2.5.3 below. FDRs must be prepared by a qualified Professional Engineer licensed in the State of Colorado, or under their direct supervision, whose seal and signature must be affixed to the report and all plan sheets at signature set. The Engineer must also complete, sign, and submit the Civil Plan Submittal Checklist to ensure all applicable elements are included prior to formal review. The Civil Plan

Submittal Checklist can be found at this location and all requirements listed therein are considered part of this Manual by reference.

2.5.2 Final Drainage Report Format and Required Information

The following FDR outline is a structured format to provide consistency in drainage reports and to speed the review. The applicant must structure the report in this format, label each heading as shown, and address all of the items identified. Sections that are not applicable should be shown but noted as "N/A." Additional information may be requested for complex sites.

Final Drainage Report and Plan Name

The name of the FDR and civil plan set shall be the full platted subdivision name. If a replat is proposed with the site plan, the name shall be the proposed re-platted subdivision name. The platted subdivision name shall be noted on the cover page of the FDR and included in the title block on each sheet of the civil plan set.

All reports shall be submitted digitally in PDF format and be legible. The cover must include: the title of the project (platted subdivision name); the Owner's name, address, phone number, email, and point of contact; the Engineer's name, address, phone number, email, and point of contact; and approval block (see Section 2.6 below).

Note that while the outline below is similar to that of the PDR (see Section 2.4.3), the FDR must provide more detailed information than the PDR. Should the drainage concept change between approval of the preceding PDR and the initial submittal of the FDR, the FDR submittal must address those changes explicitly in Section A.3 of the FDR.

FDR OUTLINE

TABLE OF CONTENTS

A. INTRODUCTION

1. Location

   a. Include a vicinity map. Label adjacent arterial and collector streets, surrounding developments and associated subdivision names, major drainageways, etc.

   b. Note major drainageways and facilities within or adjacent to the development.

2. Proposed Development

   a. Describe the proposed development. Include a general project description, the proposed land use, and the proposed density.

3. Changes from the PDR and MDR

   a. Discuss any changes made to the approved MDR.

   b. Address any conditional approval comments on the approved MDR or MDR plan sheets.

c. Discuss any changes made to the approved PDR. If there have been no changes to the hydrologic analysis of the approved PDR, indicate as much here (this information must still be included in the FDR).

d. Address any conditional approval comments on the approved PDR or PDP.

4. Variances

a. If variances are requested, see Section 2.10 for guidance. If there are no variances requested, state “No variances requested.”

B. HISTORIC DRAINAGE

1. Description of Property and Drainage Basin

a. Provide a description of the existing/historic condition of the overall drainage basin and property that is analyzed in the FDR including: area in acres, soils and hydrologic soil groups, existing land uses and imperviousness, and other characteristics related to land use and hydrology.

b. Identify any major drainageways adjacent to or within the proposed development, and indicate they have FEMA regulated floodplains or MHFD FHADs.

c. Identify any existing irrigation facilities (i.e., canals/ditches) within or within 100 feet of the proposed development. Note if the identified irrigation facilities will influence or be influenced by local drainage.

d. Identify any off-site basins and describe their impacts to the existing property.

e. Identify all outfalls from the property.

f. Reference all relevant major drainageway planning studies, including (but not limited to): FEMA FISs and FIRMs, MHFD FHAD Reports, MHFD MDPs, major watershed planning reports, OSPs, SMCs, FHZ studies, existing MDRs, etc. Note relevant reference information (e.g., EDN or RSN, panel number, etc.) where applicable.

C. DESIGN CRITERIA

1. Hydrologic Criteria

a. Identify the minor and major design storm frequencies that will be used per the criteria in Chapter 6.

b. List the one-hour point precipitation depths for the minor and major storm events per the criteria in Chapter 5.

c. Identify the calculation method or methods used in the hydrologic analysis (e.g., Rational Method, CUHP, SWMM, etc.).

d. Identify the detention volume computation method (e.g., CUHP/SWMM, MHFD-Detention workbook, etc.; CUHP/SWMM preferred) and any other equations used in the hydrologic analysis.

e. Note any other design criteria referenced aside from Manual or the MHFD Manual. See Chapter 3.

2. Hydraulic Criteria

a. Identify design storm frequencies for culverts, swales, channels, detention basins, street flow, inlets, and storm drain pipes. See Chapter 6.

b. Describe the criteria and methodology for sizing proposed water quality and detention facilities. Identify the calculation method used to determine preliminary sizing for proposed detention facilities (e.g., CUHP/SWMM, MHFD-Detention workbook, etc.).

c. Describe the criteria and methodology for establishing the drainageway corridor widths. Note that open channel, HFLMS are required unless otherwise approved by a variance. Drainageway corridor widths can be established quickly and easily by utilizing the existing MHFD Stream Corridor Mapping or by performing additional analysis as further described in Chapter 7.

d. Identify regulatory FEMA or FHAD floodplains and any anticipated or ongoing LOMCs (i.e., CLOMRs/LOMRs) that will be required for the development. Indicate whether or not a Floodplain Development Permit (FPDP) has been submitted, if applicable.

e. Indicate whether proposed infrastructure is public (i.e., maintained by CoA) or private (i.e., maintained by a metropolitan district, homeowner's association, owner, etc.); if private, note agency responsible for maintenance. Note that regional facilities and/or facilities which qualify for the MHFD's MEP should be identified during the Drainage Kick-off Meeting (see Section 2.3.2); any deviations from the MDR or PDR must be approved by AW.

f. Note any temporary proposed stormwater infrastructure.

g. Identify the design calculation method(s) and software used in the hydraulic analysis (e.g., MHFD-Detention workbook, HY-8, HEC-RAS, etc.).

h. Note any other sources referenced aside from this Manual or the MHFD Manual.

i. Provide information on starting tailwater condition(s) (e.g., outfall into channel, pond, or another storm drain). Note that the appendices shall provide relevant calculations and excerpts to support the starting tailwater condition(s).

D. DRAINAGE PLAN

1. General Concept

a. Discuss the proposed drainage concept in detail, including typical drainage patterns.

b. Discuss conformance with the MDR(s), PDR(s) or other previously approved documents with respect to imperviousness, basins, channels, ponds, etc. Note any changes or departures from applicable MDR(s), PDR(s), City MP, floodplain studies, and/or MHFD MDPs. Changes to a MDR may require a MDR Amendment to be approved prior to FDR approval (see Section 2.3.6); changes to a PDR may require a PDL to be approved prior to FDR approval (see Section 2.4.5 above).

c. Discuss conformance with the Public Improvement Plan, if applicable.

d. Describe the conveyance of off-site drainage. Note locations where off-site emergency overflows are both received by and sent from the subject property.

e. Discuss coordination with surrounding developments and indicate whether the proposed FDR, CPs, and a copy of the *Stormwater Conveyance – Notification of Adjacent Property Owners* memorandum have been provided to the off-site owners.

f. Describe the proposed downstream outfall(s). Discuss downstream capacity and note any off-site infrastructure upon which the proposed drainage concept relies. Identify the tailwater condition(s) used in the hydraulic modeling.

g. Discuss the effects of the proposed development on downstream, upstream, and adjacent sites under both existing and future buildout conditions.

h. Discuss the water quality SCMs and detention plan. Identify ownership and maintenance responsibilities. If the site relies on an off-site SCM, such as detention pond or water quality device, state the project platted subdivision name and EDN.

2. Specific Details

a. Discuss project phasing as applicable. Describe the interim condition(s) and ultimate condition. Include discussion of both project phasing and phasing/coordination with ongoing surrounding developments as applicable. Note that separate hydrologic/hydraulic analyses of each phase may be required. If there is no project phasing, state the project will not be phased.

b. Discuss provisions for drainage during construction.

c. Discuss each basin or sub-basin in detail (in words). Include descriptions of land use, basin outfall, design points, proposed internal stormwater infrastructure, upstream drainage areas, and minor and major storm flow patterns through the basin.

d. Provide a table summarizing the percent impervious, runoff coefficient values for minor and major storms, and corresponding discharges for each sub-basin. Show routed flows where appropriate.

e. Describe detention pond design, location(s) and outfall(s). Include the tributary area in acres; the composite percent imperviousness; the required WQCV, EURV, and 100-year storage volume; and the release rates and drain times. Design considerations should also include pond side slopes, bottom slope, forebays, trickle channel, embankment elevation, spillway crest elevation, maintenance access, etc. See additional guidance in Chapter 10. Note whether pond(s) will be publicly or privately maintained and party responsible for maintenance.

f. Discuss any off-site water quality SCMs or detention facilities utilized by the project. Include the RSN or EDN and demonstrate that this project complies with the off-site facility's design. Include a figure showing the location of the off-site facility with respect to the project; alternatively, include a sheet in the CPs showing the off-site facility's location with respect to the project.

g. Provide a table summarizing proposed culverts. Include a designation to locate each culvert on the FDP, culvert dimensions, major and minor design discharges, emergency overflow discharge, number of barrels and material, and the headwater-to-culvert-depth (HW/D) ratio during major storm. If a SSR was prepared, reference said report as applicable (see Section 2.8 below).

h. Discuss each bridge. Include the location; type (steel arch, beam, etc.), material, length, and width; number of spans; number and shape of piers; abutments and wingwalls; scour depths with reference calculations; major and minor discharges; emergency overflow discharge, if applicable (see Chapter 9); and freeboard. If a SSR was prepared, reference said report as applicable (see Section 2.8 below).

i. Describe emergency overflow paths for sump inlets, culverts, bridges (if applicable, see Chapter 9), and detention ponds. Sump inlet, culvert, bridge, and detention pond emergency overflow path descriptions may be included with the individual discussions of each of those elements above. Indicate where the accompanying overflow calculations are located in the appendix and where the overflow cross sections are provided in the CPs.

j. Provide a table summarizing proposed swales, ditches, and open channels. Include a designation to locate each element on the CPs, cross section shape, longitudinal slope, major and minor design discharge, velocity, depth, and freeboard. Include a discussion of the Manning's n-value values used in the hydraulic analysis (see Chapter 7).

k. Discuss street flow capacity. Note the flow depth and street spread for the major and minor storms (see Chapter 6).

l. Discuss how the requirements set forth in the approved MHFD MPD or OSP have been met, if applicable.

m. Discuss the proposed permanent SCMs. See Chapter 11 for more information on permanent SCMs. Do not provide discussion on construction CMs or temporary SCMs.

n. Address how Transportation Oriented Development (TOD), City Center, and Urban Center developments will intercept and convey non-TOD or non-Urban Center upstream development runoff, if applicable.

o. Include any other information deemed necessary to the project and solutions to problems encountered.

E. LIST OF REFERENCES

a. List all criteria, existing drainage reports, MDR(s), City MP(s), floodplain studies, MHFD MDPs, etc. used in the report. Provide citation information including author and date of each reference. Note the EDN or RSN for CoA-approved documents.

F. APPENDICES

1. Soil, Precipitation, Floodplain, and Airport Pond Buffer Information

a. NRCS Soils Report with the site boundaries delineated and the hydrologic soil groups identified.

b. One-hour point precipitation depths for all design events per NOAA Atlas 14.

c. FEMA FIRM or FiRMette with the site boundaries delineated.

d. Airport Detention Pond Buffer Zone with the site boundaries delineated.

2. Hydrologic Computations

a. Identify all equations used in the hydrologic analysis (e.g., time of concentration equation, rainfall intensity equation, detention volume computation method, etc.). Use standard MHFD workbooks where applicable to standardize submittals and help with review timelines. Include copies of the equations and tables from this Manual used in the calculations.

b. Land use assumptions for existing and proposed conditions.

c. Runoff coefficient and percent imperviousness calculations for each drainage basin under historic and developed conditions.

d. Time of concentration calculations for each drainage basin under existing and proposed conditions.

e. Model printouts for any CUHP and/or SWMM modeling, as applicable. Include the inputs and outputs for modeled design storms under historic and proposed conditions. Include a model schematic for any SWMM modeling which depicts all drainage basins, conveyance elements, storage elements, and junctions.

f. Minor and major storm runoff computations for historic and developed runoff conditions for all drainage basins and design points. Include flow routing.

g. Detention pond calculations. Include the WQCV, EURV, and 100-year runoff detention volumes and WSELs, 100-year allowable release rate, detention pond capacity, outlet structure design, and design release rates with supporting calculations. Include all CUHP/SWMM model calculations, MHFD-Detention workbooks, etc., in both hardcopy (i.e., PDF) and digital executable formats.

h. Updates to MDR/MDR plan sheets, PDR/PDP, and/or MHFD MDP modeling (e.g., CUHP, SWMM) which reflect the proposed drainage concept, if applicable. Include model schematic as applicable. Model schematic must depict all drainage basins, conveyance elements, storage elements, and junctions. Include all CUHP/SWMM model calculations, MHFD-Detention workbook, etc., in both hardcopy (i.e., PDF) and digital executable formats. Note that changes to the MDR/MDR plan sheets and/or PDR/PDP may require amendments to those documents (see Sections 2.3.6 and 2.4.5 above).

3. Hydraulic Computations

a. Swale and ditch normal depth design calculations. Calculations should be provided for each cross section and longitudinal slope. Alternatively, calculations may be provided for only the flattest and steepest slopes for each cross section, to demonstrate compliance with freeboard and velocity criteria under the worst-case conditions. The normal depth calculations must include the design flow, channel invert, WSEL, velocity, and Froude number. Provide all calculations in both hardcopy (i.e., PDF) and digital executable formats, where applicable.

b. Open channel design calculations (normal depth calculations, HEC-RAS, etc.). Include a profile for each open channel element which notes the design flow, tailwater condition, cross sections, channel inverts, channel bank elevations, building LFEs, Hydraulic Grade Lines (HGLs), velocities, and Froude numbers. Include all HEC-RAS, FlowMaster, etc., model calculations in both hardcopy (i.e., PDF) and digital executable formats, where applicable.

c. Forebay, micropool, trickle channel, and/or spillway sizing calculations.

d. Detailed geomorphic calculations and analysis for regional channels. Include channel sizing and channel/bank stabilization calculations.

e. Design calculations for all erosion protection and bank stabilization measures.

f. Culvert design calculations.

g. Scour calculations for bridges.

h. Storm inlet design calculations.

i. Street, drive, and alley capacity and flow depth calculations.

j. Storm drain hydraulic calculations for both the minor and major design storms. Provide a schematic of the proposed storm drain system (i.e., “stick diagram”) with all elements identified. Include a printout table of the proposed storm drain system which notes the design storm, design element, size, inverts (in and out),

design flow (do not include full capacity flow), velocities, Froude numbers, hydraulic loss method, hydraulic loss coefficients, HGLs (in and out), and starting tailwater condition. The starting tailwater condition must be clearly identified with annotations referencing the information used to establish the starting tailwater condition (e.g., approved drainage plan set EDN, pond 100-year WSEL, etc.). If necessary, provide any additional calculations necessary to establish the starting tailwater conditions. Include all model calculations in both hardcopy (i.e., PDF) and digital executable formats.

k. Parking lot depth calculations.

l. Emergency overflow calculations for sump inlets, culverts, bridges (if applicable, see Chapter 9), and detention pond spillways. Note the emergency WSELs. Include drainage tract sizing as necessary.

m. Design calculations for all water quality enhancement measures and SCMs (e.g., grass buffers, water quality swales, bioretention cells, forebays, trickle channels, proprietary devices, disconnected impervious areas, etc.).

4. Supporting Documentation

   a. Copies of graphs, tables, nomographs, etc., referenced or used in report or calculations.

   b. Excerpts from previously approved reports, plans, etc. Annotate/highlight relevant information. Note the EDN or RSN where applicable.

   c. SSR justifying the selection of each bridge or culvert with a span greater than 20 feet for each applicable site. See Section 2.8 below.

   d. A copy of the *Stormwater Conveyance – Notification of Adjacent Property Owners* memorandum, if appliable.

5. Digital Data

   a. Electronic copies of models used in above analysis. Provide all input and output files and ensure all submitted models are executable.

2.5.3 Final Drainage Plan and Drainage Information Required on Civil Plans

The FDP is the map which accompanies the FDR and shows the details of the proposed drainage plan. The FDP shall be included in the CP set. Additional drainage information is also shown on a number of sheets in the CP set, including the Cover, Notes (where provided), Grading Plan or Area Grading Plan, Drainage Plan, Pond Plan and Details, Channel Plan and Profile, and Storm Drain Plan and Profile. Sections 2.5.3.1 through 2.5.3.7 below note the specific information that should be provided in each section of the CPs.

2.5.3.1 Notes and Information Required on All Sheets

The following information should be provided on all sheets of the CPs which include drainage information:

A. General Conformance and Adjacent Property Owner Coordination notes (see Section 2.6 below), and reference to a CoA NAVD 88 benchmark.

B. Formal platted subdivision name in title block of each sheet (see textbox at the beginning of Section 2.5.2 above).

C. Public/Private Maintenance note (see Section 2.6 below). For private infrastructure, identify the responsible maintenance party.

D. Ensure that no copyright notes are included on the CP sheets.

2.5.3.2 Cover and Notes Required Information

A. All items in Section 2.5.3.1 above.

2.5.3.3 Grading Plan or Area Grading Plan

A. All items in Section 2.5.3.1 above.

B. LFEs for all structures.

2.5.3.4 Final Drainage Plan Required Information

The FDP shall be included in the CP set. The following items shall be included in the FDP:

A. All items in Section 2.5.3.1 above.

B. Pond Certification note (see Section 2.6 below).

C. Pond Recertification note, if applicable (see Section 2.6 below).

D. Notification of Downstream Water Rights Holders note (see Section 2.6 below).

E. Overview plan sheet depicting and labeling all drainage basins (on-site and off-site).

F. Sheet index for entire FDP area where site cannot fit on a single sheet at the required scale. This may be combined with Item E above.

G. Plan sheets with minimum scales as follows:

1. Single family detached: 1” = 50’

2. Multifamily: 1” = 30’

3. Commercial and Industrial:

- Building footprint less than 500,000 ft^2: 1” = 30’

- Building footprint greater than 500,000 ft^2: 1” = 50’

H. Existing topography at a 2-foot contour interval minimum. Proposed grading at 2-foot contour interval minimum. Contours must provide sufficient coverage to completely

encompass all existing and proposed drainage basins (on-site and off-site). Contours must be extended a minimum of 50-feet beyond the property lines or further as necessary to clearly identify off-site drainage patterns and show the tie-in between the proposed grading and existing topography.

I. Flow direction arrows with slope in percent for proposed on-site grading and off-site areas.

J. Drainage basin boundaries and design points. Note that drainage basins shall incorporate required roadway improvements, including perimeter street sections.

K. Table with basin identifier, basin area (acres), major and minor runoff coefficients, percent imperviousness, and minor and major runoff for all basins and design points. The table must include the direct runoff for each basin and the accumulated (routed) flows for each design point, with tributary basins to a design point identified. Note that design points should not have an imperviousness or runoff coefficient value associated with them in the table row (separate tables for the basin information and design point flows may be provided if so desired).

L. Floodplain information, including the 1PAC floodplain and floodway limits BFEs, if available, from FIRMs, FISs, FHADs, or other Best Available Information (see Chapter 4). Identify the map panel and effective date as applicable on any sheet depicting the floodplain. Identify any LOMCs (i.e., CLOMRs and LOMRs) along with their case number and effective date as applicable.

M. If any work is planned within the floodplain, include the Floodplain Development Permit note (see Section 2.6 below).

N. SMCs. Label corridor widths and identify locations for grade control and bank revetment structures. SMCs shall be per MHFD SMC map unless stream corridor width is revised by accompanying geomorphic analysis (see Chapter 7). Include flow direction arrows.

O. FHZ mapping, if applicable.

P. Location of all existing drainage facilities and public improvements. Include the size and EDN or RSN for each existing facility.

Q. Size, location and type of all proposed drainage facilities with details provided as necessary (see Section 2.5.3.7 below). Reference CoA standard details where applicable. If CoA standard details are used, they need not be included in the CPs; details which are not CoA standard details shall be included. Note: for hydraulic features requiring structural calculations (e.g., inlets, manholes, wingwalls, etc.), the structural calculations must be included with the first submittal of the CPs.

R. Existing and proposed detention pond locations. For each detention pond, label the WQCV, EURV, and 100-year storage volumes and WSELs, design release rates, maximum depths, ponding limits, and any other water quality SCM data as needed for the proposed SCM. Identify the pond side slopes and pond bottom slope, the trickle channel slope and width, forebays, micropool, spillway, and outlet structure (provide details per Section 2.5.3.7 below). Provide the maintenance access width, radii,

longitudinal slope, and cross slope.

S. Size, location, and maximum depth of all permanent SCMs.

T. Location and direction of all emergency overflows for sump inlets, culverts, bridges (if applicable, see Chapter 9), and detention ponds. Emergency overflow arrows shall be unique and included in legend. Label all inlets in sump.

U. Type and height of curb and gutter.

V. 100-year flood depths in all streets in which the curb is overtopped during the 100-year storm.

W. Existing and proposed outfall location(s). Include reference label to applicable report/plan denoting projected received flows.

X. Labeling of any interim infrastructure. Do not include Stormwater Master Plan (SWMP) CMs.

Y. Project phasing as applicable. If necessary, include plan sheets for both interim and ultimate conditions, with relevant hydrologic and hydraulic information adjusted to match each condition.

Z. LFEs for all structures.

AA. Location of all retaining walls, with elevations at the top and bottom of wall and maximum height noted.

BB. Existing and proposed easements (drainage, utility, fire lane, etc.), property lines, tracts, streets, and ROW. Dimension all easements, street widths, and ROWs, and label all roadways, including the roadway classification. Label all lots and blocks, and show all sidewalks. Identify any necessary license agreements.

CC. Labeling of all adjacent properties, subdivisions, developments, etc. Include the platted subdivision names where applicable. Note the EDN or RSN where applicable. Provide CoA jurisdictional boundaries as applicable.

DD. SWMM model schematic diagram depicting all drainage basins, conveyance elements, storage elements, junctions, outfalls, etc., if applicable. The schematic may also be included in the FDR as long as all elements are clearly identifiable.

EE. Any other information deemed necessary to the project.

FF. For drafting standards, scales, and other standard requirements, see the RDCS.

2.5.3.5 Channel Plan, Profile, Cross Sections, and Details

The following items are required for all channel sheets:

A. All items in Section 2.5.3.1 above.

B. Plan view of channel, including the following:

1. Existing topography at a 2-foot contour interval minimum. Proposed grading at 2-foot contour interval minimum. Contours must provide sufficient coverage to completely encompass all existing and proposed drainage basins (on-site and off-site).

2. Match lines and associated sheet numbers.

3. Stream centerline stationing.

4. HEC-RAS cross sections with 100-year discharge and WSEL labeled.

5. 100-year inundation extents.

6. Permanent erosion control and/or bank stabilization features with appropriate sizing and dimensions.

7. Property lines, ROW, easements, and/or tracts with appropriate labeling. Dimension all ROW, easements, and tracts.

8. Streets. Label the roadway classification of each street, and dimension the street width.

9. Lots and blocks.

10. Sidewalks.

C. Profile view of channel, including the following:

1. Channel thalweg.

2. Top of bank elevation(s).

3. HEC-RAS cross sections. Label cross section stationing.

4. 100-year discharge and HGL.

5. Other design storm discharges and HGLs.

6. Dimensioned freeboard.

7. Permanent erosion control and/or bank stabilization features with appropriate sizing and dimensions,

8. Existing and proposed utilities. Provide clearance dimensioning. Identify any utility conflicts.

9. Reinforcement locations.

10. Adjacent building LFEs, LPEs, easements, and property lines as applicable.

D. Cross sections for each channel section, including the following:

1. Bottom width and thalweg elevation.

2. Side slopes.

3. Top of bank elevation(s).

4. 100-year discharge and WSEL.

5. Other design storm discharges and WSELs.

6. Dimensioned freeboard.

7. Permanent erosion control and/or bank stabilization features with appropriate sizing and dimensions.

8. Adjacent building LFEs, LPEs, easements, and property lines as applicable.

E. Size, location, dimensions, and necessary detail(s) of all permanent erosion control and/or bank stabilization features.

2.5.3.6 Storm Drainage Plan and Profile

The following items are required for all storm drainage sheets. The storm drainage plan and profile may be combined with the roadway plan and profile. If the storm drainage plan and profile are combined with the roadway plan and profile, see the RDCS for additional requirements. Note that all private stormwater infrastructure that is proposed to collect runoff from the 100-year storm event must provide a plan and profile.

A. All items in Section 2.5.3.1 above.

B. Plan view of storm drainage system, including the following:

1. Note stating the following: "*Contractor shall maintain a minimum of 0.5% grade at flow line into inlet."*

2. Existing topography at a 2-foot contour interval minimum. Proposed grading at 2-foot contour interval minimum. Contours must provide sufficient coverage to completely encompass all existing and proposed drainage basins (on-site and off-site).

3. Stationing based on roadway centerline only.

4. Station and critical elevation (flow line, invert of culverts, etc.) of all existing and proposed drainage appurtenances.

    - For each pipe and inlet, include the invert, type, size, structural class, length, material, and bedding classification.

5. Flow direction arrows, particularly at intersections and manholes.

6. Match lines and associated sheet numbers.

7. Station and elevation of all points of curb return (PCRs). Curb returns that are turning water shall show the slope of the gutter between the PCRs.

8. Existing and proposed utilities and structures.

9. Proposed construction phasing, if applicable.

10. Property lines, ROW, easements, and/or tracts with appropriate labeling. Dimension all ROW, easements, and tracts.

11. Streets. Label the roadway classification of each street and dimension the street width.

12. Lots and blocks.

13. Sidewalks.

C. Profile of storm drainage system, including the following:

1. Stationing based on roadway centerline only. Stationing shall proceed from left to right and shall align on the same sheet with the plan view.

2. Existing and proposed grading. The existing grade shall use a dashed linetype, and the proposed grade shall use a heavy, solid linetype. Each shall be plainly labeled.

3. Station and critical elevation (flow line, invert of culverts, etc.) of all existing and proposed drainage appurtenances.

   - For each pipe and inlet, include the invert, type, size, structural class, length, material, and bedding classification.

   - For manholes, label all manhole inside diameters and drop-throughs.

   - For inlets, label all inlet sizes and drop-throughs.

4. Storm drain design flows and HGLs for each pipe segment. This applies for both private and public storm drain systems.

5. Existing and proposed utilities and structures. Provide clearance dimensioning. Identify any utility conflicts.

6. Adjacent building LFEs, LPEs, easements, and property lines as applicable.

2.5.3.7 Details

The following are required details in the CPs for drainage features. The CPs shall provide adequate details of miscellaneous structures. Reference CoA standard details where applicable. If CoA standard details are used, they need not be included in the details; details which are not CoA standard details shall be included. Features that are not maintained by the CoA shall be clearly identified as private details.

1. Detention Pond

    a. Pond Certification Note (see Sections 2.6 and 2.7 below).

    b. Notification of Downstream Water Rights Holders note (see Section 2.6 below).

    c. Spillway cross section depicting length of spillway, side slopes, invert elevation, design flow, depth of flow, freeboard dimensions, LFEs and LPEs of adjacent buildings, and top of berm elevation.

    d. Outlet structure details, including the following: multiple cross sections through outlet structure, micropool details (including plan view), grate details, orifice plate section, orifice screen details, and restrictor plate section with outlet pipe size. Show the controlling WSELs (e.g., WQCV, EURV, and 100-year WSELs). Include relevant elevations and dimensions.

    e. Profile through outlet structure and spillway depicting: the micropool, outlet structure, and outlet pipe, with invert elevations labeled for each; controlling WSELs; spillway slope grading; cutoff wall depth, size, and foundation; and riprap type and depth.

    f. Pond bottom slope and side slopes.

    g. Trickle channel slope and width.

    h. Plan and profile of forebays with reinforcement labeled.

    i. Maintenance access typical cross section depicting width, turning radius, material, longitudinal and cross slopes.

    j. Plan view of maintenance access showing width, turn radii, material, and longitudinal and cross slopes.

    k. Detail of Detention Pond Signage with required sign area and text. Indicate installation location of signage for all ponds.

    l. Easements

    m. Height of any walls and top of wall elevation.

2. Underground Detention

    a. Note stating as follows: "*As a part of the pond certificate submittal, a letter from the manufacturer is required to confirm that the underground detention facility has been installed per the plan*."

    b. Note stating as follows: "*Photographs of the installation of the underground detention facility, along with photographs of major features thereof, are required as a part of the pond certificate submittal.*"

    c. Plan view.

d. Profile along main system with inverts and required cover labeled.

e. Cross section with dimensions.

3. Swales and Ditches

a. Typical cross sections for each swale and/or ditch. Note the bottom width, side slopes, top of bank elevation, major and minor design storm discharges and WSELs or flow depths, dimensioned freeboard, and adjacent building LPEs, easements, and property lines as applicable. Include a note identifying all swales and/or ditches as privately maintained.

4. Emergency Overflows

a. For each emergency overflow location, include a cross section noting the bottom width, side slopes, emergency overflow discharge, WSEL, dimensioned freeboard, and adjacent building LPEs, easements, and property lines, if applicable.

5. Structural Details for Cast-In-Place Structures (note that no details or calculations required for pre-cast concrete structures)

a. Inlets greater than 10 feet in depth.

b. Forebays and micropools.

c. Special outlet structures.

d. Special inlets.

e. Headwalls and wingwalls less than 4 feet in height that do not require additional calculations.

f. Storm drain connections to structural inlets larger than 15 feet.

g. Multiple storm drain connections to inlet.

h. Skewed storm drain connections to inlets where pipe penetration exceeds the inside wall width.

i. All structures with non-standard grate openings and grate hinges.

j. Wingwalls with pipe penetrations.

k. Spillway cutoff walls and baffle blocks.

6. Bioretention

a. Plan and profile view with dimensions.

b. Cross section with dimensions.

c. Specifications for filter media.

7. Grass Swales

    a. Profile with top of bank elevation, major and minor design storm discharges and WSELs or flow depths, dimensioned freeboard, underdrain, and filter media identified. Note adjacent building LPEs, easements, and property lines as applicable.

    b. Cross section with bottom width, side slopes, top of bank elevation, major and minor design storm discharges and WSELs, dimensioned freeboard, underdrain, and filter medium identified. Note adjacent building LPEs, easements, and property lines as applicable.

2.5.4 Final Drainage Letter

A FDL (letter; conformance letter) is a simplified drainage submittal that can be used to document conformance with a previously approved FDR and FDP/CP set when a site meets all of the following qualifying criteria:

1. Prior approval to submit a FDL in lieu of a FDR must be obtained from AW. If a pre-application meeting with the ODA was held, the meeting notes from that meeting should be consulted to determine if a FDL will be allowed in lieu of a FDR.

2. The property must be included in a previously approved FDR and FDP/CP set where the site conditions and site plans have not significantly changed. The FDL must reference the previously approved plan and any subsequently approved FDL(s), and must also include the EDN or RSN where applicable.

3. The development must not alter flow or drainage patterns which affect other properties from those previously established in approved PDRs, FDRs, or CPs which included the property.

4. The site must currently discharge to an improved drainage channel or existing storm drain system. The adjacent surface drainage system must have the hydraulic capacity for post-development runoff, and additional storm drains are not required for development of the site.

5. The development must not require additional on-site detention or water quality treatment. Water quality, EURV, and detention are provided for the site from an off-site facility.

A FDL may also be required when there are changes to CoA-approved CPs. A FDL submittal to amend approved CPs are required when any of the following conditions apply:

1. A site plan amendment is required by the CoA Planning Department. If there are no changes to the drainage plans, the FDL will simply be a conformance letter stating that there are no changes to the drainage plan of the approved FDR.

2. The FDR includes more than one development or covers a commercial or industrial site with one or more lots to be developed at different times, where changes to the drainage design may impact the other portions of the development.

3. There are any changes to the drainage design from the approved FDR, including (but not limited to):

    a. Changes in land use or density that increase the imperviousness and/or area contributing to a drainage facility such that the sizing or design of the facility requires modification.

    b. Changes in pond or channel sizing or location.

    c. Changes to drainage basin or subbasin boundaries.

    d. Changes to roadway locations or widths.

    e. Changes in grading that affect drainage infrastructure.

FDLs are primarily applicable to development of pad sites within previously approved commercial developments or for minor changes to existing properties. They are generally appropriate if preceded by a PDL (see Section 2.4.5 above). A FDL is required if there any any changes to the CPs. The letter must be addressed to the AW Drainage Supervisor. The letter must be submitted as a PDF and must be signed and sealed by a qualified Professional Engineer licensed in the State of Colorado.

The letter must identify the platted subdivision name, location, project land use, and any minor drainage changes to the previously approved drainage study. The letter must include information that demonstrates that the design of the site is in general conformance with the previously approved drainage study. Updated calculations may need to be provided to document changes to basin areas, impervious values, runoff coefficient values, flows, volumes, or other drainage characteristics established in a previously approved drainage report.

A general location map must accompany the letter, and a site map (8-1/2” x 11” or 11” x 17”) is required that shows at a minimum:

1. Property boundaries.

2. Existing and proposed site features (buildings, parking areas, drive lanes, and other impervious surfaces).

3. Arrows showing existing and proposed drainage patterns. Include existing and proposed contours.

4. Labels identifying relevant drainage infrastructure.

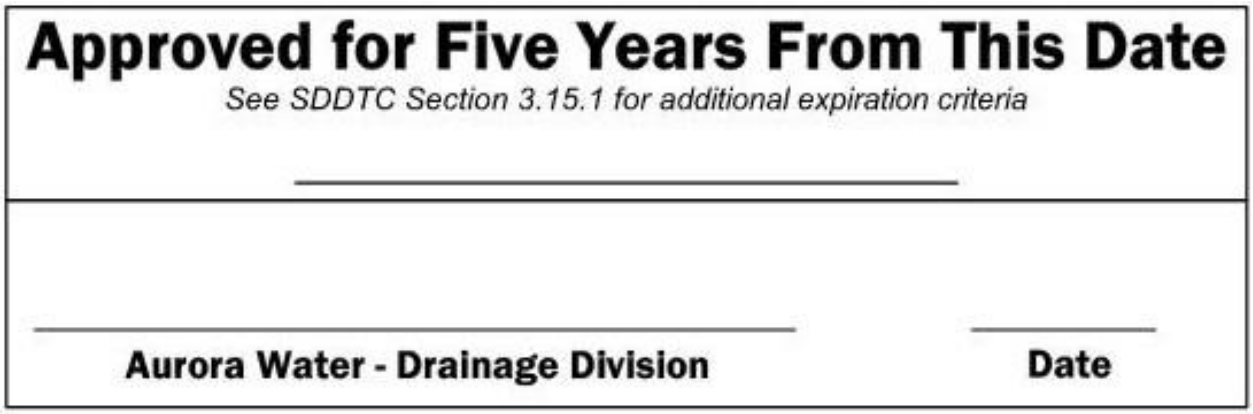
5. Labels identifying existing and proposed peak flow rates at any points where concentrated runoff leaves the property.

Design drawings are not required for a FDL but may be included by the applicant if they are needed to explain how the project conforms to the previously approved drainage plan; these typically take the form of revised plan sheets from the FDP/CPs, updated to reflect proposed changes. If design drawings or details are provided, they must be an 8-1/2” x 11” or 11” x 17” size attached to the letter. Revisions shall be shown in clouded annotations on the FDP/CP

sheets, FDR text, model sheets, etc. Where computer models are used, executable input and output files must be provided in digital format.

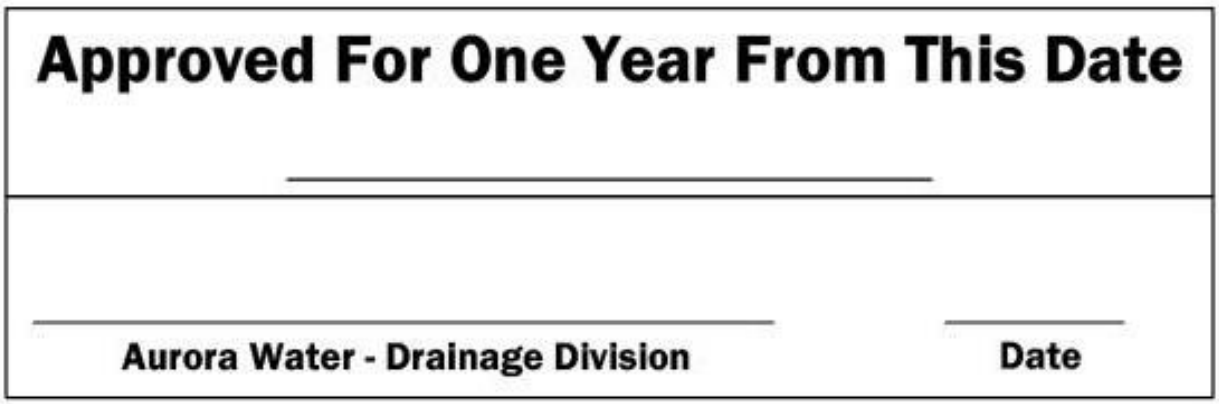
2.6 APPROVAL BLOCKS AND TYPICAL NOTES

For MDRs, the title page of the report and the lower right-hand corner of all drawings must include the following approval block:



APPROVAL BLOCK
(nts)

For PDRs, PDPs, and FDRs, the title page of the report and the lower right-hand corner of all drawings must include the following approval block:



APPROVAL BLOCK
(nts)

Each drainage plan sheet must also include the following General Conformance note and Adjacent Property Owner Coordination note:

City of Aurora plan review is only for general conformance with City of Aurora Design Criteria and the City Code. The City is not responsible for the accuracy and adequacy of the design, of dimensions and elevations which must be confirmed and correlated at the job site. The City of Aurora, through the approval of this document, assumes no responsibility for the completeness and/or accuracy of this document.

Approval of this document by City of Aurora does not imply approval for any off-site work on adjacent private property. In is the owner's responsibility to coordinate with adjacent property owners and obtain all necessary approvals and easements for such work.

The following Public/Private Maintenance note may be used to identify stormwater infrastructure as either publicly or privately maintained. For private infrastructure, identify the responsible maintenance party.

All storm infrastructure is [*private/public*] and designed for the [*design recurrence interval]* storm event.

The following Notification of Downstream Water Rights Holders note shall be included on each drainage plan sheet with detention pond information:

Ensure that the provisions of CRS 37-92-602, as amended by Senate Bill 15-212, regarding Notification of Downstream Water Rights Holders are upheld.

The following Pond Certification note shall appear next to each detention pond plan and permanent SCM on the construction drawings:

The developer shall have a licensed Professional Engineer certify each stormwater detention pond and/or water quality SCM is built according to the approved plans and specifications and the required detention volume, including the WQCV when used, is met. The certification shall also verify all pertinent dimensions, elevations, required outlet orifice plates for detention and WQCV and other permanent SCMs requirements are installed per the approved plans and specifications, and shall show the as-built design volumes (WQCV, EURV, 100 year) and other pertinent dimensions, elevations and capacity requirements associated with the SCM used. The certification shall be provided to the City of Aurora Engineering Control Section Principal Engineer. An approved pond certificate shall be required prior to the return of any Fiscal Security Deposit (as well as satisfying other conditions of the Stormwater permit) for sites that do not require a certificate of occupancy. Examples of these sites include but are not limited to: sites without vertical construction, oil and gas well pads, outdoor storage, and tow yards. An approved pond certificate shall be required prior to commencement of business operations. In no case shall a Certificate of Occupancy or Temporary Certificate of Occupancy be issued without an approved pond certificate.

For drainage concepts which rely on an existing pond for detention or water quality, the following Pond Recertification note shall appear next to each existing facility upon which the drainage concept relies:

Applicant understands recertification may be required. If a pond certificate, an executed I&M plan, or drainage easements do not exist, the applicant will be required to provide these prior to civil plan approval.

If any work is planned within the floodplain (regulatory or non-regulatory, see Chapter 4), the following Floodplain Development Permit note shall be included on any sheet depicting proposed modifications within the floodplain:

Applicant understands that work in 100-year Floodplain requires a Floodplain Development Permit which must be obtained prior to grading or construction within the floodplain.

2.7 CERTIFICATION OF PONDS AND WATER QUALITY FACILITIES

All detention and water quality ponds (and water quality devices) must be certified. The intent of the certificate is to ensure the facility was constructed and will function per the design. Certificates are required for all detention and water quality facilities, including detention and/or water quality ponds, parking lot detention, underground detention, pumped detention, retention ponds, permanent SCMs, and water quality devices (proprietary or otherwise). A new certificate for an existing facility (i.e., recertification) is required if there are any changes or recent/required improvements to an existing facility. For submittals with more than one pond, SCM, or other facility, a separate pond certificate shall be submitted for each pond, SCM, and facility. In the

case of a proprietary SCM or water quality device, all such facilities shall be combined into one pond certificate.

A Professional Engineer licensed in the State of Colorado must ensure and certify that each stormwater detention pond and/or SCM is built according to the approved plans and specifications, and that the required detention volume (including the WQCV, if applicable) is met. The certification must verify that all pertinent dimensions, elevations, volumes, orifice plate sizing, permanent SCM feature sizing, etc. are installed per the approved plans and specifications, and must also show the as-built design volumes (WQCV, EURV, and 100-year). Other specific requirements for pond certifications are noted at Pond Certificate Requirements for Engineers (Aurora Water, latest edition).

The certification must be submitted in letter format and addressed to the AW Drainage Supervisor. The letter must state the EDN and platted subdivision name as shown on the CPs. The letter shall be stamped (i.e., unlocked with scanned stamp) by a Professional Engineer licensed in the State of Colorado. The certification must be emailed to aurorawaterdrainage@auroragov.org.

An approved pond certificate is required prior to the return of any Fiscal Security Deposit (as well as compliance with any other conditions of the Stormwater permit) for sites that do not require a Certificate of Occupancy (CO), such as: sites without vertical construction, oil and gas well pads, outdoor storage, and tow yards. For sites which do require a CO, under no circumstances can a CO or Temporary CO be issued without an approved pond certificate. No paving operations may proceed until initial certification of the required detention and water quality facilities is provided. Off-site infrastructure upon which the site relies must have a pond certificate submitted prior to CP approval or the issuance of building permits. An approved pond certificate is required prior to commencement of business operations.

The Pond Certification note included in Section 2.6 above shall appear next to each detention pond plan, pond detail sheet, and permanent SCM on the construction drawings. Additionally, for drainage concepts which rely on an existing facility for detention or water quality, the Pond Recertification note included in Section 2.6 above shall appear next to each existing facility upon which the drainage concept relies.

2.8 STRUCTURE SELECTION REPORT

A SSR is required whenever a crossing of a major drainageway has a span greater than 20 feet is proposed and must be provided as part of the PDR and included in the subsequent FDR. The purpose of the SSR is to recommend a structure type (i.e., culvert or bridge), with its attendant configuration, dimensions, and materials, for a roadway crossing of a major drainageway. Examples of structure types include reinforced concrete box culverts (RCBCs), concrete arch culverts, and bridges with piers. Examples of configuration parameters may include the number of cells, openings, and/or piers, and the relative inverts of each. Examples of dimensions may include the diameter or width and height (for culverts) or the opening widths and pier diameters (for bridges). Examples of materials may include concrete or steel.

Reference is made to the CDOT Bridge Design Manual (Colorado Department of Transportation, latest edition), and the CDOT Structure Selection Report QA Checklist (Colorado Department of Transportation, latest edition); a SSR meeting CDOT requirements will also meet CoA requirements. Alternatively, a more streamlined SSR than described by CDOT criteria may also fulfill the CoA's requirements, as long as the following items are provided:

- Location with vicinity map.
- Description of the existing structure, if applicable.
- Required roadway cross section based on roadway classification, along with the horizontal and vertical alignment.
- Required accommodation for grade-separated regional trails under the deck.
- Discussion of traffic impacts during construction, if applicable.
- Discussion of utilities and potential conflicts.
- Discussion of hydraulics, including design flows, geomorphic and sediment transportation considerations, and regulatory impacts.
- Discussion of environmental concerns.
- Discussion of geotechnical concerns. A geotechnical report addressing these matters is required.
- Discussion of selection criteria, which should be based on the preceding information.
- Development and evaluation of several viable alternatives for the proposed crossing.
- Cost estimates for each alternative.
- Recommendation of a structure based on the selection criteria.
- Conceptual drawings of the selected structure. Drawings should fully define the geometry of the structure but need not include structural details or reinforcement.

All reports shall be submitted digitally in a PDF sized to 8 ½" x 11" or 11” x 17” paper and be legible. The cover must include: the name of the project, structure number, and platted subdivision name; the Owner’s name, address, phone number, email, and point of contact; the Engineer’s name, address, phone number, email, and point of contact; and approval block (see Section 2.6 above). The report must include all items listed above, along with supporting calculations, charts, and design aids included in the appendix. SSRs must be prepared by a qualified Professional Engineer licensed in the State of Colorado, or under their direct supervision, whose seal and signature must be affixed to the report and all plan sheets.

2.9 INSPECTION AND MAINTENANCE PLANS

I&M Plans are required for all permanent SCMs installed on a site; see the Aurora City Code, Section 138-442.5(b). The purpose of the I&M Plan is to provide information to the person or entity responsible for inspection and maintenance of the facility to ensure that the facility is adequately maintained and can function as designed. The information provided in the I&M will help maintenance personnel understand the facility, provide guidance for inspection and maintenance operations specific to the type of facility, and provide mechanisms for ensuring that long-term maintenance of the facility is performed. I&M Plans shall be submitted concurrently with the FDR and CPs submittal.

The I&M Plan will include the following documents:

1. **I&M Plan Template** – This document provides general instructions and requirements for performing inspection and maintenance. The document does not need to be modified other than inserting project-specific information in the relevant sections of the template.

2. **Stormwater Facility Maintenance Agreement** – This is a legal document that must be filled out and signed by both the facility owner and the AW Drainage Division.

3. **Description of Stormwater Facilities** – This document summarizes the stormwater facilities included on the project site.

4. **I&M Standard Operating Procedures (SCM-specific)** – This document describes the standard operating procedures (SOPs) for inspecting and maintaining a particular SCM. Each type of SCM has a different set of SOPs.

5. **Inspection Form (SCM-specific)** – This is the form to be filled out during inspections of the facility. Each type of SCM has a different inspection form.

6. **Maintenance Form (SCM-specific)** – This is the form to be filled out after performing maintenance activities. Each type of SCM has a different maintenance form.

7. **Annual Inspection and Maintenance Reporting Form** – This form is required to be filled out by the facility owner and submitted to the CoA annually. This form helps the CoA document and track inspection and maintenance activities to confirm that they are being completed appropriately.

8. **Stormwater Facility Map, Plan and Detail Drawings** – A map showing the location of all stormwater facilities and their proximity to other infrastructure. Additional sheets that show various SCM-specific design plans and details are also required to assist inspectors and maintenance personnel. Checklists have been provided that identify the information required on these documents.

I&M Plan templates and additional information is located here.

2.10 PROCEDURE FOR VARIANCES

Variances are not encouraged; however, CoA understands unique situations exist whereby a variance may be required. Variance review and coordination may increase the review time and the number of iterations required to receive approval. If more than one variance is being requested, provide a numbered list of all requested variances and include the information below. At a minimum, each variance request must:

1. Identify the specific criteria for which a variance is requested.

2. Identify the specific location of each instance of a requested variance, if the same variance is requested for multiple locations (e.g., Inlet 1, Inlet 4D, etc.). If a variance is requested to a criterion which requires a specific numeric value (e.g., 1 foot of freeboard), the replacement value at each instance of a requested variance must be provided.

3. Explain why the criteria cannot be met.

4. Demonstrate that no significant adverse effects to public safety or property will be caused if a variance is granted.

5. Provide supporting documentation, necessary calculations and other relevant information supporting the request.

Upon receipt, AW will review the variance and provide a decision approving, denying, or approving with modifications or conditions. Variances shall be approved by an authorized representative of the AW department. Variances are not approved until the final approval of the submittal (MDR, PDR, or FDR).

Variances that were approved for a previous report (provided there is no change to the parameters that were used to approve the original variance) do not need to be re-requested for a later report provided that the subsequent report is submitted within one year and approved within two years (e.g., a variance approved with a PDR need not be reapplied for during the FDR process as long as the FDR is submitted within one year and approved within two years of the PDR being approved). Subsequent reports must note the prior variances approvals in the variance section and include appropriate documentation in the appendix.

2.11 REFERENCES

Aurora Water. (latest edition). *Pond Certificate Requirements for Engineers.* Aurora: City of Aurora. Retrieved from https://www.auroragov.org/business_services/development_center/aurora_water_design_standards_and_specifications

Aurora Water. (latest edition). *Stormwater Conveyance - Notification of Adjacent Property Owners.* Aurora: City of Aurora. Retrieved from https://www.auroragov.org/business_services/development_center/aurora_water_design_standards_and_specifications

City of Aurora. (n.d.). Aurora City Code Section 138-191. In *Aurora City Code.* Retrieved from https://aurora.municipal.codes/Code/138-191

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Mile High Flood District. (2012). *Maintenance Eligibility Program Guidelines For Flood Control Facilities Constructed By Others.* Denver. Retrieved from https://www.mhfd.org/wp-content/uploads/uploads/working%20with%20us/maintenance%20eligibility/Mefs%20Guidelines.OLD

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United States Army Corps of Engineers. (latest edition). *Hydrologic Engineering Center's River Analysis System (HEC-RAS)*. Retrieved from https://www.hec.usace.army.mil/software/hec-ras/

United States Environmental Protection Agency. (latest edition). *Storm Water Management Model (SWMM)*. Retrieved October 2, 2023, from https://www.epa.gov/water-research/storm-water-management-model-swmm

Urban Drainage and Flood Control District (now Mile High Flood District). (latest edition). *CUHP 2008 User Manual, Version 2.0.0.* Denver. Retrieved from https://mhfd.org/resources/software/

CHAPTER 3.0 STORM DRAINAGE POLICY

3.1 INTRODUCTION

This chapter describes the City of Aurora's (CoA's) policies with respect to various storm drainage topics. It also defines the authority and regulations under which this Manual operates, provides the relationship between this Manual and other criteria manuals, defines numerous terms used throughout this Manual, and explains the special requirements for particular watersheds within the CoA.

3.2 OVERARCHING PRINCIPLES

The purpose of this Manual is to present the design criteria and regulations governing storm drainage and stormwater in the CoA. All planning and design must manage storm drainage with regard to quantity and quality to protect the health, safety, and welfare of current and future residents of the CoA. The criteria in this Manual support the mission, vision, and goals of the CoA as outlined by the City Council. In particular, these criteria aim to provide safe and functional infrastructure and facilities.

The well-established principles outlined in the Mile High Flood District's (MHFD's) *Urban Storm Drainage Criteria Manual* (MHFD Manual) are also adopted by reference in this Manual and supplement the criteria in this Manual (Mile High Flood District, latest edition).

3.3 REGULATORY DRIVERS

The criteria in this Manual are adopted by Aurora Water (AW) under the authority granted to it by the Aurora City Code (see Chapter 1). Regulatory drivers for criteria in the Manual include the following:

1. The CoA's Municipal Separate Stormwater System (MS4) permit and Colorado Department of Public Health and the Environment (CDPHE) regulations form the basis of the criteria related to stormwater quality. The MS4 permit and CDPHE regulations arise from the Clean Water Act.

2. The requirements of the National Flood Insurance Program (NFIP) provide the basis for floodplain management criteria.

3. Wetland regulations of the United States Army Corps of Engineers (USACE) are referenced in this Manual.

4. Colorado drainage law, summarized in Volume 1, Chapter 2: Drainage Law of the MHFD Manual.

5. Colorado water law, including Colorado Revised Statute (CRS) 37-92-602 (8) related to water rights exemptions for certain stormwater management facilities (Colorado Revised Statutes 37-92-602 (8)).

6. The regulations and requirements of the Aurora City Code (see Section 3.4).

3.4 REGULATIONS

Aurora City Code ordinances specifically addressing drainage requirements for subdivisions are noted in Table 3-1 with a link to the applicable section of the Aurora City Code, as amended.

Table 3-1. Aurora City Code Drainage Regulations

Section	Link
138-361. Definitions.	https://aurora.municipal.codes/Code/138-361
138-362. Liability.	https://aurora.municipal.codes/Code/138-362
138-363. Rules and regulations.	https://aurora.municipal.codes/Code/138-363
138-364. Master plan.	https://aurora.municipal.codes/Code/138-364
138-365. Dedication of easements; construction and maintenance of minor facilities.	https://aurora.municipal.codes/Code/138-365
138-366. Construction of regional facilities.	https://aurora.municipal.codes/Code/138-366
138-367. Preliminary and final drainage plans.	https://aurora.municipal.codes/Code/138-367
138-368. Requirements for mains, structures or facilities.	https://aurora.municipal.codes/Code/138-368
138-191. Use of turf and ornamental water features.	https://aurora.municipal.codes/Code/138-191

Specific regulations concerning floodplains are included in Chapter 4 of this Manual. Specific regulations concerning stormwater quality are included in Chapter 11 of this Manual.

3.5 HIERARCHY OF GUIDANCE FOR DRAINAGE DESIGN

In addition to the criteria specifically outlined in this Manual, drainage design guidance and criteria are available in many other manuals and references. Where criteria differ between references, the following hierarchy applies (criteria contained in those references higher on the list shall govern over criteria contained in those references lower on the list):

1. Aurora City Code, including the UDO.

2. *Storm Drainage Design and Technical Criteria* (i.e., this Manual).

3. Other CoA publications, such as the CoA's *Roadway Design and Construction Specifications* (RDCS); AW's *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications*, *Erosion Control & Stormwater Standards*, and *Stormwater and Wastewater Lift Station Design and Engineering Guidelines*; and the Parks, Recreation, and Open Space (PROS) Department's *Dedication and Development Criteria Manual*.

4. MHFD's *Urban Storm Drainage Criteria Manual* and supporting publications, including Outfall System Plans (OSPs), Major Drainageway Plans (MDPs), and Flood Hazard Area Delineations (FHADs).

5. Publications from State of Colorado agencies, including but not limited to:
    a. Colorado Department of Transportation (CDOT),
    b. CDPHE,
    c. Colorado Water Conservation Board (CWCB),
    d. State Engineer's Office (SEO), and
    e. Cherry Creek Basin Water Quality Authority (CCBWQA).
6. Publications from federal agencies and professional associations, including but not limited to:
    a. America Association of State Highway and Transportation Officials (AASHTO),
    b. American Society of Civil Engineers (ASCE),
    c. ASTM International,
    d. Environmental Protection Agency (EPA),
    e. Federal Aviation Administration (FAA),
    f. Federal Emergency Management Agency (FEMA),
    g. Federal Highway Administration (FHWA),
    h. National Oceanic and Atmospheric Administration (NOAA),
    i. National Resource Conservation Service (NRCS),
    j. USACE, Hydrologic Engineering Center (HEC),
    k. United States Bureau of Reclamation (USBR),
    l. United States Department of Agriculture (USDA), and
    m. United States Geological Survey (USGS).

3.6 KEY DEFINITIONS

This section provides definitions of key terms used in this Manual. The following list of definitions is supplemental to definitions provided in the Aurora City Code and UDO, as well as definitions in the MHFD Manual. Where definitions were taken from the Aurora City Code or UDO, citations are provided. Other definitions were based on those found in the MHFD Manual and in other regulatory guidance documents.

Adequate Assurances Agreement – An adequate assurances agreement is an agreement between reservoir owner(s), affected municipalities, and the MHFD which formally recognizes the importance of the flood routing capability of a reservoir or other storage area. Such

agreements help preserve flood storage in private and/or non-flood control reservoirs, such as water supply or irrigation reservoirs. An adequate assurances agreement is needed in order to consider privately-owned reservoirs and non-flood control reservoirs or other storage areas in watershed hydrology and must be included within a MHFD-approved Master Plan.

Colorado Urban Hydrograph Procedure (CUHP) – CUHP is a Colorado-based unit hydrograph procedure used for calculating peak flows and runoff hydrographs.

Detention Pond – A detention pond is a stormwater management facility that attenuates (i.e., reduces) peak flow rates by temporarily storing stormwater and releasing it in a controlled manner. Detention ponds should fully drain between storm events with the exception of the micropool area. The CoA requires detention facilities to be designed for Full Spectrum Detention (FSD). Detention ponds are also often referred to as “detention basins.”

Developer – A developer is the entity which will install, or cause to be installed, the stormwater infrastructure which supports a development.

Development – A development is any manmade change to improved or unimproved real estate, including but not limited to the construction, reconstruction, conversion, or enlargement of any structure; and any clearing, dredging, grading, paving, excavation, drilling, or mining operation. The term "development" shall also include the subdivision of real property.

Development Improvement Project (DIP) – A DIP is a project where a developer partners with MHFD to design, permit, and construct stream improvements along major drainageways.

Directly Connected Impervious Area (DCIA) – DCIA is impervious area that drains to the storm drain system or stream without flowing over surfaces that would allow for infiltration (i.e., pervious areas).

Drainage Basin Development Fee – The Drainage Basin Development Fee is the fee levied and assessed upon each vacant and undeveloped lot and parcel of land within the CoA for the purpose of funding the construction and installation of regional facilities in accordance with the drainage master plan (Aurora City Code Section 138-361).

Drainage Basin Plans – Drainage basin plans are plans that describe flood control and storm drainage channels, structures, storm drains and facilities for conveyance, control or storage of stormwater in individual drainage basins. Upon approval by the director of water, such plans shall become detailed subsections of the drainage master plan (Aurora City Code Section 138-361).

Emergency Overflows – Emergency overflows refer to flows that exceed the design capacity of a stormwater facility (e.g., detention and water quality ponds, culverts, bridges, sump inlets, open channels, and similar features), or those flows which occur when such a facility becomes clogged with debris and cannot convey the full design discharge. Emergency overflows must be managed to avoid adverse impacts to life and property along the emergency overflow path.

Excess Urban Runoff Volume (EURV) – The EURV is the difference between the developed condition runoff volume and the pre-development runoff volume. Based on the hydrologic methods used within the MHFD region, the EURV is relatively consistent at any given level of imperviousness for the range of storms that produce runoff.

Flood Hazard Area Delineation (FHAD) – A FHAD is a document prepared by MHFD in cooperation with local governments to identify flood hazards along major stream corridors (and tributaries, where applicable). FHADs typically build on the future conditions baseline hydrology developed as part of a MDP and perform a hydraulic analysis to delineate the floodway and floodplain(s). FHADs are typically precursors to changes in FEMA Flood Insurance Rate Maps (FIRMs).

Freeboard – Freeboard is a factor of safety usually expressed as the vertical distance (in feet) between a water surface elevation (WSEL) and the elevation of a feature, such as the lowest floor of a building or the top of a streambank. Freeboard compensates for the many unknown factors that could create flood heights greater than the height calculated for a given flood discharge. The amount of freeboard required is related to risk.

Full Spectrum Detention (FSD) – FSD is a water quality and detention design approach intended to reduce flooding and stream degradation impacts associated with urban development by controlling peak flows in the stream for a range of events. FSD is focused on controlling peak discharges over the "full spectrum" of runoff events, from small, frequent storms up to the 100-year flood.[8] FSD produces outflow hydrographs that, other than the small release rate of the EURV, replicates the shape of pre-development hydrographs. FSD modeling shows a reduction of urban runoff peaks to levels similar to pre-development conditions over an entire watershed, even with multiple independent detention facilities. Design and sizing of FSD facilities may be accomplished using the MHFD-Detention workbook.

Inspection and Maintenance (I&M) Plan – An I&M Plan is a document that includes: a legal agreement defining inspection and maintenance requirements and responsibilities; technical criteria for maintenance activities, methods, and frequencies; and record (i.e., as-built) drawings of the facility annotated with maintenance requirements. I&M Plans are required for all private detention and water quality facilities, minor streams, and other private infrastructure for which specific maintenance activities must be performed by the owner or association.

Interim Drainage Facilities – Interim drainage facilities are temporary drainage facilities used instead of permanent drainage facilities to support phased development. The use of interim drainage facilities in lieu of permanent drainage facilities shall be discussed and approved by AW. Interim drainage facilities shall be privately maintained and are not maintained by AW.

Jurisdictional Dam – A jurisdictional dam is a dam which creates a reservoir with a capacity of more than 100 acre-feet or a surface area in excess of 20 acres at the high water line, or a dam where the jurisdictional height exceeds 10 feet. Refer to the SEO's *Rules and Regulations for Dam Safety and Dam Construction* (Colorado Department of Natural Resources, latest edition).

Lowest Floor Elevation (LFE) – The LFE is the elevation of the lowest floor of the lowest enclosed area (including basements and crawl spaces) used for living purposes, which include working, storage, sleeping, cooking, eating, recreation, or any combination thereof. This includes any floor or enclosed area that could be converted to such a use (e.g., unfinished basement or crawl space). The LFE is a determinate for the flood insurance premium for a building, home, or business. An unfinished or flood resistant enclosure, usable solely for parking or vehicles, building access, or storage (in an area other than a basement or crawlspace area), is not considered a building's lowest floor provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirement of Section

[8] Also known as the 1% annual chance (1PAC) flood.

60.3 of the NFIP (44 CFR 60.3(c)(5); Aurora City Code Section 70-4).

Lowest Point of Entry (LPE) – The LPE is the lowest elevation at which surface water may enter a structure, such as the elevation of the bottom of a door frame, or the elevation of the top of a basement window well. The LPE is distinct from the LFE, though in some cases the elevations of each may be identical.

Major Drainageway Plan (MDP) – A MDP is a document prepared by MHFD in cooperation with local governments to evaluate current and future hydrology and hydraulics and plan for improvements along major drainageways and streams.

Major Facility – A major facility is a drainage facility identified in the drainage master plan that provides for the conveyance or detention of stormwater runoff generated from an area of 130 acres or larger. Such facilities include but are not limited to regional detention ponds (i.e., major facility serving multiple properties) and stream improvements along channels with tributary areas exceeding 130 acres. Many major facilities may also be regional facilities if they serve multiple properties; however, not all major facilities are regional facilities (e.g., a single developer owning land draining to a major facility would not be a regional facility because the major facility only serves one property owner). All major facilities shall be constructed as maintenance eligible projects (Aurora City Code Section 138-361).

Major Stream – A major stream is any open channel meeting the definition of a major facility.

Master Drainage Report (MDR) – A MDR is the project development report submitted to the CoA for review and approval concurrently with the development Master Plan (MP) submitted to the Planning Department. The MDR addresses various matters relating to storm drainage within the CoA, including the identification of drainage and flooding problems, the compilation of base data related to rainfall and runoff, the proposal of various measures for controlling stormwater flows, and the ownership and maintenance of proposed drainage facilities. See Chapter 2 for detailed information on MDR submittals. Note that the MDR includes plans sheets depicting drainage basins, design points, and other drainage information; these plan sheets are often called Master Drainage Plans. To avoid confusion with MHFD Major Drainageway Plans (MDPs), this Manual uses the term “MDR” or “MDR plan sheets” to refer to the plan sheets which accompany the MDR instead of the acronym.

Minor Facility – A minor facility is a drainage facility that provides for the conveyance or detention of stormwater runoff generated within a master planned parcel, or that serves a project area of fewer than 130 acres. Examples of minor facilities include but are not limited to storm drains, overflow tracts, drop structures, subregional detention ponds, and drainage conveyance (Aurora City Code Section 138-361). Most minor facilities are privately owned and maintained.

Minor Stream – A minor stream is any open channel meeting the definition of a minor facility.

Municipal Separate Storm Sewer System (MS4) – A MS4 is a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) that is:

> (A) Owned or operated by a State, city, town, county, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under State law

such as a sewer district, flood control district or drainage district, or similar entity, or a designated and approved management agency under Section 208 of the Clean Water Act that discharges to state waters;

(B) Designed or used for collecting or conveying stormwater. Stormwater conveyances also includes conveyances that are owned or operated by a MS4 permittee through agreement, contract, direct ownership, easement, or right-of-way (ROW) and are for the purpose of managing floodplains, stream banks, and channels for conveyance of stormwater flows in order for the discharges to be authorized by a MS4 permit;

(C) Not a combined sewer; and

(D) Not part of a publicly owned treatment works.

See the CoA's MS4 permit for additional information on MS4s (Colorado Department of Public Health & Environment, 2011).

Offline Detention or Water Quality Facility – Offline detention or water quality facilities are facilities that are located adjacent to the receiving stream. They are typically private subregional or on-site facilities that serve drainage areas that are less than 130 acres.

Online Detention or Water Quality Facility – Online detention or water quality facilities are facilities that are situated within or along the receiving stream. They are typically located on major drainageways (i.e., watersheds of 130 acres or larger).

On-site Detention Facility – On-site detention facilities are detention facilities that serve a single development and provide detention for small drainage areas up to approximately 20 to 30 acres. Most on-site detention facilities are privately owned and maintained.

Outfall System Plan (OSP) – An OSP is a document prepared by MHFD in cooperation with local governments to evaluate current and future hydrology and hydraulics and plan for improvements for outfall systems including major storm drains and minor streams that drain into major drainageways and streams.

Private Facility – A private facility is a drainage facility (e.g., detention pond, channel, inlet, storm drain, etc.) that is privately owned and maintained.

Private Stormwater Infrastructure – For the purposes of this Manual, and for use on drainage plans and reports and on civil plans (CPs), private stormwater infrastructure is any stormwater infrastructure that is not owned, operated, nor maintained by AW. Stormwater infrastructure that is owned, operated, and maintained by other CoA departments, such as a detention pond for a recreation center, is considered private infrastructure. Stormwater infrastructure that is owned, operated, and maintained by other governmental agencies, such as Metro Districts, the Regional Transportation District (RTD), or CDOT, is also considered private infrastructure.

Public Facility – A public facility is a drainage facility (e.g., detention pond, channel, inlet, storm drain, etc.) that is publicly owned and maintained.

Public Stormwater Infrastructure – For the purposes of this Manual, and for use on drainage plans and reports and on CPs, public stormwater infrastructure is stormwater infrastructure that is owned, operated, and maintained by AW.

Receiving Pervious Area (RPA) – RPA is pervious area that receives runoff from Unconnected Impervious Area (UIA) and allows for infiltration.

Redevelopment – For the purposes of this Manual, redevelopment is defined as modifications to a site that is already developed. Redevelopment activities include but are not limited to: expansion of a building footprint; addition or replacement of a structure; structural development including construction; replacement of impervious area that is not part of a routine maintenance activity; and land disturbing activities. See Chapters 10 and 11 for the water quality and detention requirements associated with redevelopment.

Regional Facility – A regional facility is a facility that serves multiple property owners and receives runoff from a tributary area equal to or greater than 130 acres. Regional facilities are typically maintained by AW. Regional facilities are considered major facilities by definition as they serve a tributary area equal to or greater than 130 acres; however, not all major facilities are regional facilities (e.g., a single developer could own the land draining to a major facility, in which case the facility would be a major facility but not a regional facility).

Retention Pond – A retention pond is a stormwater facility that is designed to have a permanent pool of water that remains between storm events. Because of this, retention ponds require water rights.

Separate Pervious Area (SPA) – SPA is pervious area that does not receive runoff from impervious surfaces.

State Waters – State Waters means any and all surface and subsurface waters which are contained in or flow in or through this state, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed (Colorado Revised Statutes 25-8-103). Also known as Waters of the State.

Stormwater Control Measure (SCM) – A SCM is any practice or method used to prevent or reduce the discharge of pollutants to waters of the State. SCMs include, but are not limited to, best management practices (BMPs), green infrastructure (GI), green stormwater infrastructure (GSI), and low impact development (LID).

Stream – A stream is any open channel used to convey stormwater flows, whether perennial or intermittent. Other terms for streams including channel, creek, draw, gulch, river, run, wash, drainageway, and other similar terms. These terms are used interchangeably and without distinction in this Manual.

Stream Management Corridor (SMC) – SMCs are the general corridors needed to allow a stream to function in a way that replicates natural processes to the extent possible (Mile High Flood District). A stream's overall corridor can be projected based on its past location and physical characteristics of the landscape, such as geology and topography. SMCs reflect areas where dynamic stream processes are likely to occur. They are distinct from FEMA regulatory floodplains, as they may encompass areas designated as low risk by FEMA regulatory floodplains which may nonetheless still be prone to flooding and erosion (Mile High Flood District, 2021).

Subregional Facility – A subregional facility is a facility that serves multiple landowners or lots and has a total watershed of less than 130 acres.

Swale – Stormwater conveyance with a design peak flow rate of less than 40 cfs.

Turf – Turf refers to any cool-season turf species, variety or blend, including but not limited to Kentucky bluegrass and fescue (Aurora City Code Section 138-191).

Unconnected Impervious Area (UIA) – UIA is impervious area that drains to a RPA where there is an opportunity for infiltration.

Water Quality Capture Volume (WQCV) – The WQCV is a storage volume intended to attenuate and treat runoff from the Water Quality Event (WQE). The WQCV is calculated using a regression equation that relates the mean storm depth, imperviousness, and SCM drain time to the WQCV. The WQCV represents the 80th percentile runoff-producing event.

Water Quality Event (WQE) – MHFD defines the WQE as a design storm representing a rainfall depth equal to the 80th percentile runoff-producing storm event for the Denver metropolitan region (Mile High Flood District, latest edition). The design storm depth corresponding to the WQE is 0.60 inches for the Denver metropolitan region. This regional design storm depth is used to calculate the WQCV and the Water Quality Peak Flow (WQPF).

Water Quality Peak Flow (WQPF) – The WQPF is the design flow rate for SCMs that are designed based on a flow rate for the WQE instead of a volume (Zivkovich & Piza, 2022).

Waters of the State – See definition for State Waters.

3.7 CONTEXT AND COMMUNITY VALUES

Drainage systems must reflect community values and fit within the context of their natural and built environments, in addition to providing utilitarian value. They are essential to protecting the health, safety, and welfare of current and future CoA residents and businesses.

To tailor zoning, subdivision, and development standards to different areas of the CoA, the UDO defines three different character areas. The three character areas generally reflect areas within the CoA that were platted and developed at different times (Unified Development Ordinance Section 2.2). Figure 3-1, taken from the UDO, illustrates the three character areas.

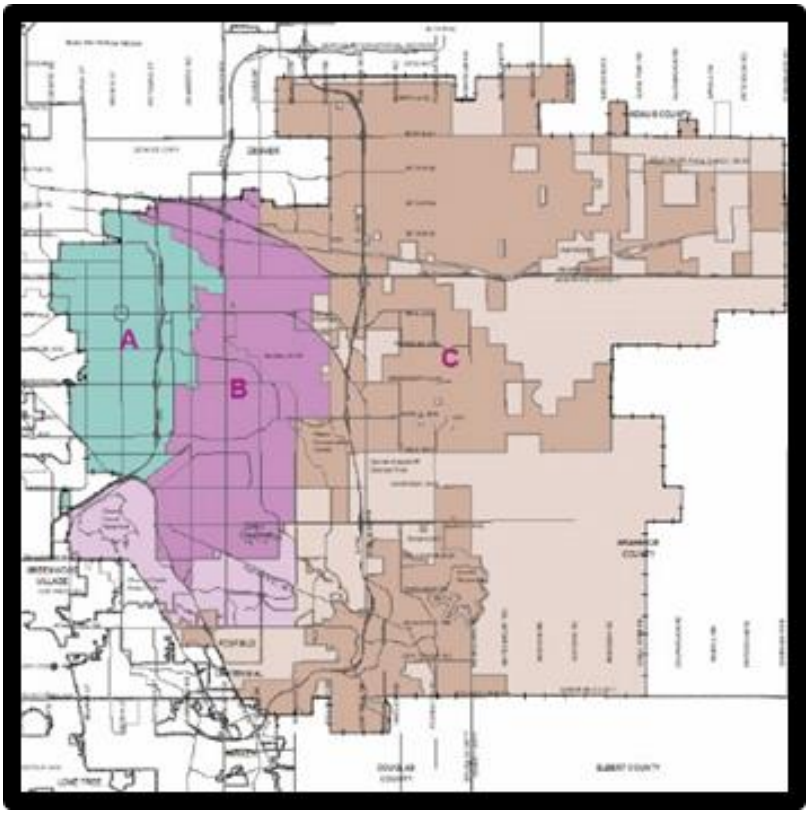

Figure 3-1. CoA Character Areas (Unified Development Ordinance Section 2.2)

- **Subarea A** "…generally includes areas of west Aurora that were primarily developed and platted before or within the decade after World War II, with development occurring in the southern portion of the area into the 1970s…Currently, Subarea A includes a mix of industrial, residential and commercial developments. Future development will occur as mainly infill as well as redevelopment of existing sites and structures. Larger developments are expected to occur along transit routes" (Unified Development Ordinance Section 2.2).

  When originally developed, stormwater infrastructure in Subarea A was largely absent. As a result, stormwater infrastructure in Subarea A tends to be deficient in conveying design storms based on current standards. Through a combination of CoA capital improvement projects and redevelopment, a significant amount of storm drains have been added. Most storm drains are sized for the 2-year event or smaller, which produces localized street flooding in larger storms. Little detention or water quality is present in this subarea.

  Development and redevelopment in this subarea can be challenging due to a lack of storm drains to provide an outfall for detention or stormwater quality treatment facilities. Development and redevelopment sites are often small, making infrastructure investments financially infeasible. Designers are encouraged to explore innovative approaches, including infiltration practices and manufactured treatment devices, in Subarea A.

- **Subarea B** "…generally includes areas that were platted and developed after World War II. Subarea B has a suburban character, with a mix of older residential subdivisions[,] existing retail strip shopping centers, and growing industrial campuses. Future development will occur as mainly infill as well as redevelopment of existing sites and structures" (Unified Development Ordinance Section 2.2).

  Earlier post-war development in Subarea B usually has good roadway drainage and storm drain collection systems. Detention was not required until around 1980, and water quality was not required until around 2000. Early stormwater detention systems were often experimental in nature, and many do not meet current standards. The prevailing wisdom of the time focused on quickly getting drainage off-site, and minimizing the area needed for drainage functions. Designers should focus on established practices for providing stormwater management, such as FSD ponds. Where possible, naturalized surface conveyances should be provided.

- **Subarea C** "…generally includes rolling, semi-arid, largely undeveloped lands with large open fields of prairie grass in northeast Aurora and mostly developed newer developments in southeast Aurora. It currently includes expanding residential developments, industrial parks and areas of City-owned open spaces and parks. Development pressures within Subarea C continue to rise as the demand for more housing choices intensifies; the pressure for large industrial storage facilities increases and the need for expanded infrastructure to accommodate the demands of growth become a priority. Because these lands will develop over a long period of time, their layouts, design, and building styles need to be flexible enough to accommodate new forms of development at a variety of development densities while avoiding patterns and practices that have increased traffic congestion and/or reduced the visual appeal of the City in the past" (Unified Development Ordinance Section 2.2).

  Stormwater management in Subarea C is generally consistent with current practices, commonly using detention ponds with FSD and naturalized open channel conveyances. This subarea predominantly contains greenfield development areas. The standards outlined in this Manual can and should be utilized in Subarea C.

3.8 ROLES AND RESPONSIBILITIES

This section describes the roles and responsibilities of various CoA departments and other entities involved in the design and implementation of drainage infrastructure in the CoA.

3.8.1 Aurora Water

This Manual is focused on AW's stormwater management policies and criteria that apply from inlets to the CoA's MS4 to the downstream regional stream system. While this Manual provides criteria related to street flow, AW is generally responsible for the review and approval of stormwater management beginning at inlets to the drainage system. AW is the primary agency responsible for the review and approval of entitlement documents and construction conformance.

3.8.2 Public Works

The CoA's Public Works Department (Public Works) is responsible for the review and approval of streets, including curbs, gutters, and cross pans (where allowed; see Chapter 6). General site

grading, including area grading plans, lot grading, and swales between homes is also the responsibility of Public Works. See the Civil Plan Submittal Checklist for additional details on specific distinctions in review responsibilities for AW and Public Works.

3.8.3 Mile High Flood District (MHFD)

Drainage is a regional concern that affects all governmental jurisdictions and all parcels of property, regardless of jurisdictional boundaries or property lines. MHFD serves to coordinate regional hydrology and plan major drainage projects throughout the Denver metropolitan area. These efforts are reflected in their MDPs, OSPs, and FHADs.

Generally, the MHFD is responsible for informing CoA MDRs to ensure they comply with regional MHFD watershed and stream master planning studies. In addition, the MHFD may assist the COA in certain areas of technical expertise (e.g., geomorphology). The CoA has adopted and applied MHFD criteria in this Manual where appropriate. In addition to the role that MHFD plays supporting the CoA, the MHFD also can work with developers to prepare MDRs and PDRs on their behalf for regional improvements and/or construct drainageway improvements through MHFD's Developer Improvement Program (DIP). All documents developed by the MHFD require review by the CoA.

3.8.4 Submitting Engineers and Other Design Professionals

CoA plan review is only for general conformance with CoA design criteria and the City Code. The CoA is not responsible for the accuracy and adequacy of the design, dimensions, and elevations which shall be verified at the job site. The CoA, through the approval of drainage reports and CPs, assumes no responsibility for the completeness and/or accuracy of these documents. Instead, the submitting engineer and/or other design professionals assume this responsibility, typically (but not exclusively) via the certification of a document by a Professional Engineer.

3.8.5 Landowners and Developers

Landowners and Developers are required to:

1. Retain qualified engineers and design professionals to prepare the reports and plans required by City Code and the criteria in this Manual.

2. Provide the land dedications and easements required by City Code and the criteria in this Manual, at no cost to the CoA.

3. Obtain all permits required by the CoA, the State of Colorado, and the Federal government.

3.9 DRAINAGE DESIGN PRINCIPLES

The criteria in this Manual are based on the following drainage design principles, which must be followed:

1. Grading and drainage should honor historic patterns.

2. Downstream properties must accept stormwater flows at historic locations and rates.

3. All development and redevelopment projects must drain to an acceptable outfall in accordance with CoA-approved MDRs, PDRs, and FDRs and applicable regional master drainage plans. Where no approved MDR exists and is not required by the CoA, the applicant must prepare and obtain approval of a PDR and FDR for the project area.

4. Historic major drainage pathways must be maintained, and inter-basin transfers of storm drainage must be avoided to the maximum extent practicable. Deviations from this policy may be granted on a case-by-case basis, but only when the following criteria are met:

    a. No other viable alternative exists.

    b. No additional potential damage is created by the proposed transfer.

    c. No impairment of water rights is caused.

    d. No other regulatory requirement is violated.

5. Where practicable and feasible, site planning and design techniques should minimize DCIAs in order to decrease the volume and velocity of stormwater runoff from a site.

6. The CoA encourages multi-purpose uses of storm drainage and detention facilities (i.e., multi-use facilities) that are safe, maintainable, and compatible with adjacent land uses, Colorado Water Law, and water quality enhancement objectives. Special care must be taken when storm drainage facilities are located in recreational, park, and open space areas to ensure that uses are compatible.[9]

7. Major drainageways must remain in open channels and must not be piped unless a variance is approved by the CoA. Such variances will be considered only in unique instances where an open channel is infeasible or where there is other benefit as determined by the CoA.

8. In areas with known drainage problems or water quality impairments, development and redevelopment project plans must include measures that minimize further impacts.

9. Development is not responsible for fixing preexisting drainage system deficiencies. However, projects must protect their proposed structures from existing hazards and may not make conditions worse for other properties.

10. In areas where downstream outfall systems are inadequate or non-existent and where provision of outfall facilities cannot be reasonably accomplished, retention ponds may be used to meet stormwater quality requirements when designed in accordance with MHFD criteria and when adequate water rights have been obtained. Retention ponds are not allowed for stormwater detention, and detention ponds must drain within the time limits specified by CRS 37-92-602 (8) (Colorado Revised Statutes 37-92-602 (8)). Special drain time requirements apply near airports. See Chapter 10 for additional information on drain time limitations near airports.

[9] See Chapter 10 for additional information on multi-use facilities.

11. The impacts of groundwater on the construction, capacity, long-term function, and maintainability of stormwater management facilities must be considered in design.

3.10 DRAINAGE DESIGN PROCESS

Stormwater management should be considered in the earliest stages of planning for all developments and redevelopments to ensure that adequate space is allocated for drainage facilities. All land development and redevelopment proposals must conduct drainage site planning and engineering analyses. Drainage reports and plans consistent with Chapter 2 of this Manual are required for all new development and redevelopment in the CoA's jurisdiction.

3.11 REGIONAL DESIGN APPROACH

The CoA supports and pursues a jurisdictionally unified approach to drainage to ensure an integrated comprehensive regional drainage plan. In partnership with the MHFD and other local governments, the CoA will continue to participate in and encourage the development of MHFD OSPs and MDPs that establish regional drainage requirements and conceptually identify the major stream corridors, jurisdictional inflows/outflows, and (in some instances) regional detention. Master plans will be approved, adopted, and revised as necessary to accommodate changes that occur within a specific watershed.

Drainage improvements included in applicable CoA-approved MDRs, MHFD OSPs and MDPs, or otherwise required by the CoA's submittal process must be designed and constructed with all new development and redevelopment. Prior to implementing master plan recommendations based on modeling, the CoA may require reasonableness checks of modeling results based on site observations and other information (e.g., maintenance records or known flooding problems due to existing pipe size), where such information is reasonably available. Improvements, as designed and approved, must meet the intent of master plan recommendations.

Major drainageway design and flow rates will be closely coordinated with the MHFD.

3.12 WATERSHEDS WITH SPECIAL REQUIREMENTS

Several watersheds within the CoA have additional criteria specific to those areas. Special requirements for each of these watersheds are discussed in the following sections.

3.12.1 Aurora Reservoir

Aurora Reservoir is the primary localized storage for the CoA's raw water supply prior to treatment and also provides an amenity for recreation. As such, protecting water quality in the reservoir is of paramount importance. A stormwater bypass line to divert runoff for up to the 10-year event around the reservoir has been constructed around the south and west sides of the reservoir. See the MDR for Southshore at Aurora (EDN[10] 203201) and subsequent plans and reports for details.

- New sites that are tributary to the existing bypass line must provide the WQCV and detention for the 10-year event. The 10-year storage volume and WQCV must be released over a period of 48-hours to the bypass storm drain line.

[10] Engineering Drawing Number. See Chapter 2.

- New sites that are not tributary to the existing bypass line may be required to bypass flows up to the 10-year event in a new conveyance structure.

3.12.2 Cherry Creek Reservoir

Special water quality requirements apply to the Cherry Creek Basin. All developments and redevelopments within the Cherry Creek Basin must comply with the latest edition of the "Cherry Creek Reservoir Watershed Stormwater Quality Regulation," as promulgated by the CCBWQA, as well as the requirements of the Cherry Creek Reservoir Control Regulation (Water Quality Control Commission, latest edition). The CCBWQA shall also review all development and redevelopment proposals in the basin for water quality impacts and mitigation. Construction adjacent to any stream within the Cherry Creek Basin shall protect all native soils and vegetation within the stream corridor (from the top of the bank to the top of the bank) as well as the area to be dedicated for stream and trail corridor use. See Chapter 11 for water quality requirements specific to developments within the Cherry Creek Basin.

3.12.3 Highline Canal

The Highline Canal was constructed by Denver Water's predecessors to convey raw water from mountain sources to users in Denver, the CoA, and other communities. It is no longer in use as an irrigation system within the CoA limits. Effective January 1, 2024, ownership of portions of the canal within the CoA will be transferred to Arapahoe County.

In the past, stormwater discharges have not been allowed to the Highline Canal. In most cases, it is safe to assume that stormwater discharges to the canal are still prohibited. However, plans are being made to use the canal for water quality and/or stormwater conveyance in some areas. Developers considering discharging into the canal should contact AW staff for details about the latest plans.

3.12.4 Areas Tributary to Peoria Street Outfall

The area east of North Peoria Street, from Quari Court north to Sand Creek, used to have limited storm drain capacity, and development was thus limited to a maximum release rate of 0.5 cfs/acre. A major AW capital project known as the Peoria Street Outfall (EDN 218198) was constructed between 2018 and 2022, and now provides adequate outfall to the area.

Therefore, the 0.5 cfs/acre restriction in this watershed no longer applies to areas served by the improvements.

3.12.5 Peterson Subdivision

The Peterson Subdivision, including portions that have been further subdivided, is located northeast of the intersection of North Chambers Road and East 32nd Street. Originally platted in 1963, the Peterson Subdivision had no storm drain system. Various public and private projects added storm drains over the decades. A 1986 CoA project (EDN 860101) installed storm drains along Chambers Road. The report notes that due to outfall limitations, discharges must be limited to 0.5 cfs/acre. Development within the Peterson Subdivision, including single-family residences on large lots, are therefore required to provide detention and water quality so as to maintain the maximum discharge of 0.5 cfs/acre.

3.12.6 Watersheds near Airports

For detention infrastructure within airport zones, there are additional requirements for pond drain times that limit the time that ponds are filled with water. These additional requirements are intended to reduce the attractiveness of detention facilities as waterfowl habitat, thereby reducing the potential for bird strikes with airplanes. See Chapter 10 for additional information on this topic.

3.13 DETENTION AND WATER QUALITY POLICIES

3.13.1 When Detention and/or Water Quality is Required

The CoA requires detention in accordance with Colorado drainage law and water quality treatment in accordance with the CoA's MS4 permit. Detention and water quality facilities must be designed to be safe, maintainable, and aesthetically pleasing, serving as community assets rather than liabilities. Regional or subregional detention and stormwater quality facilities must be designed and constructed prior to development of any properties that are to be served by the facility.

The conditions for when detention is required are outlined in Chapter 10. In general, some detention and water quality requirements exist for development or redevelopment projects which add 1,000 square feet or more of new impervious area. A project may be exempted from the above-mentioned requirements for added detention if the project is a redevelopment project adding new impervious area less than 10% of the existing impervious area, up to a maximum of 5,000 square feet of new impervious area. Roadway projects adding less than 1 acre of new impervious area also have different detention and water quality requirements. See Chapter 10 for additional information.

The conditions for when water quality is required are outlined in Chapter 11. Outside of the Cherry Creek Reservoir Basin, all proposed development and redevelopment projects with a total disturbance greater than 1 acre must satisfy the CoA's MS4 Permit design standards. For projects within the Cherry Creek Reservoir Basin, water quality requirements exist if greater than 500 square feet of impervious area is added by a development or redevelopment project. Additional requirements may exist at specific sites, per Chapter 11.

Additional water quality and detention measures are not required for building-interior-only redevelopment. The CoA reserves the right to impose additional water quality requirements based on land use considerations.

See Chapters 10 and 11 for additional information on detention and water quality requirements, respectively.

3.13.2 Consideration of Effects of Detention in Sizing Infrastructure

When detention ponds are used to attenuate peak flows, downstream infrastructure may be sized for detained flows; however, a surface overflow path must be provided for emergency overflows. Any structures along an emergency overflow path must have the LPE raised above the emergency overflow WSEL with freeboard as described in Chapter 10.

When analyzing major drainageways, the effects of private detention facilities typically are not considered due to the timing of uncoordinated releases and concerns about long-term operation

and maintenance. In some cases, private facilities may be considered when there are adequate assurances for long term operation and maintenance.

3.13.3 Variances from Detention Criteria

Variances from the detention criteria included in this Manual may be granted if either of the following conditions apply:

1. The project is immediately adjacent to a major drainageway (i.e., no intervening parcels between the project site and the floodplain) or is located within the 100-year floodplain. On these sites, variances from detention criteria may be granted provided the following conditions are met:

    a. The EURV, as defined in Chapter 10 of this Manual and in Volume 2, Chapter 12: Storage of the MHFD Manual, must be managed to provide flood attenuation for events up to and including the EURV to protect downstream channel stability.

    b. The major drainageway must be capable of conveying the fully developed 100-year flood without channel stability issues, including excessive aggradation, degradation, or bank erosion.

    c. The fully developed 100-year flow from the project must be safely conveyed to the major drainageway without adversely impacting private properties or ROW. At a minimum, said safe conveyance must meet the criteria in Chapters 6, 8, and 9, and must not impact light rail operation or transportation. Other site-specific factors must also be considered.

2. The project is tributary to a publicly owned and maintained regional detention facility designed to accommodate flows from a fully developed watershed, and a safe and adequate conveyance of the 100-year developed flows is provided from the development to the regional facility. See Chapter 11 for additional information on water quality requirements for outfalls to State Waters upstream of regional or subregional detention facilities.

See Chapter 2 for a description of the procedure for requesting a variance. Note that variances will require additional analysis to demonstrate that no adverse effects to the overall drainage system may result from the variance. Requesting a variance will increase the review time.

3.14 DRAINAGE SUBMITTAL POLICIES

At various stages throughout the design and development process, sundry drainage submittals may be required, such as MDRs, Master Drainage Amendments (MDAs), PDRs, Preliminary Drainage Letters (PDLs), FDRs, and/or Final Drainage Letters (FDLs). See Chapter 2 for details on the specific requirements of each submittal. The below section outlines when various submittals are required:

3.14.1 Master Drainage Report

A MDR is required prior to the approval of any planned community zoned district or site plan in excess of 80 acres or any phased commercial/industrial development in excess of 10 acres. Stormwater quality control and enhancement (i.e., permanent SCMs) must also be addressed in

the MDR. See Chapter 2 for specific submittal requirements.

3.14.2 Master Drainage Amendment

A MDA is required when there are any modifications to a City Planning MP and/or CoA-approved MDR that could affect stormwater infrastructure sizing, including one or more of the following:

1. There is a change in land use or density producing an increase in impervious area greater than 5%.

2. There is a change in the proposed sizing or location of ponds and/or channels.

3. Additional tributary area is added to the area considered by the MDR, or the tributary area is otherwise revised.

4. There are changes in the basin boundaries used in the MDR.

5. There are changes in the arterial and/or collector roadway corridor widths or locations.

6. There are major grading changes that impact stream corridor routing or major drainage facilities.

7. There are changes in the basin-wide master drainage study.

3.14.3 Preliminary Drainage Report

A PDR is required prior to the approval of any Subdivision Plat or Site Plan and is typically submitted alongside those documents for review. See Chapter 2 for the specific requirements for PDRs. The requirement to submit a PDR is identified during the pre-application meeting. For projects where no pre-application meeting is held, the applicant should contact AW prior to submittal.

3.14.4 Preliminary Drainage Letter

A PDL (or letter) is a simplified drainage submittal that can be used to document conformance with a previously approved PDR and PDP when a site meets all of the following qualifying criteria:

1. Prior approval to submit a PDL in lieu of a PDR must be obtained from AW. If a pre-application meeting with the Office of Development Assistance (ODA) was held, the meeting notes from that meeting should be consulted to determine if a PDL will be allowed in lieu of a PDR.

2. The property must be included in a previously approved PDR and PDP where the site conditions and site plans have not significantly changed. The PDL must reference the previously approved plan and any subsequently approved PDL(s) and must also include the EDN or RSN[11] where applicable.

[11] Record Sequence Number. See Chapter 2.

3. The development must not alter flow or drainage patterns which affect other properties from those previously established in approved PDRs or CPs which included the property.

4. The site must currently discharge to an improved drainage channel or existing storm drain system. The adjacent surface drainage system must have the hydraulic capacity for post-development runoff, and additional storm drains are not required for development of the site.

5. The development must not require additional on-site detention or water quality treatment. Water quality, EURV, and detention are provided for the site from an off-site facility.

A PDL may also be required when there are changes to a CoA-approved PDR. A PDL submittal to amend an approved PDR is required when any of the following conditions apply:

1. A site plan amendment is required by the CoA Planning Department. If there are no changes to the drainage plans, the PDL will simply be a conformance letter stating that there are no changes to the drainage plan of the approved PDR.

2. The PDR includes more than one development or covers a commercial or industrial site with one or more lots to be developed at different times, where changes to the drainage design may impact the other portions of the development.

3. There are any changes to the drainage design from the approved PDR, including (but not limited to):

    a. Changes in land use or density that increase the imperviousness and/or area contributing to a drainage facility such that the sizing or design of the facility requires modification.

    b. Changes in pond or channel sizing or location.

    c. Changes to drainage basin or subbasin boundaries.

    d. Changes to roadway locations or widths.

    e. Changes in grading that affect drainage infrastructure.

If no additional water quality, detention, or channel facilities are required, a PDL revising an approved PDR may be waived provided that a FDL and CP revision is submitted concurrently with the site plan amendment.

See Chapter 2 for specific requirements for PDLs.

3.14.5 Final Drainage Report

A FDR must be submitted with the CPs. See Chapter 2 for specific requirements for FDRs.

3.14.6 Final Drainage Letter

A FDL (letter; conformance letter) is a simplified drainage submittal that can be used to document conformance with a previously approved FDR and FDP/CP set when a site meets all of the following qualifying criteria:

1. Prior approval to submit a FDL in lieu of a FDR must be obtained from AW. If a pre-application meeting with the ODA was held, the meeting notes from that meeting should be consulted to determine if a FDL will be allowed in lieu of a FDR.

2. The property must be included in a previously approved FDR and FDP/CP set where the site conditions and site plans have not significantly changed. The FDL must reference the previously approved plan and any subsequently approved FDL(s) and must also include the EDN or RSN where applicable.

3. The development must not alter flow or drainage patterns which affect other properties from those previously established in approved PDRs, FDRs, or CPs which included the property.

4. The site must currently discharge to an improved drainage channel or existing storm drain system. The adjacent surface drainage system must have the hydraulic capacity for post-development runoff, and additional storm drains are not required for development of the site.

5. The development must not require additional on-site detention or water quality treatment. Water quality, EURV, and detention are provided for the site from an off-site facility.

A FDL may also be required when there are changes to CoA-approved CPs. A FDL submittal to amend approved CPs are required when any of the following conditions apply:

1. A site plan amendment is required by the CoA Planning Department. If there are no changes to the drainage plans, the FDL will simply be a conformance letter stating that there are no changes to the drainage plan of the approved FDR.

2. The FDR includes more than one development or covers a commercial or industrial site with one or more lots to be developed at different times, where changes to the drainage design may impact the other portions of the development.

3. There are any changes to the drainage design from the approved FDR, including (but not limited to):

    a. Changes in land use or density that increase the imperviousness and/or area contributing to a drainage facility such that the sizing or design of the facility requires modification.

    b. Changes in pond or channel sizing or location.

    c. Changes to drainage basin or subbasin boundaries.

    d. Changes to roadway locations or widths.

e. Changes in grading that affect drainage infrastructure.

See Chapter 2 for specific requirements for FDLs.

3.14.7 Certification of Ponds and Water Quality Facilities

All detention and water quality ponds (and water quality devices) must be certified. The intent of the certificate is to ensure the facility was constructed and will function per the design. See Chapter 2 for specific requirements for pond certificates and submittal requirements.

3.14.8 Referrals

In the development review process, the CoA will refer submittals to other relevant agencies, including, but not limited to:

1. CDOT
2. E470 Highway Authority
3. USDA Denver Airport Office
4. Denver International Airport (DEN)
5. SEO
6. CCBWQA
7. Adjoining municipalities
8. Other entities as appropriate

The applicant is responsible for ensuring that appropriate permits from referral agencies are obtained. The MHFD is no longer a referral agency in the development review process; however, MHFD may assist COA in certain areas of technical expertise as needed.

3.15 APPROVAL OF REPORTS AND PLANS

This section discusses the period of validity for approved reports and plans as well as grandfathering.

3.15.1 Period of Validity

PDRs and PDLs are valid for a period of one year from the date of approval.

Once a set of CPs are approved, they are valid for one year from the date of approval; this includes all documents associated with the CPs, such as FDRs, FDLs, Stormwater Management Plans, and Structural Design Calculations. If no permits or main extension agreements are executed within that one year, the CP approval will expire. See the RDCS for additional information on CPs and FDRs.

MDRs are valid for a longer duration than PDRs or FDRs because they encompass larger areas

that typically include phased development. MDRs are valid until they expire, and a MDR is considered expired only if all the following are true:

- There has not been a PDR, FDR, or CP submittal for over two years;
- All approved FDRs and CPs (with regard for approval extensions) are considered expired; and
- It has been 5 years since the MDR was approved.

The engineer of record can request a 3-year extension of the MDR by emailing aurorawaterdrainage@auroragov.org. AW has the authority to require amendment of the MDR at that time, or to require a new MDR should the MDR require updates to comply with existing standards and criteria. Extension of MDR approval is allowed twice.

3.15.2 Grandfathering

This Manual provides updates to imperviousness values that are used as inputs to hydrologic models and to determine runoff coefficients when using the Rational Method. In some cases, these updates may result in increased calculated peak flow rates with respect to previous criteria. As regards grandfathering based on the previous criteria contained in this Manual, the following policies apply:

- For sites that rely on existing constructed infrastructure, the applicant must demonstrate that the constructed infrastructure has the capacity to accommodate the proposed development based on the updated criteria; if not, modifications to density, additional detention (including on-site detention) to reduce flows, and/or revisions to existing infrastructure to accommodate higher flows may be required. Grandfathering will not be permitted.
- For sites that rely on approved MDRs or PDRs with infrastructure not yet constructed or approved in CPs where flows are increased due to new imperviousness values, the applicant must update plans to accommodate the increased peak flow rates. Grandfathering will not be permitted.
- Approved and unexpired CPs will be grandfathered using the previous criteria.

Other changes to criteria in this Manual have the potential to change peak flow rates or the sizing of infrastructure. The same grandfathering provisions above apply to these situations.

The criteria contained in this Manual are applicable as of the Effective Date of the Manual. However, a variance may be granted to allow PDR/FDR/CP approval compliant with the previous criteria if an MDR has been approved in the last year from the Effective Date and there is continued progress on those plans. For example, if an application is in the PDR process and has been through a first review prior to the Effective Date, then these projects may be permitted to use the previous criteria. Furthermore, a variance to use previous criteria may be granted, so long as the variance would not result in impacts to already-constructed downstream infrastructure.

3.16 PUBLIC VERSUS PRIVATE INFRASTRUCTURE

Only major, regional facilities, as defined in Section 3.6 above, may be considered for public maintenance. All other facilities must be privately maintained.

3.17 FLOW FROM OFF-SITE AREAS

Flow from off-site areas may be assumed to remain at historic/existing levels in the future only if regional or subregional detention with public or quasi-public[12] maintenance is planned to manage flows from the off-site area. Otherwise, future conditions of land uses must be considered.

When off-site flow areas extend beyond the CoA jurisdictional boundary, consult with the CoA and MHFD to determine off-site flow assumptions.

3.18 EMERGENCY OVERFLOW PATHS

Emergency overflow paths must be provided for drainage infrastructure where there is a risk of overtopping due to clogging or events exceeding the design capacity of the infrastructure. Emergency overflow paths must be provided for the following:

1. **Detention and Water Quality Pond Spillway Discharges** – An emergency overflow path must be provided for the emergency overflow spillway design discharge rate (i.e., the 100-year peak inflow to the pond for fully developed conditions; see Chapter 10).

2. **Sump Inlets** – An emergency overflow path for sump inlets must be defined based on the emergency overflow discharge (i.e., the 100-year peak flow to the inlet for fully developed conditions; see Chapter 6). In situations where the existing conditions 100-year peak flow to the inlet exceeds that of the fully developed conditions, the existing conditions 100-year peak flow to the inlet shall be used to establish the emergency overflow path.

3. **Culverts and Bridges** – An emergency overflow path must be provided for culverts and bridges in accordance with the criteria in Chapter 9.

The emergency overflow path must provide a route that is free of structures or obstructions to convey the emergency overflow discharge to a downstream ROW or drainageway with adequate capacity for the discharge. “Free of structures and obstructions” means that no impediments to flow, such as fences, trees, buildings, or other types of obstructions, are allowed within the emergency overflow path. Emergency overflow paths shall not encroach upon private lots. When streets are used for emergency overflow paths, a minimum of one foot of freeboard must be provided between the emergency overflow WSEL and the LPE of each structure along the emergency overflow path.

At least one foot of freeboard must be provided between the emergency overflow path WSEL and the LPE of any adjacent structures. Emergency overflow calculations must be provided when an emergency overflow path is adjacent to any structures, or when the overtopping elevation (i.e., elevation at which emergency overflow occurs; for ponds, this is the spillway elevation) is within 1.5 feet of either a structures FFE or LPE. See Chapters 6, 9, and 10 for

[12] E.g., Metropolitan district.

additional information and criteria related to emergency overflow paths for sump inlets, culverts/bridges, and detention and water quality facilities, respectively.

3.19 IRRIGATION DITCHES

Irrigation ditches shall not be used to transmit storm runoff. Designs using irrigation ditches for conveyances or outfalls will not be approved if an alternative exists. If no alternative exists, stormwater discharges to irrigation ditches will only be allowed the written approval of the ditch owner and approval of a variance by AW.

3.20 EASEMENTS AND TRACTS

Requirements for easements and tracts are as follows:

1. Drainage easements for private detention ponds must include the toe of the embankment slope, the outlet pipe, the extent of riprap, and other components of the pond up to the elevation of the top of bank (i.e., one foot above the emergency spillway; see Chapter 10). The emergency overflow path with one foot of freeboard to LPE of adjacent building must be included in the easement up to the public ROW or stream corridor.

2. Drainage easements for underground detention or water quality facilities must extend an additional 4 feet beyond the perimeter of the Facility.

3. Private ponds can be within a tract; however, a drainage easement is still required unless the tract is dedicated as a drainage easement in its entirety and the tract only encompasses the area needed for the drainage easement. Plat language shall state that the tract is privately owned and maintained, allowing the CoA the right but not the obligation to maintain.

4. Private (i.e., metropolitan district or homeowner's association [HOA] owned and maintained) storm drain surface facilities (e.g., inlets, flared end sections, manholes, channels, etc.) are not permitted on private residential lots and shall instead be located within a tract. Private storm drain subsurface utilities on residential lots are permitted provided there is a private easement.

5. Major regional detention ponds that are owned and maintained by the CoA must be granted to the CoA as a drainage easement or tract in their entirety.

6. Major channels shall be dedicated as drainage easements or tracts, allowing the CoA the right but not the obligation to maintain. The easement shall include one foot of freeboard above the 100-year WSEL.

7. Regulated floodplain areas must be granted to the CoA as tracts. The plat language must state the tract is granted to the CoA for floodplain (or drainage) purposes. The tract must include the 100-year Base Flood Elevation (BFE) plus one foot of freeboard.

8. Public storm drains on private property require a storm easement. See AW's *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications* for the sizing of easements (Aurora Water, latest edition).

9. Drainage easements are required for emergency overflows from sump inlets and culverts/bridges as discussed in Chapters 6 and 9, respectively. When there is not a storm drain sized for the 100-year event (e.g., the storm drain systems is sized for the minor event), emergency overflow tracts must be concrete lined (as shown in the RDCS) and the tract must be dedicated to the CoA. Otherwise, overflow tracts may be designed as swales. Tracts are normally required where sump inlets are drained between residential lots to a drainageway, or where there are back draining cul-de-sacs. All emergency overflow tracts shall be designed to accommodate the emergency overflow discharge (as defined in Chapters 6, 9, and 10) with a minimum of one foot of freeboard between the emergency overflow WSEL and adjacent structures' LPE.

10. All water quality facilities require a drainage easement. The easement must include maintenance access to the facility.

11. An easement is required where public water crosses private land.

12. When a RPA is used for water quality treatment, it must be included in an easement.

13. Easements are required if more than two lots drain through a third lot, including swales.

14. In cases when a drainage easement is not contiguous with ROW or a public access easement, an "Access Easement" shall be provided to allow for maintenance access to the drainage facility.

In no case shall drainage facilities, such as detention or water quality ponds, be defined by lot and block.

3.21 MAINTENANCE

All storm drainage systems must receive regular maintenance, as outlined in the subsequent chapters of this Manual and on the CoA's I&M Plan website. I&M Plans are required for all private stormwater facilities, including conveyances (i.e., pipes, swales, and open channels) and SCMs (e.g., detention and water quality facilities; this includes receiving pervious areas relied upon to infiltrate runoff). I&M Plans must describe the types and frequencies of routine and unscheduled maintenance activities, among other requirements.

Maintenance access must be provided for all stormwater drainage facilities. In some cases, facilities may be accessed from the public ROW, but in many cases a maintenance path is required. Maintenance paths outside of public ROW require an easement (see Section 3.20 above). Criteria related to allowable slopes, turning radii, allowable all-weather surfaces, and other aspects of maintenance path design are provided in Chapters 7 and 10.

3.22 CONSTRUCTION TOLERANCES AND OBSERVATION

Hydrologic and hydraulic analyses involve inherent assumptions and abstractions which may cause disparity between calculated values and real word conditions. Moreover, construction tolerances may introduce additional variation between construction drawings and as-built conditions. For these reasons, the CoA permits small differences between the design and as-built values: the as-built volume, peak discharge, and/or release rate for detention and water quality facilities and other drainage infrastructure may deviate from the design value by no more than 5%. Deviations in excess of 5% may require the as-built conditions to be revised to be in

conformance with the design. If the as-built conditions can be demonstrated to still achieve the design intent in spite of variations in excess of 5%, a variance may be granted for the as-built conditions. The CoA reserves the right to require modification to as-built infrastructure (even for deviations less than 5%) in the event the as-built condition does not achieve design objectives.

To avoid potential rework, it is recommended that construction tolerances be considered early in the design process. It may be advantageous to include additional capacity or conveyance in the design of drainage infrastructure so that typical variation from a design introduced during construction does not invalidate the design objective and lead to costly rework. Furthermore, for any design to be properly constructed, construction observation is essential; it is strongly recommended that the design engineer perform construction observation to ensure proper construction of the proposed design.

3.23 VARIANCES

The General Manager of AW or their designee may authorize at their discretion, upon application, such waiver or variance from the requirements of the criteria outlined in this Manual. The CoA distinguishes between minor variances and major variances:

1. Minor variances are those that require slight variations from design criteria due to site constraints. Minor variances may be granted at the staff level when the variance requested is no more than a 10% change from the numeric criteria, and the variance will not affect the public health, safety, and welfare of the community.

2. Major variances are those that require major departures from design criteria. If the variance requested is more than a 10% change from the numeric criteria, or if the variance is a request for exception or modification to narrative criteria, it will be considered a major variance.

The CoA reserves the right to treat any variance request as a major variance, even if deviations from criteria are less than 10% from numeric criteria, if the variance has public health, safety, and welfare implications.

See Chapter 2 for specific details on the procedure for requesting a variance and the subsequent review process.

3.24 USE OF MODELING SOFTWARE AND DESIGN SPREADSHEETS

MHFD and other computer software programs, models, spreadsheets, and workbooks are referenced in this Manual as design aids that may be useful in designing drainage and water quality improvements. Use of these design aids is in no way a substitute for sound engineering judgment, proper engineering qualifications, and common sense. Although the design aids recommended in this Manual have been developed using a high standard of care, it is likely that some nonconformities, defects, bugs, and errors with the software programs will be discovered as they become more widely used. The CoA does not warrant that any version of these design aids will be error-free or applicable to all conditions encountered by the designer, and the CoA will not be held liable for their use. See Chapter 12 for additional information.

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CHAPTER 4.0 FLOODPLAIN MANAGEMENT

4.1 PURPOSE

The Aurora City Code, Section 70-2 states the purposes of Floodplain Management within the City of Aurora (CoA) as follows:

> *"The city council declares that the purpose of this article to promote public health, safety and general welfare and to minimize public and private losses due to flood conditions in specific areas by provisions designed to:*
>
> *1. Protect human life and health;*
>
> *2. Minimize expenditure of public money for costly flood control projects;*
>
> *3. Minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;*
>
> *4. Minimize prolonged business interruptions;*
>
> *5. Minimize damage to critical facilities, infrastructure and other public facilities such as water, sewer and gas mains; electric and communications stations; and streets and bridges located in floodplains;*
>
> *6. Help maintain a stable tax base by providing for the sound use and development of flood-prone areas in such a manner as to minimize future flood blight areas;*
>
> *7. Ensure potential buyers are notified that property is located in a flood hazard area; and*
>
> *8. Ensure all property owners can remain under the national flood insurance program."* (Aurora City Code Section 70-2)

The purpose of this chapter is to explain the policies and procedures for floodplain management in the CoA, describe the relationship between floodplain regulations and other procedures used for plan and permit review within the CoA, and to provide clarification on the requirements included in the Aurora City Code, Chapter 70.

4.2 AUTHORITY

Authority for Floodplain Management is provided in the following sources:

- Aurora City Code, Chapter 70
- Unified Development Ordinance (UDO; Aurora City Code Chapter 146)
    - Section 2.6.1, regarding the Flood Protection Overlay (Unified Development Ordinance Section 2.6.1).

- Section 4.3.5, Subsection (B)(3)(a), regarding slope conditions and flooding (Unified Development Ordinance Section 4.3.5.B.3).

- Section 4.3.10.A, regarding lot layout and design (Unified Development Ordinance Section 4.3.10.A).

- Section 4.3.15, Subsection (E)(1), regarding infrastructure improvements and stormwater management (Unified Development Ordinance Section 4.3.15.E.1).

- Colorado Water Conservation Board, Rules and Regulations for Regulatory Floodplains in Colorado (Colorado Water Conservation Board, latest edition).

- National Flood Insurance Program (NFIP) regulations (44 CFR Parts 59-80) and numerous guidance documents (44 CFR Parts 59-80).

4.3 FLOODPLAIN DATA

4.3.1 Floodplains Regulated by CoA

The CoA regulates all floodplains associated with major drainageways, as defined in Chapter 3. The key characteristic of a major drainageway is a tributary area of 130 acres or more. Included in the floodplains regulated by the CoA are floodplains identified by the Federal Emergency Management Agency (FEMA) on its Flood Insurance Rate Maps (FIRMs) and in its Flood Insurance Studies (FISs), floodplains identified by the Mile High Flood District (MHFD), and floodplains identified in drainage reports and civil plans (CPs) approved by the CoA.

Applicants who wish to develop properties in or adjacent to major drainageways where no detailed flood study has been published are required to develop a flood study showing the 1% annual chance (1PAC, i.e., 100-year) floodplain water surface elevations (WSELs)[13] and geographic extent of the floodplain.

4.3.2 Types of Floodplains Regulated by CoA

The types of floodplains regulated by the CoA may generally be categorized as either FEMA-identified or non-FEMA-identified. Sections 4.3.2.1 and 4.3.2.2 below respectively describe these categories.

4.3.2.1 FEMA-identified Floodplains

FEMA-identified floodplains are those floodplains studied in a FEMA FIS and delineated on a FEMA FIRM panel. FEMA-identified floodplains are comprised primarily of the data shown on the effective FIRM panel and FIS; however, as a part of updating its flood hazard data, FEMA may release preliminary FIRM panels and FISs which are in the process of becoming the effective data. The preliminary FIRM panels and FISs may be considered the best available data at the discretion of the Floodplain Administrator (see Section 4.3.4 below).

Figure 4-1 shows the legend from a recently issued FIRM, which explains the symbology used for various flood zones and other features. An explanation of how these flood zones are used

[13] The 1PAC WSELs are commonly known as Base Flood Elevations (BFEs).

for floodplain management in the CoA is included alongside Figure 4-1.

Special Flood Hazard Areas (SFHAs)

- The **Regulatory Floodway** (cyan-magenta hatch in Figure 4-1) is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1PAC flood can be carried without increases in WSELs exceeding 0.5 feet. The floodway appears on the FIRM as a subset of Zone AE. The floodway is the area with the highest flood depths and velocities, and thus represents the highest danger to life and property. Development in the regulatory floodway is prohibited unless either a no-rise analysis is provided (see Section 4.8.3.1 below), or a Conditional Letter of Map Revision (CLOMR) is obtained from FEMA (see Section 4.8.3.2 below).

- The **SFHA Floodplain** (solid cyan in Figure 4-1) is the area that is inundated during a 1PAC (i.e., 100-year) flood. SFHA zones mapped in the CoA include Zone A, Zone AE, Zone AO, and Zone AH.

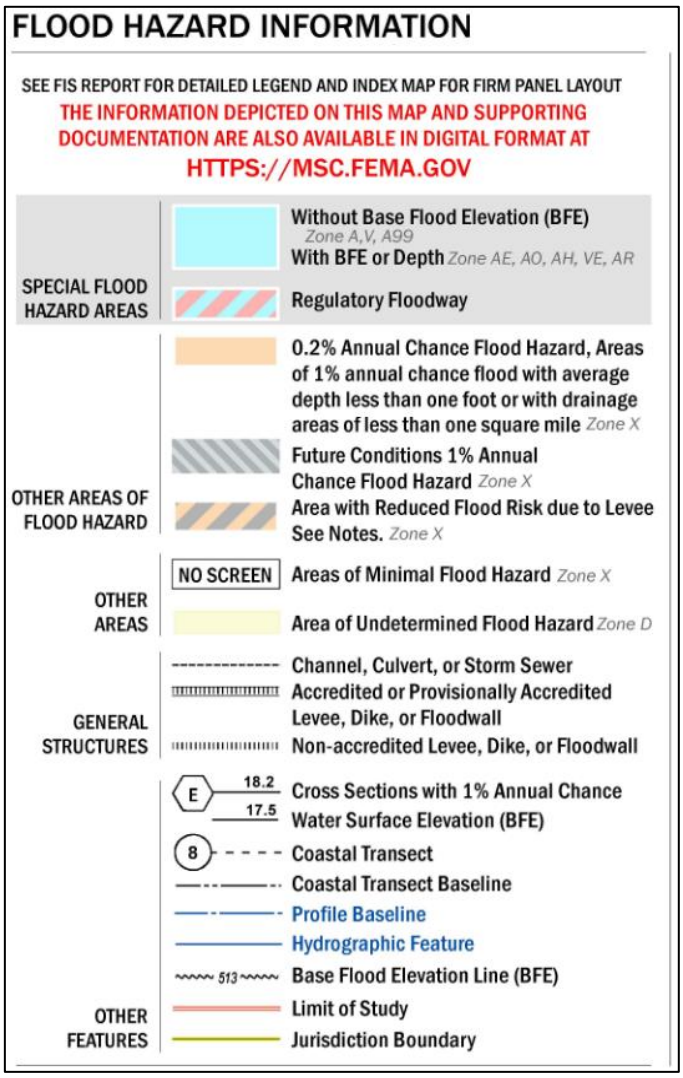

Figure 4-1. Typical FEMA Flood Zones

  - A **Zone A** floodplain is an area of identified flood hazard where BFEs have not been established. A Zone A floodplain is typically associated with an approximate floodplain analysis.

  - A **Zone AE** floodplain is an area of identified flood hazard where BFEs have been established. A Zone AE floodplain is typically associated with a detailed floodplain analysis.

  - A **Zone AO** floodplain is an area of identified shallow flooding where a flood depth has been established.

  - A **Zone AH** floodplain is an area of identified shallow flooding where a BFE has been established.

Most of the SFHAs in the CoA are Zone AE floodplains with floodways.

- The **Floodway Fringe** is the portion of a Zone AE floodplain (with regulatory floodway) that is located outside of the floodway. Development in the floodplain fringe may be allowed with a Floodplain Development Permit (FPDP).

- **Zone X** (solid tan, multi-shade gray hatch, tan-gray hatch, or no screen) is used to describe several different situations, the most common of which include:

    - Areas inundated during the 0.2% annual chance (0.2PAC; i.e., 500-year) flood, 1PAC shallow flooding with average depths less than 1 foot, and 1PAC floodplains with a tributary drainage area less than 1 square mile. These situations are reflected in the **Zone X (shaded)** floodplain (solid tan in Figure 4-1).

    - Areas of minimal flood hazard are reflected in **Zone X (unshaded)** floodplains (no screen in Figure 4-1).

  None of these are subject to floodplain regulations in the CoA.

4.3.2.2 Non-FEMA-Identified Floodplains

Non-FEMA-identified floodplains are those floodplains which are studied and delineated in sources other than FEMA floodplain studies. Typically, non-FEMA-identified floodplains are derived from Flood Hazard Area Delineation (FHAD) studies or Major Drainageway Plans (MDPs) performed by the MHFD, or from CoA-approved plans and reports. These studies will generally provide similar floodplain data to those found in a FEMA floodplain study, including identification of the 1PAC floodplain and WSELs.

As described in Section 4.3.1 above, floodplain regulations apply to all major drainageways. The floodplains for all major drainageways are handled in the same manner, regardless of whether they are identified in a FEMA floodplain study, FHAD, or a city-approved plan and report.

4.3.3 Applicability of Requirements

All requirements for the elevation and protection of buildings apply equally to both FEMA-identified floodplains and non FEMA-identified floodplains.

Encroachments on the floodplain, including placement of fill, buildings, hydraulic structures, and/or roadway crossings, are treated differently based on the type of floodplain being encroached upon. Encroachment onto a FEMA-identified floodplain typically requires a no-rise analysis (see Section 4.8.3.1 below). If a no-rise cannot be achieved, a CLOMR must be obtained (see Section 4.8.3.2 below). The CLOMR application must include property owner notifications, an evaluation of alternatives, a statement that no structures are impacted, and compliance with the Endangered Species Act (ESA). All NFIP requirements must be strictly adhered to.

Encroachments onto a non FEMA-identified floodplain may also require hydraulic analyses similar to those required for encroachment on a FEMA-identified floodplain. The standard of evaluation is that increases in WSEL by a project may be permitted if increases are limited to the applicant's property and no insurable structures are impacted. Proposed encroachments that do not meet these conditions will not be permitted.

4.3.4 Best Available Data

Floodplain management in the CoA is based on the best available floodplain data. Where multiple sources of floodplain data are available, the source that is considered the most technically correct and the most protective of life and property will be used. The Floodplain Administrator is responsible for determining which data source constitutes the best available data.

Along some flooding sources within the CoA, both FEMA effective floodplains and MHFD floodplains have been established. FEMA effective floodplains are based on a FIS which considers existing conditions hydrology. MHFD floodplains are typically derived from a FHAD study, which considers future conditions hydrology. The 1PAC WSELs determined by a FHAD will usually be higher than those determined by a FEMA FIS, and thus show a wider floodplain. If that is the case, the FHAD WSELs would be used as the basis for design grading and for determining the necessary Lowest Floor Elevations (LFEs) of buildings in or adjacent to the floodplain such that sufficient freeboard is provided (see Sections 4.5.3 and 4.5.4 below). Note that FEMA bases its requirements and premiums for flood insurance solely on the effective FIS and FIRM. As such, Elevation Certificates (ECs) should be completed based solely on information from these sources (see Section 4.6 below).

4.3.5 Digital Data

4.3.5.1 Sources of Digital Data

Digital floodplain data can be viewed and obtained from the following sources:

- CoA National Flood Hazard Layer (NFHL) Flood Map – Overlays FEMA NFHL data on CoA Geographic Information Systems (GIS) data and aerial photography (City of Aurora).
- City of Aurora, Colorado Maps – Home page for a wide range of maps and GIS data (City of Aurora).
- MHFD General Data Viewer – Overlays FEMA NFHL and MHFD FHAD data on various basemaps along with other MHFD data (Mile High Flood District).
- FEMA Map Service Center (MSC) – Contains FEMA effective FISs, FIRMs, Letters of Map Change (LOMCs),[14] and other data in both PDF and GIS formats (Federal Emergency Management Agency).
    - To access floodplain data for the CoA, select Search All Products. From the pull-down menus on the next page, select Colorado for State, Arapahoe County for County, and Aurora, City of for Community. Click on Search, and available data will appear, as shown in Figure 4-2 below.

[14] LOMCs include both Letters of Map Revision (LOMRs), Conditional LOMRs (CLOMRs), LOMRs based on Fill (LOMR-Fs), Letters of Map Amendment (LOMAs), and Conditional LOMAs (CLOMAs). Note that because CLOMRs, CLOMR-Fs, and CLOMAs are not effective data, they are not shown on FEMA's MSC.

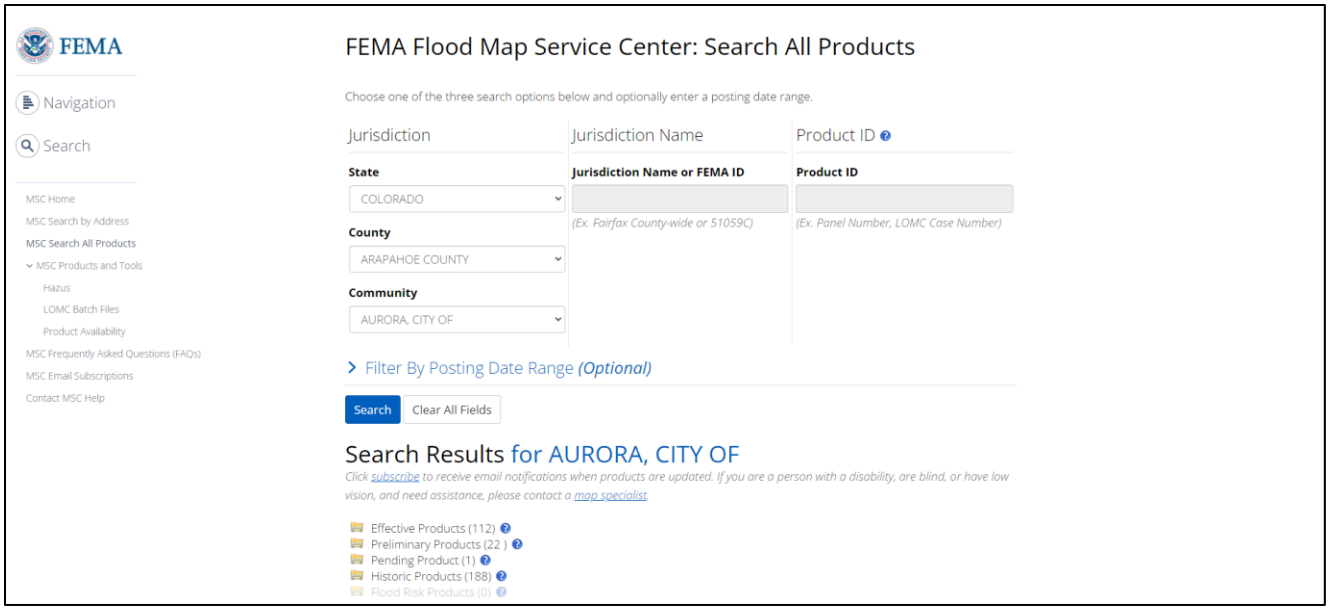

Figure 4-2. Input Fields to Access CoA Data on FEMA's MSC

Note that all of the CoA is included in the Arapahoe County FIS, even though portions of the city are within Adams or Douglas Counties. If an area was annexed after the FIS was last updated, it may be necessary to download floodplain data from the county wherein that area lies.

4.3.5.2 Best Practices for Data Interpretation

The following are best practices to be used when comparing floodplain data to data for existing or proposed buildings and infrastructure.

- Digital overlay of floodplain data over other data (e.g., building footprints, parcel boundaries, topographic contours, etc.) should be conducted using Computer-Aided Design (CAD) or GIS software. The operator must be experienced with making the proper coordinate system and projection transformations to pair differing data sets together. The operator must also understand the accuracy of the source data and their pairing so as not to overstate the accuracy of an exhibit.

- If there is a discrepancy between BFE and the resulting extent of a floodplain and the underlying ground elevation according to high-quality topography (i.e., the BFE does not match the ground elevation at the edge of the floodplain delineation), the BFE should be reprojected onto the high-quality topography and the floodplain redrawn based on the updated topography.[15]

- The extents of the floodway are based on an encroachment analysis performed for a floodplain study and are not solely based on the underlying topography. As such, the

[15] Updated topography used to reproject the floodplain must both be more recent and of the same quality or better than the topography used in the floodplain study which determined the floodplain delineation. Significant changes in the floodplain delineations due to updated topography may require an updated flood study (e.g., LOMR) to be performed at the discretion of the Floodplain Administrator.

floodway WSELs should **not** be replotted onto updated topographic information to determine an updated floodway delineation.

- Accurate determinations of the BFE, to 0.1 feet, are best made by reading from the Flood Profile in the FIS.

4.4 BUILDING PERMITS WITHIN THE FLOODPLAIN

4.4.1 New Construction

Floodplain requirements are generally evaluated during the CP phase and are documented in the Grading Plan or Area Grading Plan (AGP) sheets. These sheets must show the highest BFE affecting each proposed building or lot. Information on the submitted plot plan is compared with the approved CPs to ensure that the grades and elevations are consistent and thus comply with floodplain regulations.

Approval of the plot plan and building permit will be provided on the condition that an EC is submitted and approved prior to issuance of a Certificate of Occupancy (CO).

4.4.2 Modifications to Existing Buildings

Building permits on lots that are located within the 1PAC floodplain are automatically flagged for further review by the CoA.[16] A more detailed review is made by permit staff and the Floodplain Administrator to determine whether the building in question is within a FEMA-designated floodplain and whether the proposed work constitutes a substantial improvement or repair of substantial damage. The determination will be based on GIS layers of the floodplain; aerial photography and topography; ECs on file; and previously approved plans, reports, and permits. If the building is determined to be within the floodplain and/or if the value of the improvements/repairs is such that they may be considered a substantial improvement or repair of damage, an EC will be required for the building. If a definitive determination of whether the building is within a FEMA-designated floodplain cannot be made based on the aforementioned data, and/or if the value of the improvements/repairs is near the threshold to be considered a substantial improvement or repair of damage, CoA staff may also request that the applicant provide an EC. See Section 4.6 below for more information on ECs.

4.4.3 Substantial Damage/Improvement

Substantial Damage and Substantial Improvement are defined in Section 70-4 of the Aurora City Code as follows:

> *"Substantial damage means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure just prior to when the damage occurred.*
>
> *Substantial improvement means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before start of construction of the*

[16] This only applies to lots within a FEMA-designated floodplain.

improvement. The value of the structure shall be determined by the local jurisdiction having land use authority in the area of interest. This includes structures which have incurred substantial damage, regardless of the actual repair work performed. The term does not, however, include either:

1. *Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary conditions; or*

2. *Any alteration of an historic structure provided the alteration will not preclude the structure's continued designation as a historic structure."* (Aurora City Code Section 70-4)

Staff will examine the ratio of the value of the improvements/repairs to the market value of the structure to determine if the proposed work meets, exceeds, or is near the 50% ratio threshold identified in the definitions of substantial damage and substantial improvements. Note that the cumulative value of improvements and/or repairs will be based on CoA records starting in the year 2000. If there are multiple replacements of the same item, such as a roof or water heater, only the most recent replacement will be counted toward the value of substantial improvements/repairs. The market value of the structure will be based on the value of the primary building as determined by the County Assessor and listed on the County Assessor's website.

When the ratio of the value of the improvements/repairs to the market value of the structure approaches the 50% threshold, or if the applicant disagrees with staff's assessment, the applicant may provide additional, more detailed information (e.g., statements or analysis from architects, engineers, licensed contractors, real estate appraisers, etc.) with which the assessment may be reevaluated.

4.5 GRADING REQUIREMENTS

4.5.1 Plat Requirements

Section 4.3.10, Subsection (A) of the UDO states:

"No residential lot or parcel intended for residential or non-residential occupancy shall include any land included within the 100-year floodplain, as determined by the Floodplain Administrator or any land in the Flood Protection Overlay (-FPO) zone district pursuant to Section 146-2.6.1." (Unified Development Ordinance Section 4.3.10.A)

This regulation requires that in residential areas, no portion of a floodplain may encroach upon a lot or parcel allowing placement of a residential structure (e.g., house, apartments, townhomes, etc.). The floodplain must instead be confined to a tract owned by a homeowner's association (HOA), metropolitan district, or the CoA. This regulation also requires that in non-residential areas, no portion of a floodplain may encroach upon a lot or parcel allowing placement of a building. The floodplain must instead be confined to a separate tract owned by the commercial property owner or another entity. Note that Section 4.3.10, *Subsection* (A) of the UDO applies to any area identified as a floodplain in Section 4.3.1 above.

4.5.2 Setbacks

Setback requirements will be determined based on potential erosion and stream bank failure hazards. A minimum 15-feet foot setback is required from the 100-year floodplain boundary, with greater setbacks required as conditions warrant. The Floodplain Administrator shall determine if greater setbacks are required based on-site conditions.

4.5.3 Residential Construction

4.5.3.1 Core Requirements

Core floodplain requirements for residential construction are defined in the Aurora City Code, Section 70-31, Subsection (1), as follows (***emphasis added***):

> *"New construction and Substantial Improvement of any residential structure shall have the lowest floor (including basement or crawl space), electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities (including ductwork),* ***elevated to two feet above the base flood elevation****. Upon completion of the structure, the elevation of the lowest floor, including basement or crawl space, shall be certified by a licensed Colorado Professional Engineer, architect, or land surveyor. Such certification shall be submitted to the floodplain administrator, prior to issuance of a certificate of occupancy.*
>
> *a. All new subdivisions shall be constructed so the lowest point on any lot shall be located one foot above base flood elevation.*
>
> *b. Manufactured home standards are governed by subsection (4) of this section and not by the standards in subsection (1) of this section."* (Aurora City Code Section 70-31(1))

4.5.3.2 Area Grading Plan (AGP)

Note: The requirements listed below were previously included in Sections 2.08.2.12 and 2.08.1.13 of the CoA's *Roadway Design & Construction Specifications* (RDCS) (City of Aurora, latest edition). They are presented below with minor edits and will be removed from future editions of the RDCS.

1. The AGP shall list the proposed LFE, including basement, crawl space or enclosure floor, for any residential lot or parcel hydraulically connected, touching, or included in a floodplain in the pre-development or post-development condition.

2. An EC is required for any residential lot or parcel hydraulically connected, touching, or included in a floodplain in the pre-development or post-development condition with a residential structure with a proposed LFE (including basement, crawl space, or enclosure floor) that is less than four feet above the BFE.

3. If the proposed residential structure is placed on an area of fill within the predevelopment condition's floodplain, an EC is required.

4. The EC shall demonstrate compliance with the core requirements for residential construction (see Section 4.5.3.1 above).

5. The AGP shall note by a prominent asterisk (or other appropriate method) each lot or residential building site for which an EC shall be provided. The following note shall be added to each sheet of the plans depicting a structure for which an EC is required:

No Certificate of Occupancy shall be issued until an Elevation Certificate has been submitted to and approved by the Floodplain Administrator. The Developer/Contractor is encouraged to verify the adequacy of lot grades and the elevation of concrete forms prior to pouring a foundation. It is recommended the Elevation Certificate be submitted at least a week in advance of a request for a Certificate of Occupancy.

6. No building permit nor floodplain development permit shall be issued for the construction of a new, residential structure or addition to an existing, residential structure on a property removed from the floodplain by the issuance of a FEMA LOMR-F, unless such new structure or addition has the LFE, electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities (including ductwork), elevated to at least two feet above the BFE that is current or existed prior to the placement of fill, whichever is greater. Where a new addition to an existing residential structure is proposed, requirements for substantial improvements still apply (see Section 4.4.3 above).

4.5.4 Non-residential Construction

4.5.4.1 Core Requirements

Core floodplain requirements for non-residential construction are defined in the Aurora City Code, Section 70-31, Subsection (2), as follows (***emphasis added***):

> *"With the exception of critical facilities, outlined in section 70-37 of this Code, new construction and substantial improvements of any commercial, industrial, or other nonresidential structure shall either have the lowest floor (including basement or crawl space), electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities (including ductwork),* ***elevated to one foot above the base flood elevation*** *or, together with attendant utility and sanitary facilities, be designed so at one foot above the base flood elevation the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy.*
>
> *A licensed Colorado Professional Engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify the design and methods of construction are in accordance with accepted standards of practice as outlined in this subsection. Such certification shall be provided to the floodplain administrator prior to issuance of a certificate of occupancy."* (Aurora City Code Section 70-31(2))

4.5.4.2 Final Grading Plan

Note: The requirements listed below were previously included in Sections 2.08.1.10 and 2.08.1.11 of the RDCS (City of Aurora, latest edition). They are presented below with minor edits and will be removed from future editions of the RDCS.

1. The Final Grading Plan shall list the proposed LFE, including basement, crawl space or enclosure floor, for any non-residential parcel hydraulically connected, touching or included in a floodplain in the pre-development or post-development condition.

2. An EC is required for any non-residential parcel hydraulically connected, touching or included in a floodplain in the pre-development or post-development condition, with a non-residential structure with a proposed LFE (including basement, crawl space, or enclosure floor) that is less than two feet above the BFE.

3. If the proposed non-residential structure is placed on an area of fill within the predevelopment condition's floodplain, an EC is required.

4. The EC shall demonstrate compliance with the core requirements for non-residential construction (see Section 4.5.4.1 above).

5. The Grading Plan shall note by a prominent asterisk (or other appropriate method) each lot or building site for which an EC shall be provided. The following note shall be added to each sheet of the grading and drainage plans depicting a structure for which an EC is required:

   No Certificate of Occupancy shall be issued until an Elevation Certificate has been submitted to and approved by the Floodplain Administrator. The Developer/ Contractor is encouraged to verify the adequacy of lot grades and the elevation of concrete forms prior to pouring a foundation. It is recommended the Elevation Certificate be submitted at least a week in advance of a request for a Certificate of Occupancy.

6. No building permit nor floodplain development permit shall be issued for the construction of a new, non-residential structure or addition to an existing, non-residential structure on a property removed from the floodplain by the issuance of a FEMA LOMR-F, unless the following conditions are met:

   - The new structure or addition has a LFE (including basement, crawl space, or enclosure floor), electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities (including ductwork), at least one foot above the BFE that is current or existed prior to the placement of fill, whichever is greater; or

   - The new structure or addition is designed, together with attendant utility and sanitary facilities, such that the structure or addition is watertight to at least one foot above the BFE that is current or existed prior to the placement of fill, whichever is greater, with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy.

4.6 ELEVATION CERTIFICATES

4.6.1 EC Requirements

ECs shall be provided prior to the issuance of a CO for any lots, parcels, and/or structures identified on an approved grading plan or AGP, as required in Sections 4.4 and 4.5 above. The

most recent version of the EC form released by FEMA must be used for all new EC applications (Federal Emergency Management Agency, 2023).[17] New EC applications submitted on expired forms will not be accepted. The EC form must be fully and accurately completed based on FEMA's directions.[18] The following are tips for filling out specific fields of the EC for structures in the CoA:

Section A – Property Information

A3: Use the legal property description (e.g., subdivision name and filing number, lot and block).

A6: Provide photographs of all four sides of the building unless physically impossible.

A8(e), A9(c) and A9(e): These fields refer to engineered flood openings; the use of engineered flood openings is very rare in the CoA.

Section B – Flood Insurance Rate Map (FIRM) Information

B1.a: City of Aurora, Colorado

B1.b: 080002

B4: Use the map number without the suffix (e.g., 08005C0184).

B5: Use the letter suffix (e.g., L).

B6: Use the latest FIRM index date.[19]

B8 & B9: Provide data only from the FEMA effective FIS and FIRM. Most ECs required in the CoA are outside of the FEMA effective 1PAC floodplain. If this is the case, the Flood Zone is either Zone X (shaded) or Zone X (unshaded), and BFE is blank. The Floodplain Administrator shall supplement or correct this information in Section G.

B12 & B13: These fields are always "No" within the CoA.

Section C – Building Elevation Information (Survey Required)

This section may be completed if the structure is within any flood zone; however, if the structure is within a flood zone without BFEs, completion of Section E instead may be more beneficial. Section C must be completed if the structure is located in a flood zone with BFEs and/or the EC

[17] As of this writing, the most recent version is FF-206-FY22-152 (8/23), with an expiration date of 6/30/2026. Note that certain internet browser's Portable Document Format (PDF) viewers cannot display the latest version of the EC form; to access it, the latest EC form must be downloaded directly and opened in a separate PDF viewer.

[18] Pages 9-19 of the latest EC form contain detailed instructions for the completion of the EC.

[19] The FIRM index shows the location of all FIRM panels within a community. They are typically identified by the "IND" in the Product ID on FEMA's MSC (see Section 4.3.5.1). As of this writing, the Product ID of the FIRM index for Arapahoe County (and the CoA) is 08005CIND0E with a date of 9/4/2020 (Federal Emergency Management Agency, 2020).

is being used in support of a LOMC. This section may also be completed if the structure's First Floor Height is being documented for insurance purposes (Section H), but this is not required.

Note that a licensed surveyor, engineer, or architect must complete this section.

C1: Select the appropriate field. Note that if Finished Construction is not selected, a new EC will be required when construction of the building is complete. For the purpose of completing the EC, a structure is complete once the floors, exterior walls and roof are all in place.

C2: Use a CoA vertical benchmark. The Vertical Datum will always be NAVD 88.

Section D – Surveyor, Engineer, or Architect Certification

Complete all fields. This section must be stamped and signed by a Professional Engineer or Professional Land Surveyor licensed in the State of Colorado. If Section E is completed instead of Section C, complete Section F instead of Section D.

Section E – Building Measurement Information (Survey Not Required) For Zone AO, Zone AR/AO, and Zone A (Without BFE)

This section may be completed instead of Section C if the structure is located in a Zone AO, AR/AO, or Zone A (without BFEs), and is being completed for the purpose of documenting compliance with CoA floodplain management requirements. If the structure is located in a flood zone with BFEs and/or the EC is being used in support of a LOMC, complete Section C instead.

Note that the information in Section C shall supersede the information in this section for insurance and compliance purposes if both are completed.

Note that this section may be completed by the property owner or an authorized representative thereof.

In the Building Measurements field, select the appropriate option. Note that if Finished Construction is not selected, a new EC will be required when construction of the building is complete. For the purpose of completing the EC, a structure is complete once the floors, exterior walls and roof are all in place.

Section F – Property Owner (Or Owner's Authorized Representative) Certification

Complete all fields.

Section G – Community Information (Recommended for Community Official Completion)

This section is completed by the Floodplain Administrator. Do not complete this section.

Section H – Building's First Floor Height Information For All Zones (Survey Not Required) (For Insurance Purposes Only)

This section may be completed by the property owner, the property owner's authorized representative, or the Floodplain Administrator. Note that the information in Section C shall supersede the information in this section for insurance and compliance purposes if both are completed.

Section I – Property Owner (Or Owner's Authorized Representative) Certification

Complete all fields if Section H is completed.

4.6.2 Submittal and Review

ECs shall be submitted electronically to the portal and folder used for the building permit. Copies may also be sent via email to the Floodplain Administrator. Reviews will be completed in one business week or less. The outcome of the review will either be approval or a request for correction.

4.6.3 Availability of Approved ECs

Approved ECs are available from CoA's NFHL Flood Map (City of Aurora).

4.7 LOMC REVIEWS

LOMCs include CLOMRs, LOMRs, CLOMAs, LOMAs, CLOMR-Fs and LOMR-Fs. CLOMAs, LOMAs, CLOMR-Fs and LOMR-Fs are submitted to FEMA using the MT-1 forms, while CLOMRs and LOMRs are submitted to FEMA using the MT-2 forms. Both of these forms require community concurrence from the CoA. This section outlines the processes for submittal and review, and the review criteria.

4.7.1 Submittal

CoA requires the same items to be submitted as the MHFD and FEMA. MHFD guidelines and checklists for How to Submit Letters of Map Change should be followed (Mile High Flood District, 2022).

LOMC submittals are managed in the same manner as other development review submittals (see Chapter 2). However, unlike other submittals, the files associated with LOMCs are typically too large to be handled directly by the CoA's systems. To submit files for a LOMC review, contact the Floodplain Administrator directly via e-mail. Provide a link to a file sharing service, such as DropBox or OneDrive, containing all of the necessary files. The Floodplain Administrator will then create a folder in the CoA's system to track the LOMC's review status and manage review fees.

4.7.2 Review Process

LOMC reviews typically take 3 business weeks to complete. Review of subsequent submittals will also take approximately 3 business weeks to complete. Most LOMC reviews are completed within 2-3 cycles. Once a LOMC has been approved by the CoA, the Floodplain Administrator will sign the Community Acknowledgement section of the MT-1 Forms, or the Community Concurrence section of MT-2 Form 1, depending on the type of LOMC being reviewed. The LOMC application may then be submitted to the MHFD/FEMA for their review and approval.

4.7.3 Review Criteria

The CoA's concurrence review is less technically detailed than those conducted by FEMA, the MHFD, and their consultants. The primary review criterion is whether the submittal is sufficiently accurate and complete to sign the Community Acknowledgement or Community Concurrence

sections on the MT-1 and MT-2 forms, respectively. On the latest version of the MT-1 Forms, the Community Acknowledgement reads:

> "*As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this request for a LOMA. We understand that this request is being forwarded to DHS-FEMA to determine if this property has been inadvertently included in the regulatory floodway. We acknowledge that no fill on this property has been or will be placed within the designated regulatory floodway. We find that the completed or proposed project meets or is designed to meet all of the community floodplain management requirements.*" (Department of Homeland Security - Federal Emergency Management Agency, 2011)

On the latest version of MT-2 Form 1, the Community Concurrence reads:

> *"As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirements for when fill is placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. For Conditional LOMR requests, the applicant has documented Endangered Species Act (ESA) compliance to FEMA prior to FEMA's review of the Conditional LOMR application. For LOMR requests, I acknowledge that compliance with Sections 9 and 10 of the ESA has been achieved independently of FEMA's process. For actions authorized, funded, or being carried out by Federal or State agencies, documentation from the agency showing its compliance with Section 7(a)(2) of the ESA will be submitted. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination."* (Department of Homeland Security - Federal Emergency Management Agency, 2021)

LOMC submittals are therefore evaluated based on the above statements to which the Floodplain Administrator attests, including the following areas: completeness of submittal, hydrology, hydraulics, floodplain mapping, and regulatory requirements.

4.8 FLOODPLAIN DEVELOPMENT PERMITS

Section 70-8 of the Aurora City Code states:

> *"All development in a SFHA is prohibited unless a floodplain development permit for such development has been issued by the floodplain administrator pursuant to the requirements of this article. The floodplain development permit shall be required in addition to all other permits and requirements of this Code."* (Aurora City Code Section 70-8)

This section details the submittal and review process for FPDPs and the review criteria based on the type of project and location of the proposed work.

4.8.1 Submittal

Projects located with the floodplain must submit a FPDP application. Applicants must complete the first page of the FPDP Application Form. Basic information about the applicant and project must be included, along with the applicant's signature.[20] Completed FPDP applications and supporting materials should be e-mailed to the Floodplain Administrator.

For projects that have associated CPs, the best time to submit the FPDP is concurrent with the first CP submittal. The FPDP will then usually be approved around the same time as the CPs are approved. If the FPDP is not approved by the time of CP approval, a condition will be added to the CP indicating that work in the floodplain is prohibited until the FPDP is approved.

The following list describes the types of projects that are commonly seen in the CoA:

1. Construction with no surface disturbance, such as directional drilling of subsurface utilities.

2. Construction with no permanent surface disturbance, such as trenched installation of subsurface utilities. In this example, a trench is dug, utilities are installed, and the trench is refilled to match pre-project grades.

3. Construction with minor surface disturbance, such as the installation of utility boxes, transformers, markers or other appurtenances supporting subsurface utilities.

4. Placement of fill, buildings, hydraulic structures, and roadway crossings, or other major disturbances.

Table 4-1 identifies the submittal requirements and considerations for the different types of projects described above based on the type of floodplain wherein the work will occur. Sections 4.8.1.1 and 4.8.1.2 below describe the submittal requirements for different floodplain types in greater detail.

[20] The property owner, developer, engineer, or contractor may be the applicant.

Table 4-1. FPDP Submittal Requirements

Number	Project Type	Floodplain Type				
		FEMA-Identified			Non-FEMA-Identified	
		Zone A	Zone AE		Floodway Fringe	Floodway
			Floodway Fringe	Floodway		
1	No surface disturbance	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile
2	No permanent surface disturbance	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile	• FPDP application • Floodplain details on CP plan and profile
3	Minor surface disturbance	• FPDP application • Floodplain details on CP plan and profile • No-rise statement without hydraulic analysis	• FPDP application • Floodplain details on CP plan and profile • Statement that there are no changes in BFE > 0.3 foot without hydraulic analysis	• FPDP application • Floodplain details on CP plan and profile • No-rise statement without hydraulic analysis	• FPDP application • Floodplain details on CP plan and profile • Statement that there are no changes in BFE > 0.3 foot without hydraulic analysis	• FPDP application • Floodplain details on CP plan and profile • No-rise statement without hydraulics analysis
4	Fill, buildings, hydraulic structures, roadway crossings, etc.	• FPDP application • Floodplain details on CP plan and profile • No-rise statement with hydraulic analysis or CLOMR	• FPDP application • Floodplain details on CP plan and profile • Hydraulic analysis showing no change in BFE > 0.3 foot or CLOMR	• FPDP application. • Floodplain details on CP plan and profile. • No-rise statement with hydraulics or CLOMR.	• FPDP application • Floodplain details on CP plan and profile • Hydraulic analysis showing no change in 1PAC WSEL > 0.3 foot or CLOMR	• FPDP application • Floodplain details on CP plan and profile • No-rise statement with hydraulic analysis or CLOMR

4.8.1.1 FPDP Requirements for FEMA-Identified Floodplains

For projects within FEMA-identified floodplains, the FPDP requirements differ based on the type of SFHA affected by the proposed work.

1. **Regulatory Floodway**: For work within the regulatory floodway, a no-rise analysis must be provided to obtain a FPDP. The no-rise analysis must demonstrate that the proposed project will not have any impact on the BFEs, 1PAC floodplain, or floodway (see Section 4.8.3.1 below). If a no-rise cannot be achieved, a CLOMR must be obtained from FEMA prior to issuance of a FPDP (see Section 4.8.3.2 below).

2. **Floodway Fringe**: For work within the floodway fringe (i.e., the portion of the SFHA outside of the regulatory floodway), a hydraulic analysis must be provided demonstrating that the proposed project will not cause a change in BFEs in excess of 0.3 foot in order to obtain a FPDP.[21] In these cases, a CLOMR-F/LOMR-F may be appropriate. If the hydraulic analysis shows the project to cause a change in BFEs in excess of 0.3 foot, a CLOMR must be obtained from FEMA prior to issuance of a FPDP (see Section 4.8.3.2 below).

4.8.1.2 FPDP Requirements for Non-FEMA-Identified Floodplains

For projects within non-FEMA-identified floodplains, the FPDP requirements differ based on the type of floodplain affected by the proposed work.

1. **Non-Regulatory Floodway**: For work within the non-regulatory floodway, a no-rise analysis must be provided to obtain a FPDP. The no-rise analysis must demonstrate that the proposed project will not have any impact on the 1PAC WSELs, 1PAC floodplain, or floodway (see Section 4.8.3.1 below). If a no-rise cannot be achieved, a hydraulic analysis must be provided which demonstrates that any increase in 1PAC WSELs, 1PAC floodplain, and/or floodway is confined to the applicant's property and does not impact any insurable structures. If these requirements cannot be met, a FPDP cannot be issued.

2. **Floodway Fringe**: For work within the floodway fringe (i.e., the portion of the SFHA outside of the floodway), a hydraulic analysis must be provided demonstrating that the proposed project will not cause a change in 1PAC WSELs in excess of 0.3 foot in order to obtain a FPDP.[21] Any increase in 1PAC WSELs must not impact an insurable structure, and any increases must be confined to the applicant's property. If the hydraulic analysis shows the project to cause 1PAC WSEL changes in excess of 0.3 foot, the WSEL increases occur outside of the applicant's property, or the WSEL increases impact an insurable structure, a FPDP cannot be issued.

4.8.2 Review Process

FPDP reviews typically take 3 business weeks to complete. Review of subsequent submittals are generally completed in 1 business week or less. Most FPDP reviews are completed within 1-2 cycles.

[21] See 2 Code of Colorado Regulations (CCR) 408-1, Rule 12H (Colorado Water Conservation Board, latest edition).

4.8.3 Review Criteria

The review criteria for various items submitted to support a FPDP application are described in the proceeding sections.

4.8.3.1 No-Rise Analysis and Statement

A no-rise statement is a letter and supporting analysis, signed and sealed by a Professional Engineer licensed in the State of Colorado, that the proposed work will have no impact on the 1PAC floodplain and BFEs (and floodway, if applicable).

If the proposed work within the floodplain is entirely at or below existing grades, no hydraulic analysis is required. This condition must be demonstrated by exhibits such as cross sections, profiles, and/or cut-fill grids.

If the proposed work within the floodplain and/or floodway increases grades or includes other factors which may increase WSELs, a hydraulic analysis is required. The hydraulic analysis process for a no-rise analysis is described below, and generally follows the same procedure as is required for CLOMR/LOMR applications:

1. **Obtain Original/Effective Model**: The engineer must first obtain a copy of the original/effective model used to delineate the floodplain/floodway in the floodplain study. For FEMA-identified floodplains, this is the effective model; for non-FEMA-identified floodplains, this may be the model from a FHAD study, MDP, or another CoA-approved study or plan. Contact the Floodplain Administrator, MHFD, and/or FEMA to obtain a copy of the original model. If no previous floodplain study exists, the original/effective model need not be obtained.

2. **Create Duplicate Effective Model**: Once the original/effective model is obtained, the engineer shall rerun the model using the same software as was used to develop the model originally to ensure that the model outputs (e.g., WSELs, floodplain topwidths, etc.) match the results of the associated floodplain study. If no previous floodplain study exists, a duplicate effective model need not be created.

3. **Develop Corrected Effective Model**: Once a duplicate effective model is created, a corrected effective model shall be developed, if necessary. A corrected effective model fixes any errors in the original model. Most commonly, this involves rerunning the model using the latest version of the modeling software (e.g., HEC-RAS 6.4.1 instead of HEC-RAS 4.1) but may also involve fixing typos in the model input data. The corrected effective model should **not** update the model to reflect existing conditions (e.g., updated topography); the existing conditions model shall reflect current site conditions instead. If no previous floodplain study exists, or if the original model contains no errors and need not be run in more recent software, a corrected effective model need not be developed.

4. **Prepare Existing Conditions Model:** Once the duplicate and/or corrected effective model is created, an existing conditions model shall be prepared. The engineer shall update the duplicate/corrected effective model to reflect the existing conditions. Such updates may include implementing updated topography, land cover, road crossings, and/or any other model changes necessary to ensure the existing conditions model reflects current site conditions. If no previous floodplain study exists, a new hydraulic model shall be created which reflects the existing conditions.

5. **Create Proposed Conditions Model**: Once the existing conditions model is prepared, a proposed conditions model shall be created. The proposed conditions model shall be based on the existing conditions model and incorporate all changes within the floodplain due to the proposed project. Such changes may include proposed project grading, altered land cover, new or revised road crossings, and/or any other proposed project improvements.

6. **Analyze Results**: The results of each of the models described above shall be reviewed and compared. The engineer shall input the model results into the MHFD BFE Comparison Table (Mile High Flood District, 2022). The engineer shall also prepare figures and maps as necessary to show any changes in floodplain delineation.

7. **Prepare No-Rise Statement and Submittal Package**: Once the model results have been analyzed, the engineer shall prepare the no-rise statement and submittal package. The submittal for a no-rise statement based on hydraulic analysis must include the signed and sealed statement, a brief narrative describing the modelling process and results, a BFE Comparison Table, any necessary figures/maps, model outputs, and electronic copies of the hydraulic models.

A "no-rise" means that the proposed conditions hydraulic model shows no change in 1PAC WSELs with respect to the existing conditions model, to the precision of 0.00 foot. **Therefore, a no-rise analysis must show no-rise at the precision of 0.00 foot.** A no-rise statement and analysis submitted in support of a FPDP will be reviewed to ensure that the no-rise statement is accurate, and that the attendant hydraulic analysis is complete and reasonable.

4.8.3.2 CLOMR

For projects which require a CLOMR from FEMA, the FPDP cannot be issued until the CLOMR has been approved. Upon CLOMR approval, the FEMA case number will be noted on the FPDP and approved. Note that the submittal requirements and process outlined in Section 4.7 above must also be followed.

4.8.3.3 Other Hydraulic Analyses and Supporting Materials

Hydraulic analyses apart from a no-rise analysis or CLOMR may be required to obtain a FPDP (e.g., a hydraulic analysis demonstrating that a proposed project in the floodway fringe does not cause a change in BFEs in excess of 0.3 foot, as described in Sections 4.8.1.1 and 4.8.1.2 above). Such analyses shall generally follow the same procedure used for a no-rise analysis (e.g., obtaining original/effective model, creating existing and proposed conditions models, etc.; see Section 4.8.3.1 above); however, instead of a no-rise statement, the analysis shall note the hydraulic impacts of the proposed project and how the project complies with the criteria set forth in this chapter (e.g., proposed project in floodway fringe does not change BFEs by more than 0.3 foot).

Additionally, other supporting materials may be required as part of an FPDP application. The following list provides typical additional supporting information that may be required (not an all-inclusive list):

1. Topographic work map(s), certified by a Professional Engineer licensed in the State of Colorado.

2. Annotated FIRM(s) or equivalent (for non-FEMA-identified floodplains).

3. Design drawings which depict the proposed project, certified by a Professional Engineer licensed in the State of Colorado.

4. Comparison table(s) which demonstrate changes in 1PAC WSELs between modeled conditions (e.g., effective, duplicate effective, corrected effective, existing, proposed, etc.) and consistency between the model results and mapped floodplain.

5. Certification that the proposed project does not impact any insurable structures.

6. Certification that increases in 1PAC WSELs, 1PAC floodplain, and/or floodway are confined to the applicant's property.

4.8.3.4 FPDP and Other Plans

If the proposed work is part of a CP, the CoA Record Sequence Number (RSN) or Engineering Drawing Number (EDN) should be listed on the application form.[22] Do not attach copies of CPs.

If the proposed work is not part of a CP, such as work covered under a License Agreement, then a plan should be included as an attachment to the FPDP application. The plan must show the proposed work; floodplain information, including the extents of the floodplain, floodway, and BFEs, where applicable; property information, including right-of-way (ROW), lots, parcels, tracts, and easements; and other features as necessary to locate and understand the proposed work. Underground utilities must also include a profile. Note that the intent of this requirement is to overlay floodplain features onto documents already required for other CoA applications, rather than requiring additional, separate documents.

4.9 TIMING OF FLOODPLAIN APPROVALS IN RELATION TO OTHER APPROVALS

The following sections outline the timing of various floodplain approvals with respect to other CoA reviews and approvals.

4.9.1 Timing of Floodplain Approvals when LOMC Required

The following is a list of steps and checkpoints for the development of property where a LOMC is required to remove occupiable land from the FEMA-identified pre-project floodplain:

1. The Planning Department Site Plan, Plat, and Preliminary Drainage Report (PDR) cannot be approved if the floodplain is shown on any buildable lots, parcels, or tracts. If portions of the property are outside of the floodplain, they may be approved as long as those portions of the property in the floodplain are placed in unbuildable tracts.

2. CPs are subject to the same restrictions as the documents listed in 1 above.

3. A CLOMR application can be submitted to the Floodplain Administrator based on 60% design plans at minimum. The CLOMR application may occur prior to the CP submittal for drainage infrastructure but be aware that the CLOMR submittal effectively locks in

[22] See Chapter 2 for additional information on the RSN and EDN.

major design elements and elevations.

4. CPs for the drainage infrastructure cannot be approved until the CLOMR has been approved by FEMA. CPs may be conditionally approved prior to approval of the CLOMR by FEMA for areas outside the floodplain.

5. Following the approval of the CLOMR and CPs for drainage infrastructure, construction may begin.

6. Once construction has been completed, the developer's engineer shall create surveyed as-built drawings of the improvements, prepare a LOMR application, and submit the LOMR application to CoA for a concurrence review (see Section 4.7.3 above). Once concurrence has been granted, the LOMR application shall be submitted to the MHFD/FEMA.

7. Once FEMA has issued the LOMR, revised Planning Department Site Plans, Plats, Drainage Reports, and CPs for areas formerly within the floodplain may be approved. The review of these revised documents should be coordinated with multiple CoA departments.

8. No building permits will be issued within the floodplain until the LOMR has been approved.

9. The developer may proceed with approvals and construction in the previously mapped floodplain in the time between when FEMA issues a LOMR and when it becomes effective.[23] However, the developer does at risk of delays or changes to the final mapped floodplain as a result of appeals submitted to FEMA during this period. The developer must acknowledge this risk in writing.

Variances to these procedures will be considered on a case-by-case basis using the factors found in the Aurora City Code (Aurora City Code Section 70-22(c)), risk analysis, and sound engineering judgement. In no case will platting of single-family residential lots be permitted prior to approval of a LOMR by FEMA.

4.9.2 Timing of Floodplain Approvals when No-Rise Statement or Other Hydraulic Analysis Required

The following is a list of steps and checkpoints for the development of property where a no-rise analysis or other hydraulic analysis is required to demonstrate compliance with CoA floodplain regulations:

1. The Planning Department Site Plan, Plat, and PDR cannot be approved if the floodplain is shown on any buildable lots, parcels, or tracts. If portions of the property are outside of the floodplain, they may be approved as long as those portions of the property in the floodplain are placed in unbuildable tracts.

2. CPs are subject to the same restrictions as the documents listed in 1 above.

[23] The time between when a LOMR is approved and when it becomes effective is typically 90 days. This time may be extended if FEMA receives appeals of the LOMR.

3. The no-rise analysis and statement or other hydraulic analysis may be submitted with the FPDP application alongside the CPs.

4. CPs for the drainage infrastructure cannot be approved until the FPDP and associated no-rise statement and analysis have been approved. CPs may be conditionally approved prior to approval of the FPDP under the provision that work in the floodplain is prohibited until approval of the FPDP is obtained.

5. Following the approval of the FPDP and CPs for drainage infrastructure, construction may begin.

Variances to these procedures will be considered on a case-by-case basis using the factors found in the Aurora City Code (Aurora City Code Section 70-22(c)) risk analysis, and sound engineering judgement.

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CHAPTER 5.0 HYDROLOGIC CRITERIA

5.1 INTRODUCTION

This chapter presents hydrologic criteria for design rainfall, as well as methods for calculating peak flow rates and runoff hydrographs in the City of Aurora (CoA). Hydrologic criteria and methods in the Mile High Flood District's (MHFD's) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 1, Chapter 5: Rainfall and Chapter 6: Runoff are hereby incorporated by reference.

5.2 RAINFALL

Rainfall intensity for a duration equal to the time of concentration is required for Rational Method analyses, and the 1-hour point rainfall depth is a required input for Colorado Urban Hydrograph Procedure (CUHP) analyses (Urban Drainage and Flood Control District (now Mile High Flood District), latest edition). For watersheds with areas 15 square miles or larger, the 3-hour and 6-hour rainfall depths are also required for use with CUHP. The National Oceanic and Atmospheric Administration's (NOAA's) Atlas 14, Volume 8, Version 2 (NOAA Atlas 14) may be used to determine the necessary rainfall intensity and depth data (National Oceanic and Atmospheric Administration's National Weather Service, 2013). Table 5-1 provides the 1-, 3-, and 6-hour point rainfall depths for the CoA for a range of return periods. The point rainfall data in Table 5-1 were taken from NOAA Atlas 14 near the geographic center of the CoA (i.e., the intersection of Colorado E-470 and East 6th Avenue). These values may be used for conceptual analyses; however, for design, engineers must determine the site-specific values using the NOAA Atlas 14 online tool.

Table 5-1. Point Rainfall Depths for the CoA[24]

Duration	Rainfall Depth (inches)							
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
1-hour	0.70	0.86	1.14	1.40	1.79	2.11	2.46 (2.36 - 2.55)*	3.38
3-hour	0.93	1.12	1.48	1.81	2.31	2.73	3.18 (3.05 - 3.30)*	4.39
6-hour	1.11	1.34	1.75	2.12	2.69	3.16	3.68 (3.57 - 3.74)*	5.02

* Typical ranges of depths within the CoA provided for 100-year return period for selected durations as a "reasonableness check" on values determined using the NOAA Atlas 14 online tool. The 100-year depth ranges were determined near the eastern and western boundaries of the CoA. For conceptual analyses, use the mid-range value. For site-specific design, determine the site-specific rainfall based on the current version of the NOAA Precipitation Atlas.

[24] Data from NOAA Atlas 14, Volume 8, Version 2 (National Oceanic and Atmospheric Administration's National Weather Service, 2013). Data reported for central Aurora (i.e., the intersection of Colorado E-470 and East 6th Avenue).

To develop depth-duration-frequency (DDF) curves or intensity-duration-frequency (IDF) curves for the Rational Method, use the 1-hour depth(s) obtained from NOAA Atlas 14 and apply Equation 5-1 and Equation 5-2 for the duration (or durations) of interest:

$$I = \frac{28.5 \cdot P_1}{(10 + T_d)^{0.786}} \qquad \textbf{Equation 5-1}$$

$$D = \frac{I \cdot T_d}{60} \qquad \textbf{Equation 5-2}$$

Where:

I = rainfall intensity (inches per hour)

P_1 = 1-hour point rainfall depth from Table 5-1 or NOAA Atlas 14 online tool (inches)

T_d = storm duration (minutes)

D = rainfall depth (inches)

Table 5-2 and Table 5-3 provide tabular DDF and IDF data, respectively, for the CoA based on the 1-hour point rainfall depths in Table 5-1; Figure 5-1. Rainfall Depth Duration Frequency (DDF) Curves for the CoA plot the IDF and DDF curves, respectively. If the duration of interest (i.e., time of concentration for Rational Method) falls between the durations in Table 5-2 or Table 5-3, use linear interpolation to determine the appropriate depth or intensity, respectively; alternatively, use Equation 5-1 and Equation 5-2 to calculate the intensity and depth, respectively, for the duration of interest. Documentation of depth and intensity values must be provided as a part of drainage submittals (see Chapter 2).

Table 5-2. Rainfall Depth Duration Frequency (DDF) Data for the CoA

Duration (minutes)	Rainfall Depth (inches)							
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5	0.20	0.24	0.32	0.40	0.51	0.60	0.70	0.96
10	0.32	0.39	0.51	0.63	0.81	0.95	1.11	1.52
15	0.40	0.49	0.65	0.79	1.02	1.20	1.40	1.92
20	0.46	0.56	0.75	0.92	1.17	1.38	1.61	2.22
25	0.51	0.62	0.83	1.02	1.30	1.53	1.79	2.45
30	0.55	0.67	0.89	1.10	1.40	1.66	1.93	2.65
35	0.58	0.72	0.95	1.17	1.49	1.76	2.05	2.82
40	0.61	0.75	1.00	1.23	1.57	1.85	2.16	2.97
45	0.64	0.79	1.04	1.28	1.64	1.93	2.25	3.10
50	0.67	0.82	1.08	1.33	1.70	2.01	2.34	3.21
55	0.69	0.84	1.12	1.37	1.76	2.07	2.42	3.32
60	0.70	0.86	1.14	1.40	1.79	2.11	2.46	3.38
70	0.74	0.91	1.21	1.49	1.90	2.24	2.61	3.59
80	0.77	0.95	1.26	1.55	1.98	2.33	2.72	3.74
90	0.80	0.98	1.31	1.60	2.05	2.42	2.82	3.87
100	0.83	1.02	1.35	1.65	2.11	2.49	2.90	3.99
110	0.85	1.04	1.38	1.70	2.17	2.56	2.98	4.10
120	0.87	1.07	1.42	1.74	2.22	2.62	3.06	4.20

Table 5-3. Rainfall Intensity Duration Frequency (IDF) Data for the CoA

Duration (minutes)	Rainfall Intensity (inches/hour)							
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5	2.37	2.92	3.87	4.75	6.07	7.16	8.34	11.46
10	1.89	2.33	3.08	3.79	4.84	5.71	6.66	9.14
15	1.59	1.95	2.59	3.18	4.06	4.79	5.58	7.67
20	1.38	1.69	2.24	2.75	3.52	4.15	4.84	6.65
25	1.22	1.50	1.99	2.44	3.12	3.68	4.29	5.89
30	1.10	1.35	1.79	2.20	2.81	3.31	3.86	5.30
35	1.00	1.23	1.63	2.00	2.56	3.02	3.52	4.83
40	0.92	1.13	1.50	1.84	2.36	2.78	3.24	4.45
45	0.86	1.05	1.39	1.71	2.19	2.58	3.01	4.13
50	0.80	0.98	1.30	1.60	2.04	2.41	2.81	3.86
55	0.75	0.92	1.22	1.50	1.92	2.26	2.64	3.62
60	0.70	0.86	1.14	1.40	1.79	2.11	2.46	3.38
70	0.64	0.78	1.04	1.27	1.63	1.92	2.24	3.08
80	0.58	0.71	0.95	1.16	1.48	1.75	2.04	2.80
90	0.53	0.66	0.87	1.07	1.37	1.61	1.88	2.58
100	0.50	0.61	0.81	0.99	1.27	1.49	1.74	2.39
110	0.46	0.57	0.75	0.93	1.18	1.40	1.63	2.24
120	0.43	0.53	0.71	0.87	1.11	1.31	1.53	2.10

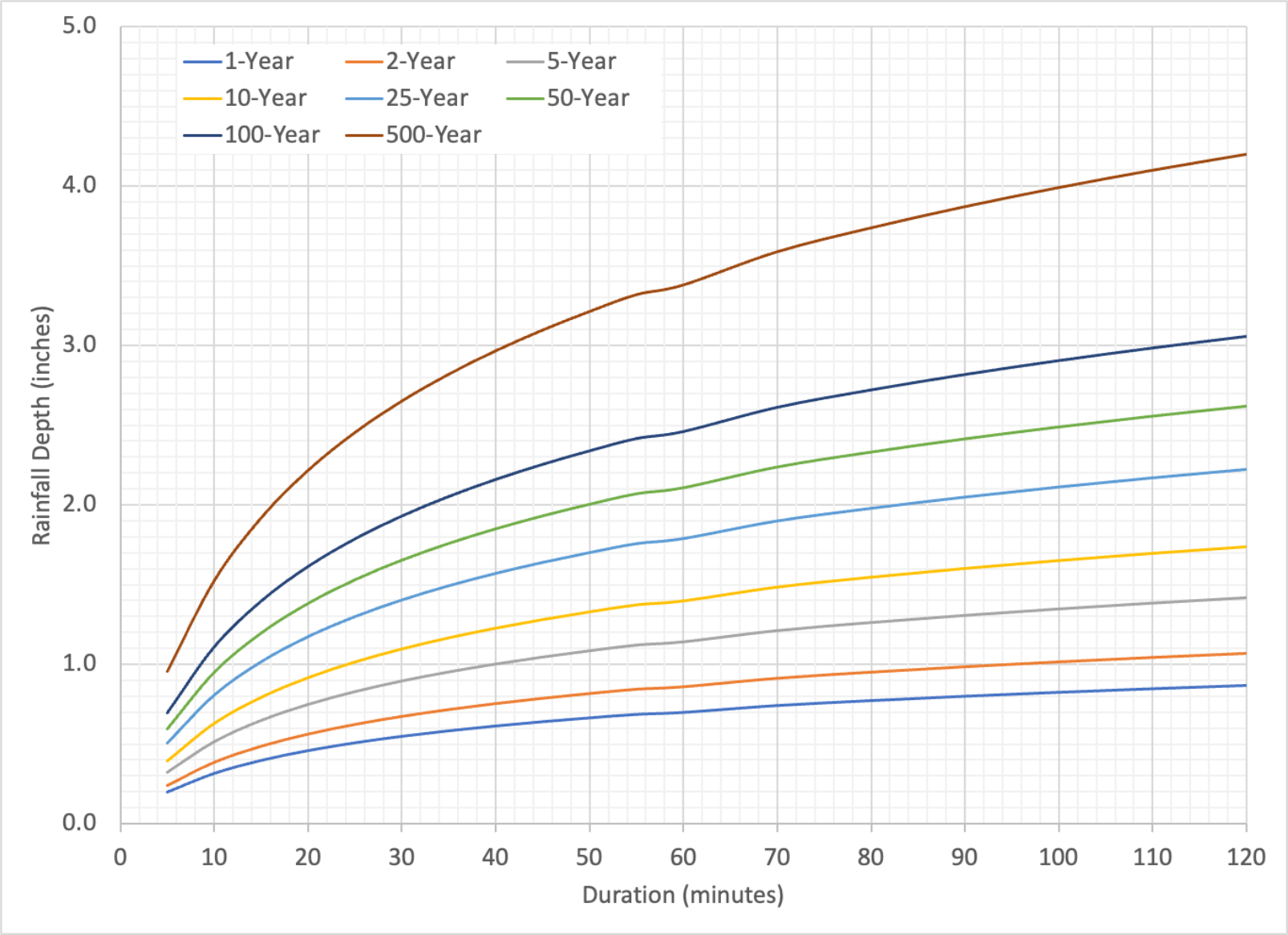

Figure 5-1. Rainfall Depth Duration Frequency (DDF) Curves for the CoA

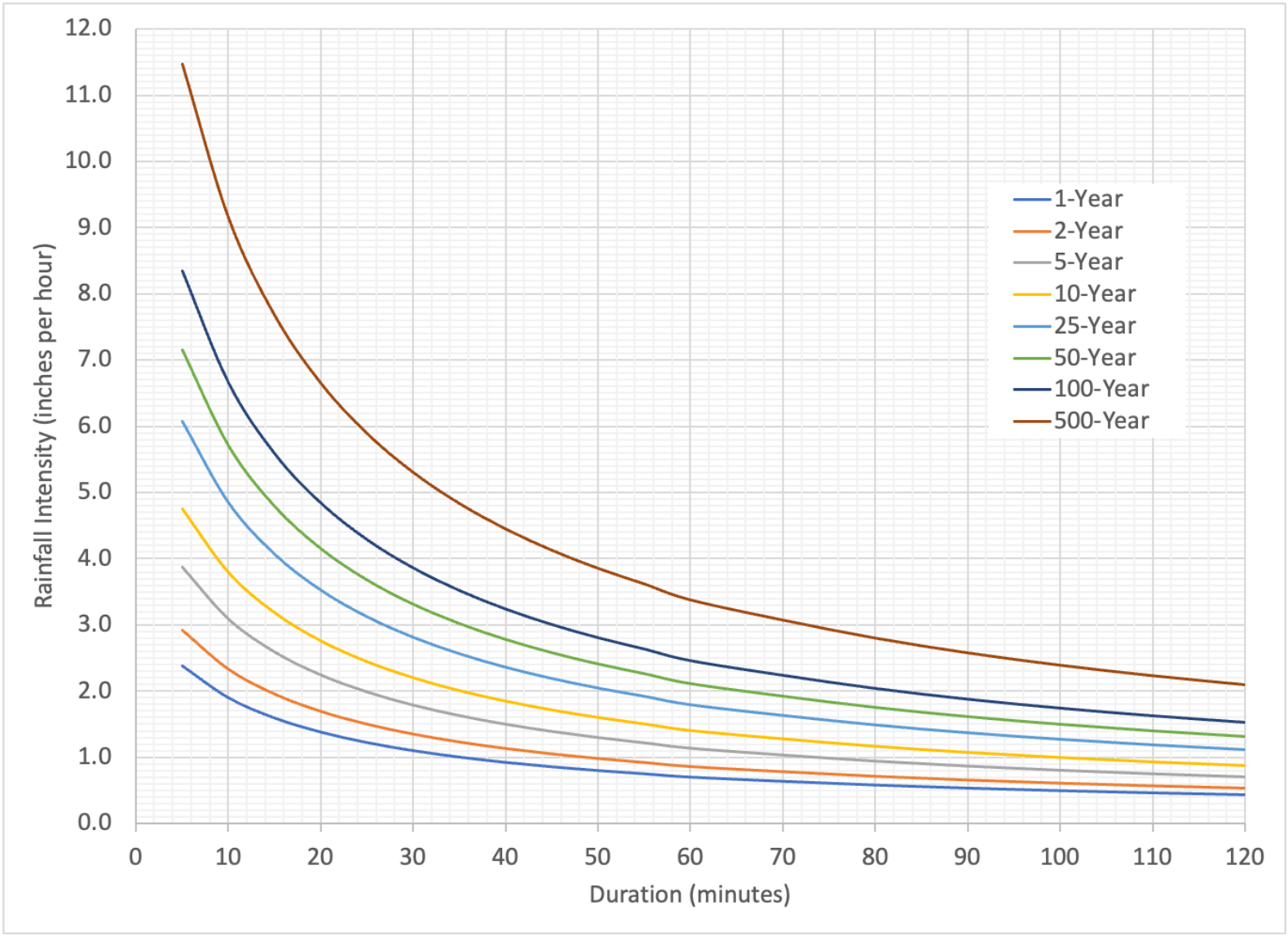

Figure 5-2. Rainfall Intensity Duration Frequency (IDF) Curves for the CoA

Current climate projections for the Front Range of Colorado do not show strong increasing or decreasing trends in average annual precipitation (see Figure 5-3); however, there is likely to be greater variability of wet and dry periods (Lukas, Barsugli, Doesken, Rangwala, & Wolter, 2014; Earles, MacKenzie, Bennetts, & Traylor, 2015). In addition, seasonal shifts are expected to result in increases in mid-winter precipitation and decreases in summer precipitation (Colorado Water Conservation Board, 2023). Given these climate projections, NOAA Atlas 14 continues to provide the best available data at the time of publication of this Manual; however, as additional data are collected and analyzed, rainfall DDF and IDF relationships may change. NOAA is currently working on NOAA Atlas 15, which will incorporate adjustments based on future climate model projections (National Oceanic and Atmospheric Administration's Office of Water Prediction); however, this resource is not yet available. The rainfall data in this chapter will remain in effect until such time as the CoA adopts a new study as the best available data.

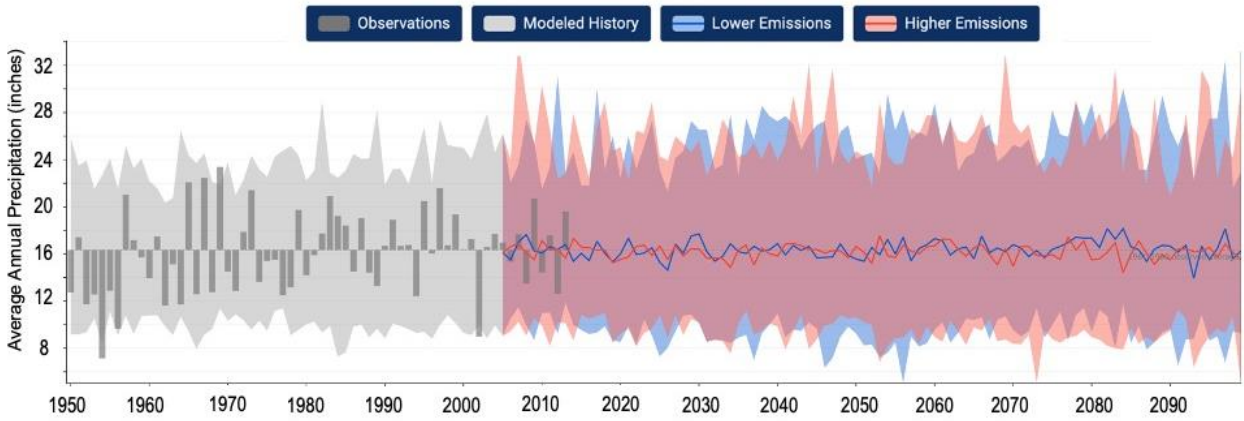

Figure 5-3. Average Annual Precipitation Observations and Climate Projections for Aurora, CO, 1950 – 2100 (National Oceanic and Atmospheric Administration's Climate Program Office)

5.3 RUNOFF

There are several acceptable methods for calculating runoff in the CoA: the Rational Method, CUHP, and CUHP combined with the Environmental Protection Agency's (EPA's) Stormwater Management Model (SWMM); in some cases, the MHFD or the CoA have completed detailed hydrologic studies that may also be used. Table 5-4 below provides criteria for when to apply each of these methods. All criteria specified in the MHFD Manual must be followed for preparation of drainage reports and storm drainage facility designs in CoA. See the MHFD Manual for background on methods, equations, runoff coefficients, time of concentration calculations, model input parameters, examples, and other related information.

The Rational Method may be used for drainage areas up to 90 acres with relatively uniform land use and soil characteristics. This method is commonly applied for the sizing of inlets and storm drain systems. The Rational Method provides a peak flow rate and time to peak but does not provide a hydrograph. For watersheds that include detention or where the timing of peak flows from different sub-watersheds (i.e., hydrologic routing) must be considered, the Rational Method is not appropriate.

CUHP must be used for watersheds with areas 90 acres or larger, or for smaller watersheds where detention and/or hydrologic routing must be evaluated. CUHP produces hydrographs,

and, when used with SWMM for routing, can be applied to size drainage infrastructure, including storm drain networks, open channels, and detention facilities. The CoA will consider other hydrologic methods on a case-by-case basis with appropriate justification, but strongly encourages the use of the standard hydrologic methods noted in Table 5-4. See Volume 1, Chapter 6: Runoff of the MHFD Manual for additional background and guidance on the applicability of various hydrologic calculation methods.

Table 5-4. Runoff Calculation Methods Acceptable for Use in the CoA

Runoff Calculation Method	Application Criteria	Requirements for Use in the CoA
Rational Method	Simple catchments less than 90 acres in size. Should not be used when routing of hydrographs is required.	Follow MHFD Manual procedures, including equation for first design point time of concentration for urban areas. Provide calculations for runoff coefficients, time of concentration, and direct and routed runoff with each submittal.
CUHP	Used when hydrographs are required for sizing infrastructure. Required for areas 90 acres or more in size. Use in combination with SWMM when routing of hydrographs is required. Can be used for smaller catchments with a smaller unit hydrograph time step.	Use 1-hour point rainfall depths from Table 5-1 for input to the CUHP computer model. Provide a copy of input/output listings for the workbook with each submittal.
SWMM	Used to route and combine hydrographs for sub-catchments developed using CUHP. Appropriate for use in more complex basins.	Use hydrographs developed from CUHP as inputs. Provide a copy of input/output listings for the model and an electronic copy of the modeling results with each submittal.
Published hydrologic information	May be used where MHFD or CoA have developed detailed hydrologic studies appropriate for use in the study area.	Use values in published reports unless compelling reason to modify published values.

The MHFD has developed spreadsheet workbooks to aid in hydrologic and hydraulic design calculations, including the UD-Rational, MHFD-Detention, and MHFD-SCM design workbooks (Mile High Flood District, latest edition). The UD-Rational workbook performs time of concentration and Rational Method calculations using the criteria included in this chapter. The MHFD-Detention workbook is used for the design of Full Spectrum Detention (FSD) facilities and runs CUHP routines to calculate runoff inflow hydrographs. The MHFD-SCM design workbook performs WQCV sizing calculations for a variety of stormwater control measures and includes a Runoff Reduction worksheet that calculates runoff volume reductions for unconnected impervious areas (UIAs) that drains to receiving pervious areas (RPAs). These workbooks are located on the MHFD's Software web page; the most recent version of a workbook should be used for hydrologic and hydraulic calculations.

5.3.1 Watershed Imperviousness

Watershed imperviousness is used in the Rational Method to determine runoff coefficients that relate rainfall intensity to peak runoff. Watershed imperviousness is also an input to CUHP for calculating runoff hydrographs.

The method for determining watershed imperviousness depends on what stage of the development process the project or watershed is at when the runoff analysis is to be performed. When conducting watershed master planning or development-scale master planning, the engineer should apply the land-use-based runoff imperviousness values from Table 5-5,[25] which incorporate the roadway imperviousness associated with the various land uses into the imperviousness values presented in the table. The imperviousness values for various land uses were developed based on published values in the engineering literature, as well as measurement of impervious areas based on recent development and redevelopment projects. The goal of the imperviousness values used at the master planning stage of a project is to provide conceptual sizing information for major infrastructure (e.g., channels, detention facilities, etc.) that is unlikely to be exceeded when the filing and lot scale plans are developed. **Therefore, engineers must carefully select imperviousness values that are not likely to be exceeded by future development.**

[25] Imperviousness criteria in Table 5-5 and Table 5-6 were developed through extensive research of other published imperviousness values and runoff coefficients, analysis of recent development characteristics, and technical analysis of rainfall and runoff, working in conjunction with the MHFD. Background information on this research and analysis is documented in a technical memorandum entitled *Compilation of Research and Recommendations for Updates to Imperviousness Criteria for Land Use and Land Cover Types in Runoff Chapter of Urban Storm Drainage Criteria Manual* (Earles, Olson, Hennon, & Howard, 2023).

Table 5-5. Land Use Based Imperviousness Values for Master Planning

Land Use/Density	Recommended Imperviousness* (Roads Included)
Residential	
Rural SFH (0 - 3 du/ac)	35%
Low & Medium-Density SFH (3 - 5 du/ac)	55%
Manufactured Housing (>= 10 du/ac)	65%
Medium-Density MFH/High Density SFH (5 - 20 du/ac)	65%
High-Density MFH (>20 du/ac)	70%
Commercial	
Low-Density Commercial	65%
Medium- to High-Density Commercial	80%
Urban Core Commercial	90%
Industrial/Institutional	
Schools	55%
Office/Institutional	65%
Industrial Areas	75%
Solar Farm, Gravel Cover*,Δ	60%
Solar Farm, Grass Cover*,Δ	45%
Parks and Open Space	
Open Space	5%
Community Parks	25%
Neighborhood Parks	15%
Golf Courses	30%
Cemeteries	25%

* Imperviousness values shown in this table are the minimum imperviousness values for a specific land use for Master Drainage Reports (MDRs) and Maser Drainage Plans. For Preliminary Drainage Reports (PDRs), imperviousness values must be calculated based on the surface type per Table 5-6. If the Engineer and/or Master Developer are aware of a proposed product type that would increase the imperviousness values beyond what is in this table, the MDR should take this into account.

Imperviousness values at the PDR stage that exceed those used in the MDR may require an amendment to the MDR (see Chapter 2). If the existing downstream infrastructure has already been constructed based on the lower imperviousness values from the MDR, an increase in imperviousness may not be permitted, or may require approved or in-process plans and/or existing infrastructure to be revised.

‡ Use these values at the master planning stage when the specific layout of panels is not known. Use the values in Table 5-6 at the site planning and design stages when the orientation of panels relative to contours is known.

Δ Assumes a 1:1 ratio of panels to aisles. See the technical memorandum entitled *Determination of Solar Panel Field Runoff Coefficients and Imperviousness Values* (Earles, Olson, & Howard, 2023) for additional information on procedures to reflect other impervious areas (such as roads and pads that may be part of a solar field) and layouts with wider inter-panel spacing.

At the detailed design and site planning phase for a project, more information is known about the proposed site layout, including the location of buildings, asphalt, sidewalks, pervious areas, and other types of ground cover. At the detailed design stage, the engineer should apply the surface-type-based runoff imperviousness values from Table 5-6 in conjunction with area measurements from Computer-Aided Design (CAD) or Geographic Information System (GIS)

programs, to calculate the imperviousness for a proposed project. The engineer should calculate the total imperviousness for a project as well as the imperviousness for individual basins/subbasins. When performing design calculations, the engineer should verify that the proposed imperviousness for the development does not exceed the master-planned imperviousness; if the master-planned imperviousness is exceeded, additional drainage and/or water quality improvements may be required.

Note that the imperviousness values included in Table 5-5 and Table 5-6 were selected to provide representative values for a given land use or surface type. Site specific conditions may vary from these representative values. The engineer is responsible for assuring that imperviousness values selected represent the actual imperviousness of the proposed development. Documentation of the selected imperviousness values should be provided in all Master Drainage Report (MDR), Preliminary Drainage Report (PDR), and Final Drainage Report (FDR) submittals (see Chapter 2).

Imperviousness for Solar Fields

Imperviousness values for solar fields were determined based on panel and aisle (i.e., inter-panel) spacing with a 1:1 ratio. Modeling was conducted using SWMM to account for differences in RPA based on the orientation of the rows of panels with respect to the orientation of the underlying topographic contours:

- For installations where the panels run perpendicular to the contours, the inter-panel area was treated as a RPA, while the rain shadow area beneath the panels was not.
- For installations where the panels run parallel to the contours, both the inter-panel area and rain shadow area were treated as RPAs.
- For installations where the panels run diagonal to the contours, the inter-panel area was treated as a RPA, while 50% of the rain shadow area was treated as a RPA.

SWMM was used to calculate volumetric runoff coefficients for each of these configurations. The percent-imperviousness criteria were then back-calculated based on the runoff coefficient and hydrologic soil group for the 100-year event using Volume 1, Chapter 6: Runoff of the MHFD Manual. As a check on results from SWMM, the University of Minnesota's *PV-SMaRT Solar Farm Runoff Calculator Version 3.0* (Mulla, 2023) was also applied with adjustments to the rainfall and Curve Number values to reflect a 2-hour storm duration.

See the technical memorandum entitled *Compilation of Research and Recommendations for Updates to Imperviousness Criteria for Land Use and Land Cover Types in Runoff Chapter of Urban Storm Drainage Criteria* Manual (Earles, Olson, Hennon, & Howard, 2023) for additional information on the procedure used to determine recommended values, an example of how to apply the solar field runoff coefficients in Table 5-6, and a discussion of how to adjust the imperviousness values in Table 5-6 to reflect other impervious areas (such as roads and pads that may be part of a solar field) and layouts with wider inter-panel spacing.

Table 5-6. Imperviousness Values for Urban Surfaces for Site and Small Watershed Analysis

Surface Type		Imperviousness
Paved Streets		95%
Concrete Drive and Walks		95%
Roofs		95%
Gravel	No Traffic Areas (pedestrian use)	40%
	Low Traffic Areas (maintenance paths and substations)	60%
	High Traffic Areas (roadways and parking)	80%
Landscaping (including water-wise vegetation, active turf, uncompacted gravel, planting beds, residential artificial turf, etc.)		20%
Artificial Turf (non-residential)	Landscape applications (with subgrade drainage layer)	25 - 45%
	Sport fields withs underdrain pipe system	65%
Open Water Areas, including footprint of WQCV		100%
Solar Panels Gravel Cover, Rows Parallel to Contours*		50%
Solar Panels, Gravel Cover, Rows Diagonal to Contours*		60%
Solar Panels, Gravel Cover, Rows Perpendicular to Contours*		75%
Solar Panels, Grass Cover, Rows Parallel to Contours*		10%
Solar Panels, Grass Cover, Rows Diagonal to Contours*		20%
Solar Panels, Grass Cover, Rows Perpendicular to Contours*		45%
Historic Flow Analysis, Undisturbed Native Grasses, Agricultural		5%
Newly Graded Areas		65%

* Assumes a 1:1 ratio of panels to aisles. See the technical memorandum entitled *Determination of Solar Panel Field Runoff Coefficients and Imperviousness Values* (Earles, Olson, & Howard, 2023) for additional information on procedures to reflect other impervious areas (such as roads and pads that may be part of a solar field) and layouts with wider inter-panel spacing.

5.3.2 Runoff Coefficients for Rational Method

Rational Method runoff coefficients shall be determined using the methodology described in Volume 1, Chapter 6: Runoff of the MHFD Manual. The MHFD methodology uses the imperviousness of a drainage area in conjunction with the hydrologic soil group (HSG) to calculate the runoff coefficient. The imperviousness of the land use/surface type draining to the point of interest should be derived from Table 5-5 or Table 5-6 above (depending on the stage of the design). The HSG may be determined using the Natural Resources Conservation Service's (NRCS's) Web Soil Survey (Natural Resources Conservation Service). These data may be used alongside the tables, charts, and equations in Volume 1, Chapter 6: Runoff of the MHFD Manual to determine runoff coefficients for the Rational Method.

Table 5-7 provides equations for calculating runoff coefficients based on the most up to date information from the MHFD Manual as of the date of publication of this Manual. It is the responsibility of the applicant to confirm that the most current runoff coefficient equations from MHFD are used.

Table 5-7. Runoff Coefficient Equations Based on NRCS Soil Group and Storm Return Period[26]

NRCS Soil Group	Storm Return Period						
	2-year	5-year	10-year	25-year	50-year	100-year	500-year
A	$C_A = 0.84i^{1.302}$	$C_A = 0.86i^{1.276}$	$C_A = 0.87i^{1.232}$	$C_A = 0.88i^{1.124}$	$C_A = 0.85i + 0.025$	$C_A = 0.78i + 0.110$	$C_A = 0.65i + 0.254$
B	$C_B = 0.84i^{1.169}$	$C_B = 0.86i^{1.088}$	$C_B = 0.81i + 0.057$	$C_B = 0.63i + 0.249$	$C_B = 0.56i + 0.328$	$C_B = 0.47i + 0.426$	$C_B = 0.37i + 0.536$
C/D	$C_{C/D} = 0.83i^{1.122}$	$C_{C/D} = 0.82i + 0.035$	$C_{C/D} = 0.74i + 0.132$	$C_{C/D} = 0.56i + 0.319$	$C_{C/D} = 0.49i + 0.393$	$C_{C/D} = 0.41i + 0.484$	$C_{C/D} = 0.32i + 0.588$

Where:

i = % imperviousness (expressed as a decimal)

C_A = Runoff coefficient for Natural Resources Conservation Service (NRCS) HSG A soils

C_B = Ruoff coefficient for NRCS HSG B soils

$C_{C/D}$ = Runoff coefficient for NRCS HSG C and D soils.

[26] Table 5-7 is a reproduction of Table 6-4 in Volume 1, Chapter 6: Runoff of the MHFD Manual as of the date of publication of this Manual (Mile High Flood District, latest edition). Note that the most up-to-date equations and methodology per the MHFD Manual shall be used to calculate runoff coefficients.

5.3.3 Runoff Modeling Inputs for CUHP

CUHP does not use Rational Method runoff coefficients. Instead, CUHP calculates runoff based on watershed imperviousness and Horton infiltration parameters. The imperviousness of the land use/surface type draining to the point of interest should be derived from Table 5-5 or Table 5-6 above (depending on the stage of the design). To determine the Horton infiltration parameters, including the initial infiltration rate, final infiltration rate, and decay coefficient, see the Volume 1, Chapter 6: Runoff of the MHFD Manual to look up these values based on the HSG; CUHP inputs for depression storage losses are also included here.

5.4 OFF-SITE STORM FLOW ANALYSIS

Off-site storm flow analysis must consider the fully developed future conditions in the contributing watershed. Off-site analysis must address the minor and major storm events as well as emergency overflows from off-site areas. When an off-site area is developed, determine runoff parameters using the surface-type-based imperviousness per Table 5-6 above and the runoff coefficients per Section 5.3.2 above unless values from other approved studies are available. Where drainage reports exist for adjacent sites, the reports must be reviewed and coordinated with the current analysis for the proposed development. The applicant is responsible for obtaining and reviewing drainage reports and plans for adjacent sites.

For undeveloped off-site areas, determine the existing or most probable future zoning and select land-use-based runoff coefficients per Table 5-5 above assuming fully developed conditions. If an area has not yet been planned, the applicant must consult with AW during the pre-application meeting to define appropriate assumptions for future land use.

Flow from off-site areas may be assumed to remain at historic/existing levels in the future only if regional or subregional detention with public or quasi-public[27] maintenance is planned to manage flows from the off-site area. Otherwise, future conditions land uses must be considered in calculating offsite runoff.

When off-site flow areas extend beyond the CoA jurisdictional boundary, consult with the CoA and MHFD to determine off-site flow assumptions.

5.5 REFERENCES

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[27] E.g., Metropolitan district.

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CHAPTER 6.0 STREETS, INLETS, AND STORM DRAINS

6.1 INTRODUCTION

This chapter provides technical criteria for streets, inlets, and storm drains in the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD) *Urban Storm Drainage Criteria Manual* (MHFD Manual), the CoA's *Roadway Design and Construction Specifications* (RDCS), and Aurora Water's (AW) *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications* are hereby incorporated by reference. Where conflicts in criteria exist between multiple documents, the most restrictive criteria must be applied.

6.1.1 Minor and Major Storm Events

In an urban area the storm drain and street system provides for conveyance of the minor and major storm events. The minor storm event, ranging from a 2- to a 5-year event depending on land use, is managed by the system of shallow surface conveyances, inlets, and storm drains to minimize traffic disruptions and prevent damages from these relatively frequent storm events. For the 100-year major storm event, the combination of the minor drainage system and the streets are designed to convey runoff to major drainageways without damage to property or loss of life. Inlets and storm drain systems shall be designed for the minor storm event at a minimum.

6.1.2 Design Frequencies

Designers must evaluate the effects of minor and major storms on the street and storm drainage system and should consider nuisance runoff from irrigation, snowmelt, and other sources. Table 6-1 lists the minor and major storm frequencies for different land uses and types of facilities. For Transit Oriented Developments (TODs) and Aurora City Center, the storm drain system must be designed for the major 100-year event (as opposed to designing for a minor storm). See the Unified Development Ordinance (UDO) and Aurora Zoning map for land use classifications.

Table 6-1. Design Storm Frequencies

Land Use or Type of Facility	Minor Storm	Major Storm
Residential, Business, and Industrial	2-year*	100-year
City Center Zone	5-year*	100-year
TODs and Aurora City Center	N/A	100-year

* Note that storm drain flows originating from a location with a larger design storm frequency must continue with that frequency to a logical point of outfall.

6.2 STREETS

6.2.1 Street Flow Capacities

The primary purpose of streets is for traffic. However, streets are also an integral part of the storm drainage system and are used to convey storm runoff within reasonable limits. The allowable street flow capacity must be calculated using the procedure described in Volume 1, Chapter 7: Streets, Inlets, and Storm Drains of the MHFD Manual. The allowable street flow

capacity shall be used in conjunction with the allowable use criteria summarized in Table 6-2 to design the storm drains and inlets. Individual hydraulic calculations should be performed using the latest version of MHFD-Inlet for all roadways. Note that variations in street cross slopes, alternate gutter dimensions, assumptions about capacity behind the curb, and other factors will yield different results. The most conservative values should be used to make calculations (e.g., if cross slope varies across an inlet, the cross slope which produces the most conservative results shall be used).

Table 6-2. Allowable Use of Roadways for Minor and Major Storm Runoff

Roadway Classification	Allowable Use of Roadways for Minor Storm Runoff	Allowable Use of Roadways for Major Storm Runoff
Local	No curb overtopping.* Flow may spread to crown of street but may not crest the crown.	• The depth of water over the gutter flow line should not exceed one foot. • Residential dwellings and public, commercial, and industrial buildings should be no less than one foot above the 100-year water surface elevation (WSEL) or two times the depth of flow, whichever is lesser, at the lowest point of entry (LPE) of the building. • Where TODs and Aurora City Center have on-street parking, the maximum depth is 6 inches at the flowline of the parking curb or the curb extension. • In no cases can garages be inundated in the 100-year event.
Collector	No curb overtopping. Flow spread must leave at least one lane (10 feet) free of water. If a median or divider is present, flow spread must leave at least one lane free of water in each direction.	
Arterial	No curb overtopping. Flow spread must leave at least one lane (10 feet) free of water in each direction and should not flood more than two lanes in each direction.	The same major storm criteria for Local and Collector roadways also applies to Arterial Roadways. In addition: • The depth of water should not exceed the street crown to allow operation of emergency vehicles.
Other	N/A	For parking lots, the maximum depth allowed is 1.5 feet for a driving lane and one foot for a parking space.

*Water may spread to the back of walk where mountable curb and attached walk are used. For mountable curb with detached walk, water may spread to the crown of the street (no crown overtopping) or six-inch depth at the curb flowline, whichever is less.

When streets are used for emergency overflow paths, a minimum of one foot of freeboard must be provided between the emergency overflow WSEL and the lowest point of entry[28] (LPE) of each structure along the emergency overflow path.

Cross pans may be used in some limited applications (see Section 6.3.3). Where cross pans are allowed, the allowable use for cross-street flow in cross pans is presented in Table 6-3.

Table 6-3. Allowable Use for Cross-street Flow in Cross Pans

Roadway Classification	Allowable Use of Cross Pans for Minor Storm Runoff	Allowable Use of Cross Pans for Major Storm Runoff
Local*	6 inches of depth in cross pan	12 inches of depth in cross pan or gutter flow line
Collector	Cross pans are not allowed to convey flows across Collector or Arterial roadways	
Arterial		

* Cross pans are not allowed where a storm drain system is available. Cross pans are only allowed at intersections controlled by stop signs. See Section 6.3.3 below.

6.2.2 Sidewalk Chases

Within multi-family, commercial, or industrial developments, stormwater from concentrated points of discharge from a storm event shall not be allowed to flow over internal, private sidewalks and/or perimeter, public sidewalks, but shall instead drain to the roadway by the use of chase sections. See the RDCS for criteria on sidewalk chases.

6.3 INLETS

6.3.1 Types of Inlets

There are three common types of inlets: curb opening, grated, and combination inlets. Inlets are further classified as being on-grade (i.e., continuous grade) or in a sump condition. The term on-grade refers to an inlet located such that the grade of the street has a continuous slope past the inlet; resultantly, significant ponding does not occur at continuous grade inlets. A sump condition exists whenever water ponds because the inlet is located at a low point. A sump condition can occur at a change in grade of the street from negative to positive or at an intersection due to the crown slope of a cross street.

[28] The lowest point of entry (LPE) is the lowest elevation at which surface water may enter a structure, such as the elevation of the bottom of a door frame, or the elevation of the top of a basement window well. The LPE is distinct from the lowest floor elevation (LFE), though in some cases the elevations of each may be identical. See Chapter 3 for definitions of the LPE and LFE.

In the CoA, the only accepted storm inlet in the public right-of-way (ROW) or for public ownership is the Type R modified curb-opening inlet (see RDCS for corresponding standard detail). Grated and combination inlets may be used in private areas; a variance is required for grated and/or combination inlets to be used within the public ROW. Grated inlets located in areas where bicycle or pedestrian traffic is expected must be bicycle/pedestrian-safe grates. Other types of inlets may be allowed on private developments if the engineer can demonstrate suitable sizing, durability, and maintainability for the flows that the inlets must handle.

On-site drainage must be designed to accommodate the 100-year event, and on-site storm drain systems must consider backwater effects from the public storm drain system to which they discharge. For private systems, the hydraulic grade line (HGL) for the 100-year event must be calculated and designed per the criteria in this chapter. The CoA may also require computation of the energy grade line (EGL) when the velocity in the storm drain exceeds 8 feet per second (fps) and the HGL is within 2 feet of the ground surface or inlet invert elevation, or when surface flow makes an abrupt turn (e.g., as at a T intersection). Calculations of the HGL (and EGL, if necessary) meeting the criteria of this chapter shall be provided as denoted in Chapter 2.

6.3.2 Inlet Design

All inlets must be designed using the MHFD-Inlet workbook.

The minimum length for a single curb-opening inlet is 5 feet, and the maximum length is 15 feet. If the required length exceeds 15 feet, multiple inlets must be used, or a structural design of the inlet, stamped and signed by a Professional Engineer, is required. The structural design calculations and details must be included with the first submittal of the civil plans (CPs) for the project. The maximum allowable length of a multiple inlet configuration is 30 feet.

Inlets greater than 10 feet in depth (from invert of inlet to bottom of manhole) also require a structural design of the inlet, stamped and signed by a Professional Engineer. The structural design calculations and details must be included with the first submittal of the CPs for the project.

To compensate for effects which decrease the capacity of inlets (such as debris plugging, pavement overlaying, and variations in design assumptions), the theoretical capacity calculated for inlets shall be multiplied by a clogging reduction factor to determine the allowable capacity of the inlet. The clogging factor varies based on the length (L) of the opening for curb opening inlets, or the number of openings for grated inlets. The clogging reduction factor for one or more curb opening or grated[29] inlets is shown in Table 6-4. For combination inlets[29], the allowable inlet capacity shall use the default parameters for inlet reduction factors in the MHFD-Inlet workbook.

[29] Grated and/or combination inlets may only be used in private areas unless a variance is obtained; see Section 6.3.1.

Table 6-4. Clogging Reduction Factors for Curb Opening and Grated Inlets

L/5 (Curb Opening Inlets) / Number of Unit Openings (Grated Inlets)	Curb Opening Clogging Reduction Factor*	Grated Clogging Reduction Factor*
1	10.0%	50.0%
2	6.3%	37.5%
3	4.4%	29.2%
4	3.3%	23.5%
5	2.7%	19.4%
6	2.2%	16.4%

* Clogging reduction factors per Equation 7-39 and Table 7-9 of Volume 1, Chapter 7: Streets, Inlets, and Storm Drains of the MHFD Manual, assuming e = 0.25 (curb opening inlets) and e = 0.5 (grate opening inlets).

The size of outlet pipes must be based upon the design flow rate at the inlet but must not be less than 18 inches in diameter.

An emergency overflow path that is free of structures or obstructions must be provided for all sump inlets to convey the emergency overflow discharge to a downstream public ROW or drainageway with adequate capacity for the discharge. The sump inlet emergency overflow discharge is the 100-year peak flow to the inlet for fully developed conditions.[30] This is the flow that must be conveyed by the emergency overflow path assuming the inlet is plugged. A drainage easement must be provided for the emergency overflow path (see Chapter 3). The property owner is responsible for maintenance of the emergency overflow path within the drainage easement and must keep this area free of obstructions. The LPE to residential dwellings and public, commercial, and/or industrial buildings shall be no less than one foot above the emergency overflow WSEL through the emergency overflow path. Sump inlets with emergency overflow WSELs within 1.5 feet of a building's lowest floor elevations (LFE) must provide freeboard calculations demonstrating at least one foot of freeboard between the emergency overflow WSEL and the building LPE. The emergency overflow WSEL should be calculated using the broad-crested weir equation at the overflow location. Note that the emergency overflow depth for sump inlets must not exceed the maximum allowable flow depth for the street classification denoted in Table 6-2. The emergency overflow calculations should be included in the first submittal of both the Preliminary Drainage Report (PDR) and CP submittal for the project, as described in Chapter 2. Cross sections of each emergency overflow location should be included in the Preliminary Drainage Plans (PDPs) and should note the emergency overflow discharge, emergency overflow WSEL, LPE of nearby buildings, and freeboard above the emergency overflow WSEL.

For sump inlets within a courtyard, the required freeboard may be scaled based on the magnitude of the discharge flowing to the inlet, as noted in Table 6-5.

[30] In situations where the existing conditions 100-year peak flow to a sump inlet exceeds that of the fully developed conditions, the existing conditions 100-year peak flow to the inlet shall be used as the emergency overflow discharge instead.

Table 6-5. Required Freeboard for Sump Inlets in Courtyards

Flow to Inlet	Required Freeboard
Less than 0.5 cfs	3 inches
Between 0.5 cfs and 1 cfs	6 inches
1 cfs or greater	1 foot

Computations for inlet design must be submitted using the MHFD-Inlet workbook. Detailed hydraulic calculations and supporting information for inputs for inlets, manholes, and other appurtenances must be included in the overall drainage plan submitted for approval.

6.3.3 Inlet Locations

Inlets are normally located at low points or points on a continuous grade where the minor or major storm runoff exceeds the allowable spread or depth criteria denoted in Table 6-2 above. The following criteria apply for locating inlets:

1. To reduce the use of cross pans to the extent feasible, inlets are required upstream of street intersections and drive entrances. On public streets, inlets are required when there is an existing or proposed public storm drain system available within 300 feet and accessible from public ROW; on private streets, inlets are required when there is an existing or proposed public or private storm drain system available within 300 feet.

2. A cross pan may be necessary when the topography makes it infeasible for an inlet alone to capture flows immediately upstream of an intersection (e.g., due to street warping). Cross pans are only allowed at intersections controlled by stop signs on local streets. See Table 6-3 above for allowable use criteria for flow in cross pans. When used, cross pans shall be constructed in accordance with the RDCS.

3. When planning locations of inlets, consider solar exposure and shading effects and locate inlets in areas to help minimize icing problems. For example, additional inlets may be required on the south side of the street to capture any snowmelt before it has a chance to freeze.

4. Inlets are required on superelevated arterial streets where the cross slope reaches 0.5% during the superelevation transitions, and where median breaks occur for intersections within superelevated streets. Inlets should be located on the upper side of the median break to capture at least 80% of minor event runoff to minimize cross flow.

5. Flanking inlets are required when an inlet is in a sump condition without an overflow (e.g., underpasses), and/or when an inlet is in a sump condition and requires more than a 15-foot inlet. Flanking inlets shall be designed to convey 100% of the emergency overflow, accounting for potential clogging (see Section 6.3.2 above).

6. Inlets are not allowed in the curb return. Inlets shall be located 5 feet from the point of curb returns' tangent points.[31] Inlets are not allowed within 5 feet of commercial and residential driveways.

7. Inlets shall be located within the parallel and diagonal parking areas of TODs and/or Aurora City Center. The top and back of curb elevations, along with the street centerline station at the centerline of the inlet and station offset, shall be shown on the plans.

8. At T-intersections, including alley intersections, when flows are transported down the leg of the T to the intersection and lots are located opposite along the top of the T with top-of-foundation elevations lower than the top-of-curb elevation or minimum elevation at the top of the intersection at the top of the T, inlets and a storm drain system are required to collect the 100-year flows to prevent the 100-year runoff from bypassing the intersection and flowing into the lots below. The use of additional inlets at the top of the T may also be required.

   Lots with top-of-foundation elevations higher than the top-of-curb intersection elevation on the leg of the T may also require inlets, unless it can be shown that the 100-year street flow depths at the top of the T do not exceed the foundation elevations along the left of the T (in the event that the 100-year flows bypass the intersection). Additional analysis, including calculation of the EGL, may be required to determine appropriate elevations for structures adjacent to the intersection.

9. At roundabouts, inlets must be located to collect runoff upgradient of the roundabout. No bypass flows past the inlet are allowed for the 2-year event.

For sump inlets in series, the 100-year WSEL at each sump must be calculated. An emergency overflow path from each sump inlet to the terminal inlet must be provided, and an emergency overflow path from the terminal inlet to the receiving public ROW or drainageway is required. Emergency overflow for each sump inlet in series must be designed for the fully developed 100-year flow of the inlet receiving the greatest runoff (i.e., the fully developed 100-year flow to the inlet of interest shall be compared to that of each upstream sump inlet in series, and the largest fully developed 100-year flow shall be the emergency overflow discharge for the inlet of interest). In other words, for each inlet in series, the design emergency overflow is the greater of the emergency overflow from the sump inlet itself or the emergency overflow from an upstream sump inlet. An example of this scenario is shown in Figure 6-1: Inlet 2 has the greatest emergency overflow, and thus that flow is used as the emergency overflow for both Inlet 2 and Inlet 3. Inlet 1 is the most upstream inlet, so the emergency overflow there is based solely on the area draining to Inlet 1.

[31] Within TODs and/or Aurora City Center, inlets may be allowed within 0-3 feet from the point of curb returns' tangent points.

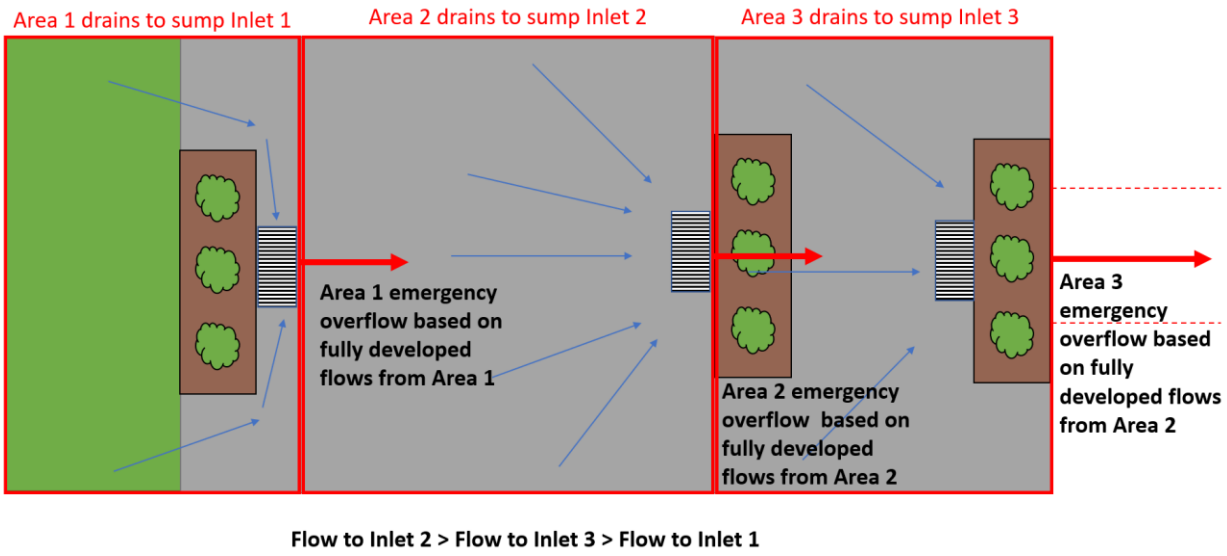

Figure 6-1. Example of Calculating the Emergency Overflows for Sump Inlets in Series

If a design requires the use of an inlet in sump condition with no emergency overflow path (i.e., when there is no feasible surface overflow path), the inlet must be designed for twice the 100-year flow while accounting for clogging unless a variance is obtained. If an inlet or storm drain system is designed to receive the emergency overflow from any source (e.g., sump inlet, detention facility, culvert, etc.), the inlet/storm drain system must be sized for that emergency overflow.

Note that the maximum allowable ponding depth for parking lots in an emergency overflow event is 2 feet unless a variance is obtained. Signage warning of parking lot flooding must be provided in areas where ponding may occur due to emergency overflows.

Other requirements for storm inlets can be found in the RDCS.

6.4 STORM DRAINS

Storm drains must be designed in accordance with Volume 1, Chapter 7: Streets, Inlets, and Storm Drains of the MHFD Manual and the AW *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications*. Storm drains must be designed to convey the minor storm peak discharge without surcharging the drain.

6.4.1 Materials

Pipe material must be in conformance with the AW *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications*.

6.4.2 Minimum Sizes

The minimum diameter for storm drain laterals and mains is 18 inches. The CoA will consider smaller laterals that are privately owned and maintained on a case-by-case basis with a variance.

6.4.3 Manhole Spacing and Size

Manhole spacing and size requirements are provided in Table 6-6. See the AW *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications* for additional information on manhole spacing and size.

Table 6-6. Manhole Spacing and Size

Diameter or Vertical Rise	Maximum Manhole Spacing (feet)
18 – 36 inches	400
42 – 60 inches	500
60 inches and larger	750
Diameter	**Minimum Manhole Barrel Size (feet)**
27 inches or less	5
30 – 48 inches	6

6.4.4 Alignment

Manholes are required wherever there is a change in storm drain size or a significant change in direction, elevation, or grade of the storm drain, and at lateral storm drain junctions. Horizontal and vertical alignment deflection shall be accomplished at manholes only. Curvilinear storm drain alignments are not allowed. The CoA may waive requirements for manholes for short laterals with diameters of less than half of the storm drain trunkline diameter on a case-by-case basis with a variance. See the AW *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications* for additional information and criteria.

The horizontal alignment between manholes must be straight. Storm drain lines must be placed within the pavement of public streets unless prior approval is granted for placing storm drains within the ROW but outside of the pavement area of the street. When there is a change in the size of the storm drain, the crowns of the two pipes must match vertically. Trees are not allowed within 10 feet of a storm drain line.

Every effort must be made to avoid placing private storm drains under a building; no private storm drain system may be placed under a building unless a variance is obtained. In no case shall private storm drain pipes be located under living areas. Private storm drains may be permitted under parking garages or internal building hallways outside of private living areas. The PDP and Final Drainage Plan (FDP) within the CPs shall provide the following note in such cases:

All storm sewer conveyance piping beneath building footprint to require carrier pipe to have restrained joint piping within casing so it can be removed if necessary.

Additional requirements for alignment, including minimum clearances between storm drains and water or sanitary sewers, are found within the AW *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications*.

6.4.5 Hydraulic Design

Hydraulic design criteria for the minor storm event are intended to provide conveyance of flows without surcharging the storm drain. See Chapter 12 for a discussion of appropriate computer programs for making such calculations. Storm drains must be designed to convey the peak discharge of the minor storm event while flowing at a maximum of 80% of the full pipe capacity. In pipes designed to convey the minor storm runoff, the HGL must be kept at least one foot below manhole lids, inlet grates, and inlet inverts; additionally, the HGL must be kept at least one foot below the ground elevation where no inlets are present.

There are conditions when the storm drain system will be sized to convey flows greater than the minor storm runoff, including locations where:

- The street capacity for the major storm is exceeded, especially where the grade slopes down behind the curb and the major storm capacity is limited to the height of the curb; see Table 6-2 above.
- Regional storm drains are designed for the major storm.
- The storm drains must convey undetained flows to a regional detention basin.

If a storm drain is to be designed to carry major storm flows, the inlets to the storm drain must be designed accordingly. In pipes designed to convey up to the major storm runoff, the HGL is allowed to rise above the top of the storm drain but must be kept at least one foot below manhole lids, inlet grates, and inlet inverts; additionally, the HGL must be kept at least one foot below the ground elevation where no inlets are present. When a storm drain system (including those for small landscape areas) is designed to carry the 100-year storm flow, the engineer must provide hydraulic calculations and profile conforming to CoA criteria.

For all storm drain designs, the HGL (and EGL, if necessary) must be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses must be calculated accounting for friction, expansion, contraction, bend, and junction losses following the methods in the Storm Drain Systems section Volume 1, Chapter 7: Streets, Inlets, and Storm Drains of the MHFD Manual. The hydraulic analysis of the storm drain system must also ensure the appropriate tailwater condition is applied at the downstream end of the system, whether the system outfalls to a drainageway or connects to an existing storm sewer system. See Chapter 12 of this Manual for a discussion of appropriate computer programs.

The maximum velocity for storm drains is 20 feet/second. The minimum velocity is 3 feet/second at half-full flow conditions in order for the pipe to be self-cleaning.

6.5 REFERENCES

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CHAPTER 7.0 OPEN CHANNELS

7.1 INTRODUCTION

This chapter summarizes the design methodology for open channels in the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 1, Chapter 8: Open Channels are hereby incorporated by reference. Except as modified herein, the design of all open channels must be in accordance with the MHFD Manual. The design of open channels for major streams must be coordinated with the Parks, Recreation, and Open Space (PROS) Department relative to trails and open space uses and the Planning Department relative to site plan landscape requirements. Project teams should include hydraulic engineers, geomorphologists, and potentially other professionals such as landscape architects, ecologists and others.

Open channels provide the critical function of safely conveying floodwaters through urban watersheds. With adequate planning and thoughtful design, open channels require less long-term maintenance and can also sustain valuable ecological diversity, support a variety of recreational uses, and create a functional amenity for the community to enjoy. The CoA therefore prefers the use of open channels for stormwater conveyance.

7.2 CLASSIFICATION OF STREAMS

Open channels vary significantly in size and contributing drainage area from small, lot-level swales to major streams. In this chapter, open channels are generally classified as major streams, minor streams, or swales/ditches depending on the contributing drainage area:

- Open channels draining more than 130 acres are considered major streams.
- Open channels draining areas of 130 acres or less with a 100-year flow greater than 40 cfs are considered minor streams.
- Small open channels with a 100-year flow of 40 cfs or less are considered swales or ditches. Swales and ditches typically have shallow flow depths of no more than two feet in the 100-year event.

Table 7-1 provides a comparison of major streams, minor streams, and swales/ditches. In general, when 100-year flows exceed 250 cfs or the drainage tributary area exceeds 130 acres, open channel flow must be provided.

Table 7-1. Stream Classifications

	Major Stream	Minor Stream	Swale or Ditch
Definition	Contributing drainage area greater than 130 acres.	Contributing drainage area 130 acres or less and 100-year flow greater than 40 cfs.	100-year flow of 40 cfs or less.
Easement requirement	Drainage easement required.	Drainage easement required.	Drainage easement only required if conveying drainage between two or more residential lots, as determined by Public Works.
Maintenance responsibility	Public.	Public (in ROW) and private (outside of ROW).	Private.
Freeboard requirement	1 foot from 100-year WSEL to top of bank and 1 foot from top of bank to LFE.*	6 inches from 100-year WSEL to top of bank and 1 foot from top of bank to LFE.	6 inches from 100-year WSEL to LPE.‡ No freeboard requirement to swale top-of-bank.
Other notes			Small lot level swales between homes are not reviewed by Aurora Water.

* Lowest Floor Elevation. See Chapter 3 for definition.

‡ Lowest Point of Entry. See Chapter 3 for definition.

7.2.1 Major Streams

Major streams are those with contributing drainage areas greater than 130 acres. Streams that have contributing drainage areas of greater than 130 acres often have mapped floodplains, either Federal Emergency Management Agency (FEMA) mapping shown on Flood Insurance Rate Maps (FIRMs) and/or Flood Hazard Area Delineations (FHADs) prepared by MHFD. Major streams serve a regional role in flood management and as such, MHFD may be consulted as a technical resource.

Historically, major streams in the CoA range from natural or naturalized open channels to engineered channels with concrete or riprap linings. While heavily engineered channel linings have been used in the past to convey runoff at high velocities, current design practice is focused on more natural, vegetation-based channel linings that provide many additional benefits including lower maintenance costs, allowing for infiltration (thus providing groundwater recharge), and providing aesthetic and recreational benefits to adjacent land uses. Such approaches may require preserving a wider floodplain compared to historical engineered channelization projects. However, this approach also results in lower lifecycle operation and maintenance costs and lower repair/replacement costs than highly engineered conveyances.

Finally, preserving stream management corridors (SMCs) provides resilience for potential future storm variability, increased redevelopment density, and increased impervious areas.

MHFD has developed the high-functioning, lower-maintenance stream (HFLMS) design approach, which helps to guide channel design with a focus on emulating natural systems. The HFLMS approach emphasizes understanding how a stream naturally functions, how development will affect the natural stream hydrology and hydraulics, and how engineering design features that mimic natural processes can create a dynamically stable stream corridor that will not require excessive maintenance or large future costs for repair/replacement later in the lifecycle. Designing a HFLMS channel requires a multidisciplinary approach to integrate hydrology, hydraulics, geomorphology, and vegetation. Unless otherwise approved by a variance, major streams must be designed as HFLMS.

CoA requires naturalized channel design following the HFLMS philosophy for any restoration or improvement projects on major streams in the CoA. Minor repair of existing engineered major streams (e.g., concrete or riprap lined) may use the same approach as the original construction if approved by CoA. All major streams in the CoA must be designed in accordance with the criteria in the MHFD Manual.

MHFD works with municipalities to plan, design, and improve many major streams within their jurisdiction, therefore any proposed improvements to major streams should be coordinated with CoA and MHFD early in the project planning phase especially during the market analysis and site plan phases. Work on major streams typically requires floodplain and wetland permitting, so coordination with permitting agencies is important early in the process to define requirements.

7.2.2 Minor Streams

Minor streams are those with contributing drainage areas of 130 acres or less and 100-year flows greater than 40 cfs. Flow depths in minor streams typically exceed a foot, and they are usually tributaries to major streams.

While open channels of this magnitude do not typically have mapped regulatory floodplains, they still may present flood hazards and serve an important role in managing floodwaters. Therefore, it is important to design adequate conveyance and provide freeboard for these features to protect adjacent buildings and infrastructure from flooding. Open channels, as opposed to closed conduits, provide opportunities to slow down runoff through vegetative resistance and promote infiltration through permeable linings. However, in some instances a closed conduit can be preferable due to site-specific constraints such as maintenance access or surface impediments (e.g., fencing). Both open channels and closed conduits should be considered for minor streams based on the project context. As with major streams, the design of open channels for minor streams should also be consistent with MHFD criteria; the MHFD may be consulted as a technical resource during the design and review process. Unless otherwise approved by a variance, minor streams must be designed as HFLMS. Similar to major streams, early coordination with the CoA and MHFD, especially during the market analysis and site planning phase, is recommended.

7.2.3 Swales and Roadside Ditches

Swales are used to convey on-site runoff to a design discharge point, typically a water quality/storage facility or a major or minor stream. Swales can also be used to route off-site runoff around a site. Swales are defined as small channels with a 100-year flow of 40 cfs or

less. Roadside ditches are defined with the same flow threshold as swales but are primarily intended to convey roadway runoff to a minor or major stream and are contained within the right-of-way (ROW). Roadside ditches are similar to swales but with sizing driven by the allowable spread in the adjacent street. Ditches often have steeper side slopes and narrower (or zero) bottom widths to provide conveyance within limited space constraints, while swales usually have milder side slopes and wider bottom widths to encourage infiltration and slow down runoff.

7.3 NATURALIZED STREAM CORRIDOR DESIGNS FOR MAJOR STREAMS

As mentioned previously, major streams should be designed to preserve and restore stream corridors through the use of naturally functioning (naturalized) features. This approach includes careful consideration of stream planform (planform is the shape and alignment of the stream as viewed from above), cross-sectional dimension, longitudinal slope, and bed material to minimize maintenance requirements. Early planning is required to preserve adequate space for naturalized stream corridors. In some cases, especially when existing conditions include incised or degraded channels, floodplain space beyond that of the existing conditions may be beneficial for providing the desired functions (for example if an incised stream is being reconnected to the floodplain or a straight channel being restored to a channel with greater sinuosity). The HFLMS approach has the potential to provide significant benefits and reduced maintenance and lifecycle costs, but adequate space is needed to achieve these benefits.

MHFD SMCs

A stream's overall corridor can be projected based on its past location and physical characteristics of the landscape, such as geology and topography. MHFD has created SMCs that comprise broad areas where dynamic stream processes are likely to occur. They are distinct from FEMA regulatory floodplains in encompassing areas designated as low risk or even outside defined floodplains, yet still prone to flooding and erosion (Mile High Flood District, 2021).

A map with SMCs identified by MHFD is available here.

At the master planning stage, development should not be planned in an area identified by MHFD as a SMC (see call-out box) unless additional hydrologic, hydraulic, geomorphic, and ecological analyses are performed (see Section 7.3.5 below). At the Preliminary Drainage Report (PDR) stage, the area defined as a SMC may be refined if designers provide additional analysis and justification as described in Section 7.3.5 below. See Figure 7-1 for an example of SMCs mapped by MHFD in the CoA. Other hydrologic and hydraulic studies, such as MHFD Major Drainageway Plans (MDPs) or Fluvial Hazard Zone (FHZ) delineations, should be consulted early in the planning and design process.

Projects must also include coordination with PROS on topics such as the platting of stream corridors and establishment of recreational trails. Designers are encouraged to begin this coordination early in the design process.

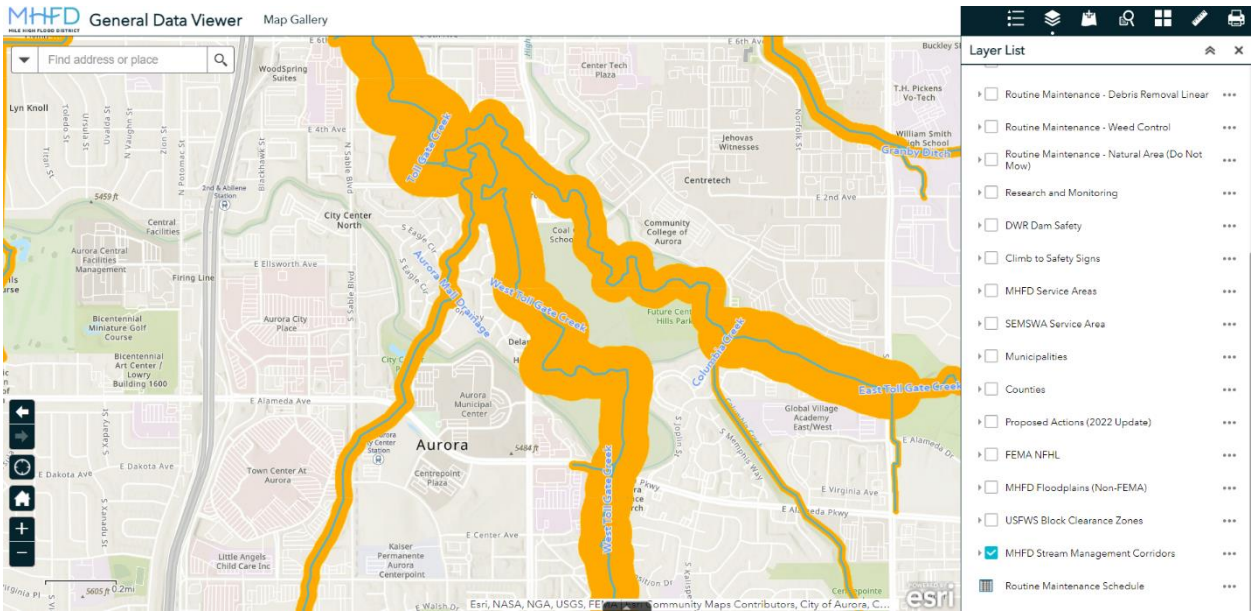

Figure 7-1. Example of MHFD Stream Corridor Mapping for Tollgate Creek and Tributaries in Aurora

7.3.1 Hydrology

Engineers must account for a range of anticipated flow rates when planning and designing naturalized stream corridors. To function properly, stream design must account for baseflows, bankfull flows, and larger flood flows. The design of a naturalized stream cross section should provide for a stable channel for each flow stage based on tractive force analysis, including a bankfull channel and floodplain terrace at a minimum (see Figure 7-2 for an example illustration of a channel cross section with bankfull discharge). Channel design must consider hydrology for both existing and future watershed conditions.

As a matter of policy, effects of on-site detention facilities are not accounted for when developing peak discharge hydrology for major streams. This is due to the unpredictable effects of uncoordinated releases on peak flows in streams. Effects of subregional and regional facilities may be accounted for when there are adequate assurances for long term operation and maintenance (public entity with dedicated funding for operation and maintenance), with concurrence from MHFD as it relates to regulatory flows for major streams. The design of minor streams, swales, and ditches may account for on-site detention; however, emergency overflow conditions must be evaluated, as discussed in Chapter 10.

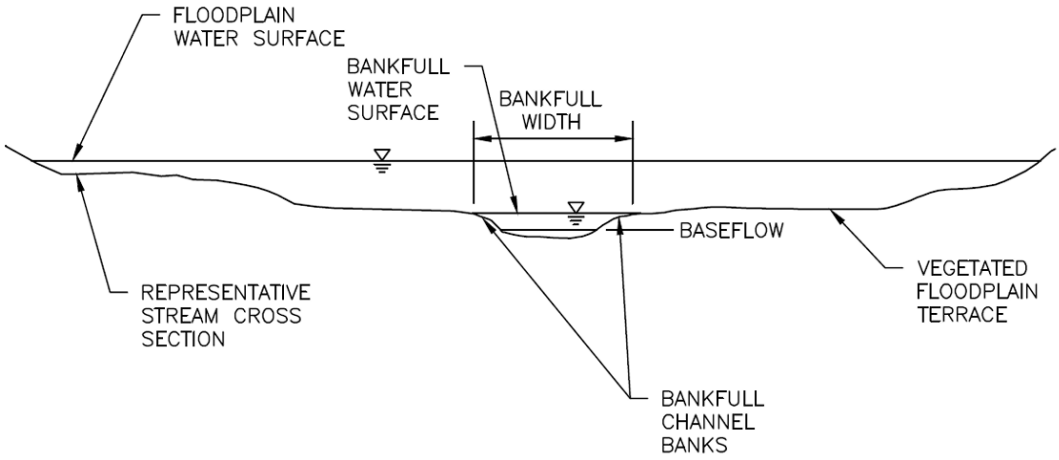

Figure 7-2. Channel Cross Section with Bankfull Discharge Illustration (Mile High Flood District, latest edition)

7.3.1.1 Baseflow and Low Flow Hydrology

In perennial and intermittent streams, baseflows and low flows play a critical role in sediment transport. Baseflows refer to dry weather flows, and low flows refer to flows that are greater than baseflows but smaller than the bankfull flows. Baseflow and low flow rates should be estimated to inform the channel geometry as well as the selection of vegetation for the lower portion of the channel cross section. Baseflows should be estimated by evaluating gage data when available. When gage data are not available, analyzing data from a reference stream with similar watershed characteristics may provide reasonable estimates of baseflows and low flows. Factors affecting baseflows in a given stream include lawn irrigation return flows, wastewater effluent outfalls, water rights releases, leaking water infrastructure, and groundwater upwelling points, as examples. The presence of these factors should be considered when estimating baseflow if gage data is not available.

Though ephemeral streams do not have a baseflow, baseflows may develop as the watershed develops due to irrigation return flows and other outdoor water uses in the watershed. For ephemeral streams, the proposed channel cross section should plan for potential development of future baseflows by concentrating these flows within the bottom channel dimension. Specifically, proposed channel cross sections should feature a cross slope to the stream centerline rather than a flat bottom.

7.3.1.2 Bankfull Hydrology

The bankfull flow rate is that at which water reaches the limits of the stream banks, just before spilling out into the larger floodplain. In most instances, this flow rate is that which does the most work to form the channel dimension, therefore an accurate estimate is necessary for the design of naturalized stream corridors. As outlined in the MHFD Manual, many design parameters of naturalized stream corridors are dependent on the bankfull flow rate, including the channel section and planform. In stable systems, estimate the bankfull flow rate based upon field indicators. Typical field indicators include breaks in topography, changes in vegetation,

transitions from cobble/gravel/sand/silt to soil, or waterline marks on boulders and bedrock, among others. For degraded and/or incised systems, estimate the bankfull flow rate based on a reference reach, or regional data where available. StreamStats (United States Geological Survey, latest edition) may be used to estimate bankfull flow rates; however, this is based on regional data, so field verification for reasonableness is recommended when StreamStats is used. Other acceptable methods for estimating the bankfull flow rate are provided in the MHFD Manual.

7.3.1.3 Flood Flows

Naturalized stream corridors should be designed to function and provide safe conveyance of larger flood flows. For major streams, flood flows are often published in FEMA's Flood Insurance Studies (FIS) and/or included in FHADs. This information can also typically be found in the relevant MHFD MDP. Chapter 5 of this Manual includes hydrologic criteria for calculating flood flows for streams which do not have published and accepted flood flow rates. Naturalized stream corridors should be designed for stability under the 100-year event. The 2-year, 10-year, 50-year, and 500-year flood flows should also be estimated and evaluated through the stream design process.

7.3.2 Hydraulics

While normal depth hydraulic calculations can be useful in the planning stages of stream design, detailed hydraulic evaluations are required to inform the design of stream corridors and show conformance with the criteria included in the MHFD Manual. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) from the U.S. Army Corps of Engineers (USACE) is required for detailed design of open channel major streams (United States Army Corps of Engineers, latest edition). Velocity, shear stress, and stream power must be evaluated. The design of streams should minimize variations in these parameters through the project and from the up- and downstream reaches to maintain continuity within the larger stream corridor. All major stream channels should provide a minimum of 1 foot of freeboard between the modeled 100-year water surface elevation (WSEL) and the top of banks and an additional foot from the top of bank to the LFE, as shown in Figure 7-3. Additional freeboard (and erosion protection) may be required in unique conditions (e.g., areas of rapid expansion or contraction, or in bends causing superelevation).

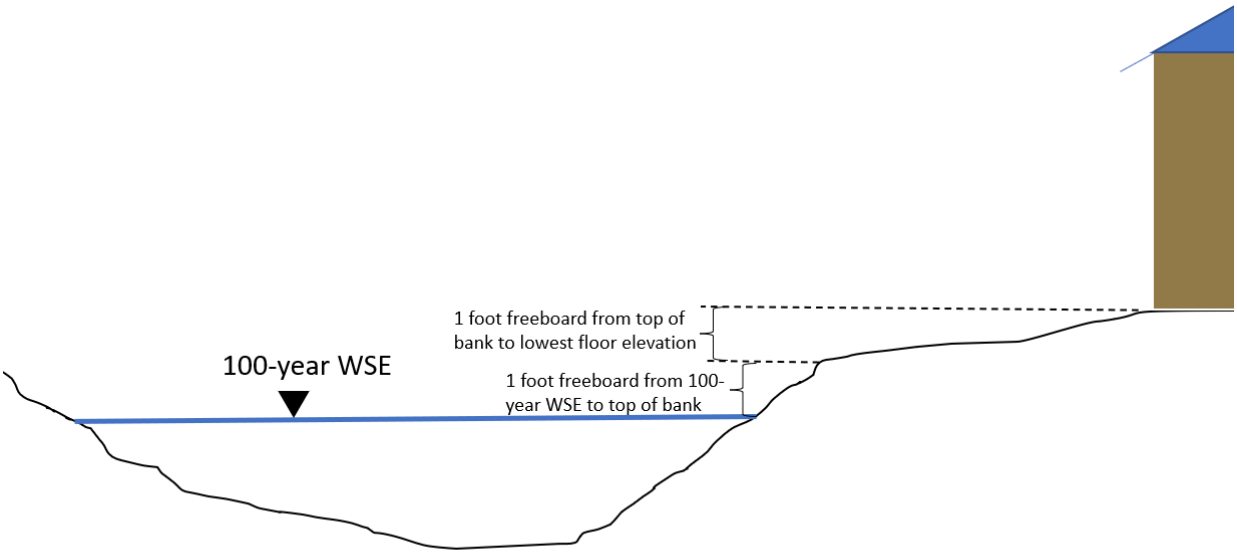

Figure 7-3. Major Stream Freeboard Requirement

7.3.2.1 Modeling Methods

HEC-RAS software must be used to model major streams and some minor streams (as discussed in 7.4). One- and two-dimensional models may be used, depending on the nature of the channel and analysis required. At a minimum, a one-dimensional hydraulic model evaluating the stream design under each of the flow rates mentioned in Section 7.3.1 must be completed. For stream corridors with significant variation in channel dimension, a two-dimensional model is required. Currently any regulatory floodplain map revisions must be done with a one-dimensional model; however, a two-dimensional model may be used to inform the one-dimensional modeling. A two-dimensional model must be used for evaluating shear stresses for natural channel design. Hydraulic models should extend far enough up- and downstream of the project reach to accurately evaluate these transitions.

7.3.3 Geomorphology

The design team must consider the geomorphology of the stream corridor during the design process. This includes consideration of water and sediment transport processes within the context of up- and downstream reaches and existing landforms through the stream. Successful design of naturalized stream corridors requires a high level of experience and understanding of stream processes and geomorphology. Careful consideration should be given to the SMCs or FHZs.[32] In areas where fluvial hazards are identified, the applicant will need to demonstrate how

[32] The SMC is the general corridor needed to allow a stream to function in a way that replicates natural processes (Mile High Flood District); see Chapter 3 for a full definition of SMCs. The FHZ is the area a stream has occupied in recent history, may occupy or may physically influence as it stores and transports water, sediment, and debris; more information on the Colorado FHZ Program can be found at coloradofhz.com (Colorado Water Conservation Board, 2023). In general, SMCs broadly identify the area a stream may occupy over time through hydrogeomorphic processes, whereas FHZs describe particular hazards within the overall stream corridor. Both SMCs and FHZs should be consulted when assessing the geomorphology of a stream corridor.

they are avoiding or mitigating these hazards.

7.3.3.1 Stream Classification

The design of naturalized stream corridors must fit the context of the surrounding landforms. Characterizing the valley within which a stream is situated is the first step in developing a naturally functioning channel design. Start by identifying the width, slope, and underlying geology of the valley. Then develop the planform, slope, dimension, and bed material of the designed channel based upon the characteristics that are typically stable within the identified valley type. There are many published stream classification systems which can be of use in identifying a stream type appropriate for the greater valley. The geomorphologist on the project team should select the most appropriate classification system for the context of the stream. When stream classification information is provided in a pre-existing master plan or in stream corridor information from MHFD, the design engineer should verify this information.

Photo 7-1. Void-filled riprap is designed to emulate natural rock riffle material and able to support riparian vegetation (Mile High Flood District, latest edition)

7.3.3.2 Sediment Transport

Natural stream corridors are inherently dynamic systems. The design intent of naturalized stream corridors is to establish a channel which is in a state of dynamic equilibrium where the channel neither aggrades nor degrades over time. For naturalized channel design, a state of dynamic equilibrium is achieved by balancing the sediment transport capacity within the design reach with the incoming sediment supply for a full range of flows. The designer must account for both the current and expected future incoming sediment supply during the design process. See the MHFD Manual for more detailed guidance related to managing sediment balance in alluvial channels.

Channel crossings have the potential to create geomorphic stability issues by disrupting the continuity of hydraulics and sediment transport. A geomorphic approach to designing stream crossings, whether culverts or bridges, seeks to minimize features within the bankfull channel to the extent practical to allow for flows up to and including the bankfull flow to pass through the crossing largely unimpeded. See MHFD's guidance in *Roadway Crossings for High Functioning, Low Maintenance Streams* for methods of geomorphic sizing of stream crossings, design guidance, and examples (Mile High Flood District, latest edition).

7.3.3.3 Imported Rock Material

The bed material of the designed naturalized stream corridor should be balanced along with the planform, slope, and cross-sectional geometry of the naturalized stream corridor. In most instances imported rock material (riprap) will be required to protect against degradation of a

naturalized stream corridor. This material is often limited to select areas within the corridor. In-stream structures, such as riffles, often consist of imported material to protect against stream degradation. Void-filled riprap should be used in most applications within the bankfull channel (see Photo 7-1). Riprap specifications for the CoA are provided in Chapter 8. In natural stream corridors, bioengineering techniques are encouraged along with the use of buried rock to protect against lateral instabilities. Rock protection outside of the low flow channel must be buried so that vegetation can establish along the banks of the channel. Grout is not recommended for in-stream structures that provide 2.5 feet of grade control or less. Avoid designing grade control structures with more than 2.5 feet of drop to the extent practical by using multiple smaller grade control structures (see Chapter 8 for additional information). The use of structures with drops greater than 2.5 feet must be coordinated with CoA early in the design process to determine if this will be allowed, and, if so, what types of drop structures may be suitable. For new stream crossings within developing areas, and for the replacement of old structures at already established crossings, geomorphic crossing design should be the first alternative investigated. MHFD's guidance document titled *Roadway Crossings for High Functioning, Low Maintenance Streams* (Mile High Flood District, latest edition) provides guidance and criteria for geomorphic design of channel crossings.

7.3.4 Vegetation

Vegetation significantly improves the stability and function of naturalized stream corridors by slowing flood flows and resisting erosion. Appropriate vegetation must be carefully selected for the specific site conditions. Where healthy, native vegetation exists, minimize disturbance to the maximum extent practical. The design of naturalized stream corridors must include a revegetation plan featuring native wetland (where conditions allow), riparian, and upland plant communities based on the hydrologic gradient from the bottom of the channel to the top of bank. Within the 10-year floodplain, riparian vegetation suitable for flood flows and which will not impede flow through the floodplain shall be used. Temporary erosion control measures are required for stability during vegetation establishment. Use biodegradable erosion control products to avoid having to remove these measures once vegetation is established.

7.3.5 Stream Management Corridors (SMCs)

Development should not be planned in an area identified as a SMC. An applicant may retain the SMC defined by MHFD or refine the SMC by submitting new hydrologic, hydraulic, geomorphic, and ecological analyses. If a SMC has not been defined for a major drainageway, the applicant must prepare new hydrologic, hydraulic, geomorphic, and ecological analyses to determine the SMC.

At the master planning stage, analyses to revise the SMC must consider the entire area studied in the Master Drainage Report (MDR). At the PDR stage, analyses to revise the SMC may consider only the area studied in the PDR.

7.3.6 Maintenance

Maintenance of naturalized stream corridors is needed to manage vegetation, debris accumulation, and more.

7.3.6.1 Maintenance Access

Provide continuous maintenance access along the length of the major stream corridor. The

access path must be at least twelve feet wide with no recovery zone. In some cases, it may be feasible to access the stream from public ROW without the need for a separate path. Recreational trails can also serve as maintenance access paths along a stream corridor as long as the stream corridor can be accessed directly from the path by an easement. Provided they can sustain the loading of maintenance equipment, maintenance paths can consist of a variety of surfacing techniques including concrete and stabilized rock. The use of crusher fines is acceptable only in areas outside of the 10-year inundation boundary and where longitudinal slopes are less than 5%. Where maintenance access paths also provide recreational use, pavement is encouraged. Recreational trails must be above the 10-year inundation boundary. See the PROS's *Dedication and Development Criteria Manual* for additional information on types of trails and criteria for shared recreational trails (City of Aurora, latest edition). Note that maintenance access must be coordinated with PROS when multiuse with a recreational trail to ensure all requirements are met.

The maximum longitudinal slope for maintenance-only trails is 10%, and the maximum slope for multi- purpose recreational trails is 5%. Centerline radii less than 50 feet will require the access to be widened to accommodate the turning movement of maintenance vehicles. In no case may the centerline radii be less than 30 feet. Appropriate turnarounds must be provided for maintenance equipment. Tandem axle dump trucks should be used as the design vehicle for turnarounds. Turnarounds must have all-weather surfaces that will be stable and not rut when accessed by heavy vehicles during wet weather.

7.3.6.2 Path Overtopping Protection

Maintenance access paths, multiuse trails, and other paths must have adequate protection to avoid damage from overtopping flows. Flow which overtops a path can cause damage to the upstream path edge and scour along the downstream path edge. A thickened edge extending two feet below the path surface shall be applied to both the downstream and upstream edges of a path at any location where flow overtopping is anticipated. Soil riprap may also be implemented for added protection. See Volume 2, Chapter 10: Stream Access and Recreational Channels of the MHFD Manual for additional guidance on path overtopping protection.

7.3.7 MHFD Development Review

All major stream projects must be designed and constructed to meet the criteria necessary for the MHFD Development Review. For minor streams, the CoA may consult with MHFD for mutually agreeable criteria if there are potential impacts to adjacent jurisdictions. Early coordination, especially during market analysis and site plan development, is recommended to provide greater predictability with the review process. This includes adherence to the criteria outlined in the latest version of the MHFD Manual. Development review guidelines are available for download from MHFD's Development Referrals website.

7.4 MINOR STREAMS

Minor streams typically act as the collector system for a watershed. They convey flows from swales, ditches, and storm drain systems to major streams. Use vegetated, open channels for minor streams when feasible. When flows in minor streams exceed 100 cfs (upper limit of Figure 7-4 through Figure 7-7), they should be designed following the same procedures as major streams. For minor streams that convey between 40 and 100 cfs, the MHFD swale stability sizing charts in Section 7.5 may be used for preliminary sizing, with verification of depths, velocities, and backwater effects for final design. All minor stream channels should

provide a minimum of 6 inches of freeboard between the modeled 100-year WSEL and the top of banks and an additional foot from the top of bank to the LFE.

For minor streams, upstream and downstream access must be provided by easement or right of way. If the maintenance access easement or right of way is more than 150 feet, with access at only one end of the easement or right of way, a turnaround is required. The minimum turning radius for maintenance access is 30 feet.

7.5 SWALES

Swales can either be native grass or soil riprap-lined, depending on site conditions such as slope, lateral constraints, depth and velocity of flow, and others. Native grass swales are preferred wherever conditions allow because they provide greater infiltration and filtration benefits and fewer maintenance requirements compared to soil riprap-lined swales. Drainage and water quality swales may not be constructed within the backfill zones of buildings unless an impermeable liner is provided.

All swales shall be designed to convey the 100-year peak discharge. A minimum of 6 inches of freeboard must be provided from the 100-year WSEL to the LPE to buildings. Swales are not required to have freeboard between the 100-year WSEL and the top-of-bank. Swales that carry emergency overflows require 6 inches of freeboard from the 100-year to the LPE.

Native grass swales shall be designed according to the criteria provided in Table 7-2 to maintain stability and reduce erosion potential. In addition, proper soil preparation and revegetation shall adhere to the criteria and guidelines provided in Volume 2, Chapter 13: Revegetation of the MHFD Manual.

Table 7-2. Hydraulic Design Criteria for Vegetated (Native Grass) Swales

Parameter	Erosive Soils	Erosion Resistant Soils
Maximum Velocity (2-year)	3.5 ft/sec	5.0 ft/sec
Maximum Velocity (100-year)	5.0 ft/sec	7.0 ft/sec
Maximum Froude Number (2-year)	0.5	0.7
Maximum Froude Number (100-year)	0.6	0.8
Minimum Longitudinal Slope	2%*	2%*
Freeboard	6 inches to LPE of buildings	6 inches to LPE of buildings

* A longitudinal slope less than 2% may be utilized with an underdrain; see Section 7.5.2 below.

In some circumstances, grade control structures and/or soil riprap lined swales may be necessary. Refer to Chapter 8 for design criteria on grade control structures.

A trapezoidal cross section is recommended for swales where feasible as it is the most efficient shape for conveyance and minimizes erosional forces. Provide a bottom width of at least 2 feet. Side slopes must be 5:1 (H:V) or flatter for native grass swales and 2.5:1 (H:V) or flatter for soil riprap-lined swales. If these criteria are followed, the swale capacity charts provided in Figure 7-4, Figure 7-5, Figure 7-6, and Figure 7-7 (from MHFD Manual) may be used for determine the type of swale for each application. See the MHFD Manual for additional information on swale sizing and design. For swales that convey flows from small drainage areas (less than 5 acres) and have space constraints that do not allow for a 2-foot bottom width, a triangular cross section

may be used following the open channel design methods in the MHFD Manual. On non-residential lots, the top of the swale embankment must also be a minimum of two feet horizontal from the nearest fence line for maintenance and access.

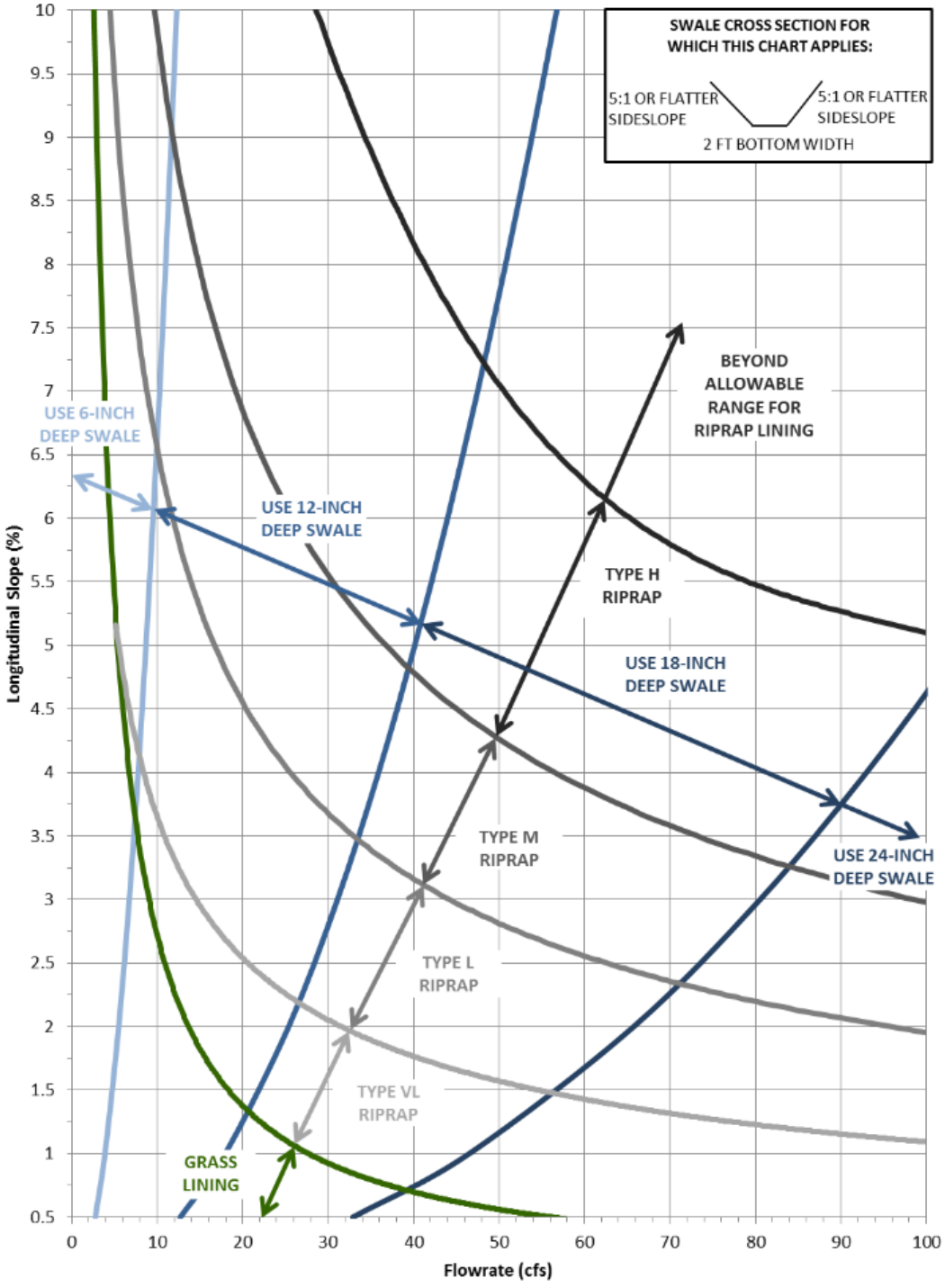

Figure 7-4. Swale Stability Chart: 2- to 4-foot Bottom Width and Side Slopes Between 5:1 and 10:1[33,34]

[33] Note: Riprap classifications refer to gradation for riprap used in soil riprap or void-filled riprap.

[34] Source: Muller Engineering Company, MHFD Manual (Mile High Flood District, latest edition)

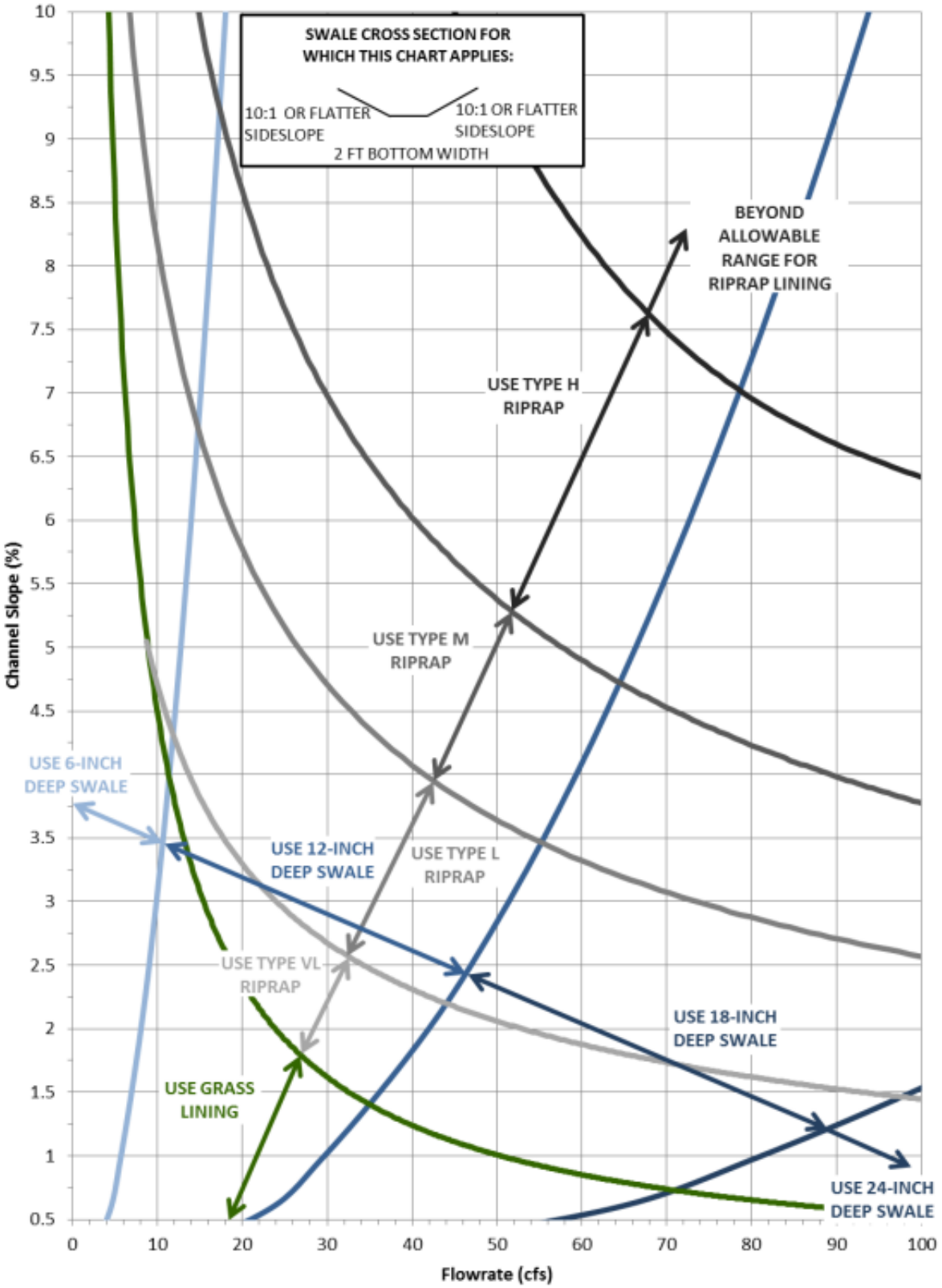

Figure 7-5. Swale Stability Chart: 2- to 4-foot Bottom Width and 10:1 (or Flatter) Side Slopes[33,34]

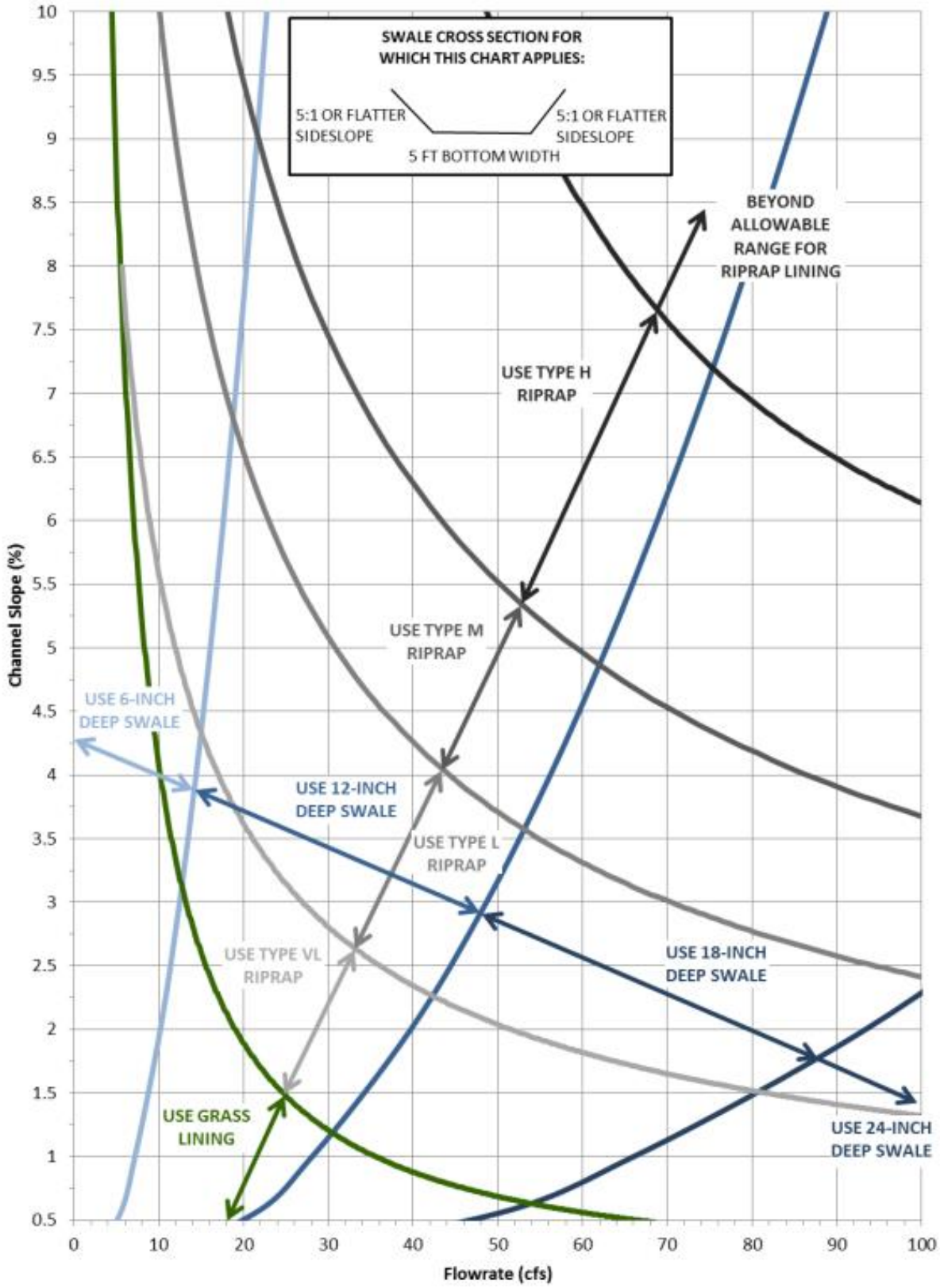

Figure 7-6. Swale Stability Chart: Greater than 4-foot Bottom Width and Side Slopes Between 5:1 and 10:1[33,34]

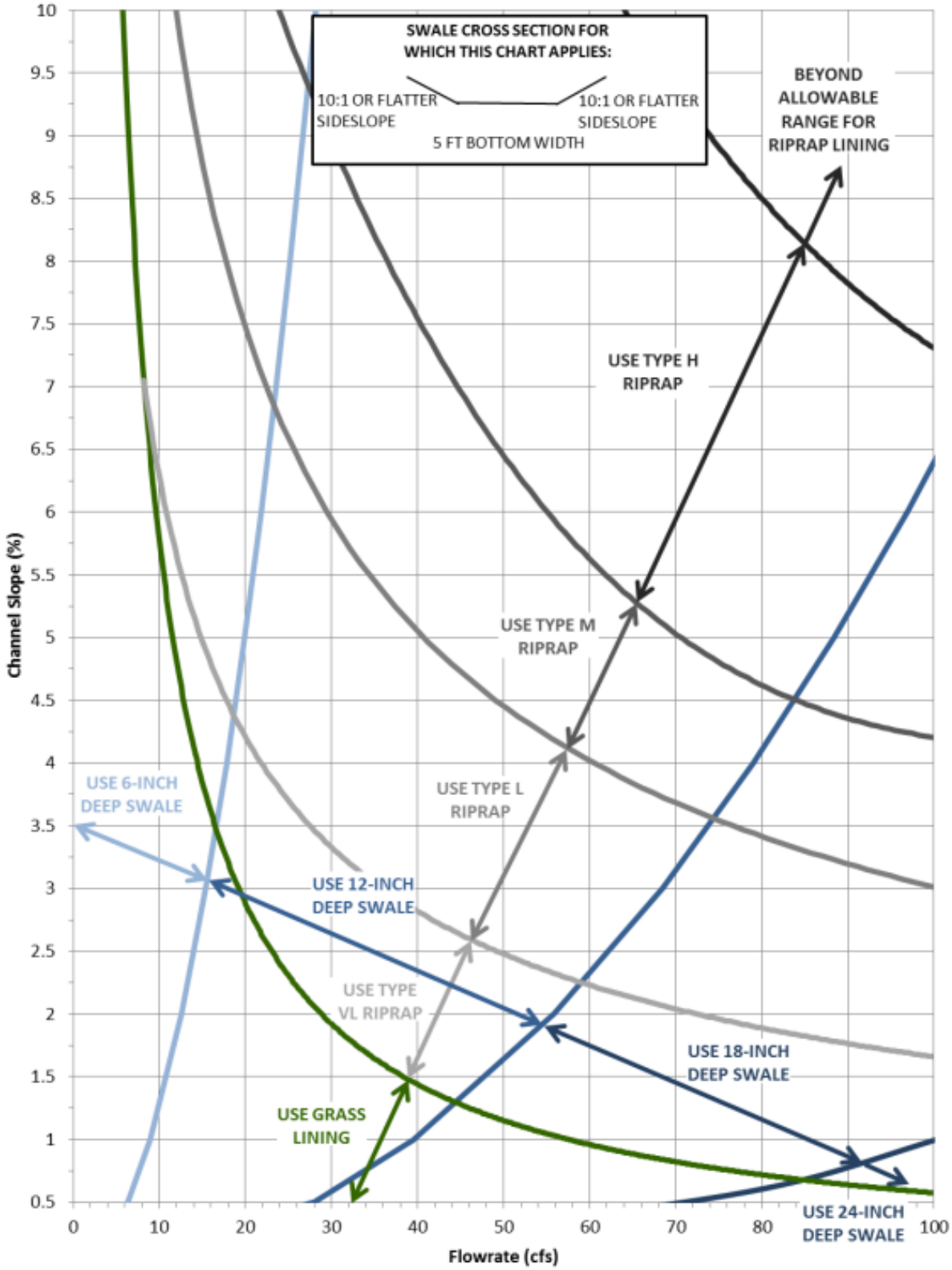

Figure 7-7. Swale Stability Chart: Greater than 4-foot Bottom Width and 10:1 (or Flatter) Side Slopes[33,34]

7.5.1 Roadside Ditches

Roadside ditches follow the design criteria set forth for swales, with the following exceptions:

1. The ditch capacity is dictated by the allowable encroachment criteria set forth in Chapter 6 of this Manual.

2. Alternative cross-sections (besides trapezoidal) may be used where necessary to meet available space or other constraints.

3. Drainage easements are not required if the 100-year WSEL is fully contained within the ROW.

7.5.2 Underdrains

An underdrain is required for all swales and ditches with longitudinal slopes less than 2%. The minimum pipe diameter for swale underdrains is 4 inches. See Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual for additional criteria and information on bedding material.

7.6 ROUGHNESS COEFFICIENTS

Surface roughness is an important parameter in performing hydraulic analyses. Whether performing a simple normal depth calculation to size a swale or a detailed HEC-RAS analysis of a major stream, the selection of appropriate roughness coefficients, or Manning's n-values, is critical to properly evaluating and designing open channels. Manning's n-values shall be assigned in accordance with Volume 1, Chapter 8: Open Channels of the MHFD Manual. Variation from the procedures and values in the MHFD Manual may be appropriate based on-site conditions and engineering judgement. However, in all cases, an explanation and justification of the Manning's n-values used in the hydraulic analysis must be provided along with said analysis (e.g., in a drainage report).

7.7 PERMITTING

The applicant must obtain all necessary federal and local permits for open channel construction and provide documentation of these permits to the CoA before plans will be approved and construction can begin. In addition to local permitting through the CoA, permits that may be required from state and federal entities include:

- Clean Water Act Section 404 authorization from the U.S. Army Corps of Engineers for Nationwide Permit or Individual Permit depending on the scale of the project and associated impacts. Early and close coordination with USACE regarding Section 404 permitting is strongly recommended to determine if permitting is feasible and, if so, what type of permit is most appropriate for the project.

- Floodplain permits through FEMA – At a minimum, local floodplain permitting through the CoA is required for work in regulatory floodplains. For projects that affect base flood elevations, permitting through FEMA and MHFD may be required in addition to local floodplain permitting. Start work on floodplain permitting as early in the design process as feasible since the local and federal review process for projects involving

CLOMRs/LOMRs is lengthy given the complexity of the analyses and submittals. See Chapter 4 for additional information on floodplain permitting.

- Colorado Discharge Permit System (CDPS) Permits – CDPS permits including the General Permit for Stormwater Discharges Associated with Construction Activity and the General Permit for Discharges from Short-term (< 2 year) Construction Dewatering Activities are permits that often apply to open channel projects.

- Channels within the Denver International Airport (DEN) drain time zone (or other airport zones) are not allowed to have any adverse slope sections and require a special plant palette. DEN review is required.

Prior to the start of construction of any channel work, the contractor is required to execute a main extension agreement through the Aurora Water Department.

7.8 REFERENCES

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CHAPTER 8.0 HYDRAULIC STRUCTURES

8.1 INTRODUCTION

This chapter provides technical criteria for the planning and design of hydraulic structures in the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 2, Chapter 9: Hydraulic are hereby incorporated by reference. Except as modified herein, all hydraulic structure designs must be in accordance with the MHFD Manual.

Hydraulic structures are used to guide and control the flow of water in streams. Structures described in this chapter include grade control structures, as well as pipe outfall and rundown structures for various applications and conditions. The discussion of grade control structures in Section 8.3 of this chapter addresses the hydraulic design of grouted stepped boulder (GSB), sculpted concrete, and vertical drop structures; the criteria in this chapter should be used in conjunction with the criteria in Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual when designing GSB, sculpted concrete, or vertical drop structures, as described in Section 8.2 below. Volume 1, Chapter 8: Open Channels of the MHFD Manual should be consulted regarding the placement of grade control structures in the stream, and Volume 2, Chapter 10: Stream Access and Recreational Channels of the MHFD Manual should be used for safety considerations relevant to urban streams as well as specialized design of boatable hydraulic structures.

Section 8.4 of this chapter provides design guidance for various pipe end treatments and rock protection to dissipate hydraulic energy at the outfalls of storm drains and culverts. Related design information may be found in Chapters 6 and 9 of this Manual. Section 8.5 includes criteria for the use of riprap.

The design of each hydraulic structure shall consider environmental, ecological, maintenance, and public safety objectives. The United States Department of Agriculture's (USDA's) *Technical Supplement 14B: Scour Calculations* should be consulted for general scour concerns at grade control structures (United States Department of Agriculture, 2007). The proper application of hydraulic structures can reduce initial and future maintenance costs by managing the character of the flow to best meet all project objectives.

The shape, size, and features of hydraulic structures vary widely between projects depending on the design discharge and functional needs of the structure. Hydraulic design procedures discussed herein govern the design of typical hydraulic structures. For the design of unique structures that do not fit the guidance provided, physical hydraulic modeling or computational fluid dynamics modeling may be required.

8.2 GUIDANCE FOR USING THIS CHAPTER IN COMBINATION WITH THE MHFD MANUAL

The drop structure guidance and criteria included in this chapter shall be used in conjunction with the criteria denoted in the MHFD Manual (particularly those included in Volume 2, Chapter 9: Hydraulic Structures) when designing drop structures within the CoA. The basic procedure for designing drop structures using both the criteria in this Manual and those in the MHFD Manual is outlined below:

1. Determine if the drop structure can be designed using the simplified method described in Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual, or if a detailed design per the same is required.

2. Perform soils and seepage analyses as necessary for the design of the foundation and seepage control system according to Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual. Additional analysis of forces acting on a structure may be necessary and should be evaluated on a case-by-case basis as described in the MHFD Manual.

3. Select an appropriate drop structure using the guidance in Section 8.3 below. Use the criteria specific to the type of drop structure selected to determine the final flow characteristics, dimensions, material requirements, and construction methods.

4. Use the specific design criteria in Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual to design the GSB, sculpted concrete, or vertical drop structure selected in 3 above.

5. If applicable, refer to Volume 2, Chapter 10: Stream Access and Recreational Channels of the MHFD Manual for design criteria for boatable structures and other requirements for public safety.

8.3 GRADE CONTROL STRUCTURES

When practical, the most effective and sustainable way of providing channel stability and grade control is by working with natural stream forms. Natural streams dissipate energy through bedforms and control grade via sinuosity. Bedforms such as riffles can be engineered and used instead of drop structures to manage energy. Energy dissipation may be provided by a series of small riffle drops constructed with void filled riprap instead of a large drop structure with high vertical relief and increased maintenance and replacement costs. When sufficient area is preserved for the natural floodplain of a stream, there are often opportunities to introduce bedforms and sinuosity into a naturalized channel design. The use of natural stream forms is preferred within the CoA.

Nevertheless, while multiple small grade control structures (i.e., void filled riprap riffles) are preferred, in some cases drops with greater vertical relief may be required. For example, larger drop structures are often used to help protect utility crossings of streams from scour. When larger grade control structures must be incorporated into a design due to steep grades, space constraints, or other factors, the following types of grade control structures may be selected within the CoA:

1. GSB Drop Structures: These types of drop structures are appropriate for most applications in the CoA. The use of GSB drop structures is described in Section 8.3.1 below.

2. Sculpted Concrete Drop Structures: These types of drop structures should be used sparingly and only when there is a recreational/interactive benefit that justifies the cost of construction, maintenance, and eventual replacement. The use of sculpted concrete drop structures is described in Section 8.3.2 below.

3. Vertical Drop Structures: These types of drop structures are most appropriate on smaller streams where there is little-to-no chance of recreation or access by the public, due to

safety concerns with the vertical drop and the potential for hazardous hydraulic currents to develop immediately downstream of the drop structure. The use of vertical drop structures is described in Section 8.3.3 below.

4. Check Structures: These types of drop structures are similar to vertical drop structures and are suitable for the same locations and contexts as vertical drop structures. The use of check structures is described in Section 8.3.4 below.

If a project includes the replacement of an existing grade control structure not meeting current MHFD criteria, the structure must be replaced with a compliant grade control structure. Natural barriers such as dense vegetation should be provided at the ends of the grade control structure on both banks to discourage pedestrian use.

The remainder of this section provides guidance for selecting the appropriate grade control structure for a given site and design criteria specific to the CoA. Other information and criteria related to grade control structures can be found in the relevant section of Volume 2, Chapter 9: Hydraulic Structure of the MHFD Manual. The criteria included in this chapter and in the MHFD Manual must be followed.

8.3.1 GSB Drop Structures

GSB drop structures have gained popularity in the MHFD region due to the close proximity of high-quality rock sources, the design aesthetics offered by the structure, and the successful application of the design in various locations and contexts within the MHFD. The quality of both the rock and grouting procedure used are very important to the structural integrity of the overall structure. GSB drop structures are a good option for most applications in the CoA where it is not feasible to use channel sinuosity and riffle bedforms to control grade.

The recommended height for GSB drop structures is 3 feet; the maximum allowable height of GSB drop structures is 5 feet. To improve the appearance of the structure, the grouted boulders above the low-flow section and on the overbanks should be covered with local topsoil and revegetated. The seed, straw, and coir fabric should be layered to prevent the potential wash out of the topsoil while vegetation is establishing. See Volume 2, Chapter 13: Revegetation of the MHFD Manual for a detail of this layering.

Criteria related to boulder sizing, grout, edge-walls, and other design elements are provided in the MHFD Manual and must be followed for the design of GSBs.

When GSB drop structures are used, significant construction oversight is required. A detailed boulder placement plan is recommended, and a field representative of the design engineer must perform construction observation during both the placement of boulders and grouting to provide quality control. The field representative must ensure that the boulders are placed close together (i.e., touching) in order to minimize the amount of grout that is required, and that the grouting is finished in a way that minimizes visibility. See the MHFD Manual for additional information and guidance on construction practices for GSB drop structures.

8.3.2 Sculpted Concrete Drop Structures

Sculpted concrete drop structures should be used sparingly and only when there is a recreational or interactive benefit that can justify the costs of construction, maintenance, and eventual replacement. High visibility locations and/or locations with public access are potential

candidates for sculpted concrete drop structures.

Sculpted concrete drop structures often employ concrete faux rock, i.e., concrete that is sculpted, carved, textured, and colored to emulate real rock. Sculpted concrete drop structures which implement concrete faux rock can be an attractive aesthetic alternative to grouted boulders in locations where natural sedimentary rock might be expected. When considering the design for a new sculpted concrete structure, existing exposed sedimentary rock in the vicinity of the project should be used for guidance. Experienced contractors skilled in producing appealing and realistic sculpted concrete drop structures should be used when selecting this drop structure option.

Specific design guidance for sculpted concrete drop structures found in the MHFD Manual must be followed, including criteria related to reinforcing steel, edge wall design, concrete thickness, and the use of concrete versus shotcrete. Additional guidance in the MHFD Manual for decorative finishing elements and construction practices should also be consulted.

8.3.3 Vertical Drop Structures

Vertical drop structures are generally discouraged due to safety concerns related to the height of the drop and the potential for dangerous hydraulic conditions (known as “reverse rollers” or “keeper waves”) to develop downstream of the drop structure. Nevertheless, vertical drop structures can be an effective tool for controlling grade, especially in locations where it is important to minimize the footprint of the drop structure and where there is little-to-no chance of recreation or access by the public. Vertical drop structures should not be used on streams where fish passage is a concern. A vertical drop structure shall not be used where the design flow exceeds 500 cfs or a unit discharge of 35 cfs/ft.

In addition to the limitations on use provided in Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual, the following criteria specific to the CoA also apply:

1. Vertical drop structures are not allowed in residential areas due to safety considerations.

2. Vertical drop structures must be integrated with the surroundings. Vegetation should be used to discourage public access and enhance aesthetics.

3. A maximum drop height of 4 feet is permitted for industrial areas. Lesser drop heights may be required by the CoA depending on the location and potential for public access.

4. Vertical drop structures and the surrounding area shall be assessed for potentially hazardous conditions. Appropriate mitigation measures for fall hazards and public access shall be installed as necessary based on this assessment.

5. The potential for reverse rollers to develop at a vertical drop structure must be evaluated.[35] If there is a potential for a vertical drop structure to create a reverse roller, mitigation of the hydraulic hazard is required (e.g., installing riprap fill on the downstream side of the drop, or reducing the drop height).

6. Sufficient energy dissipation and armoring shall be provided at the bottom of the vertical

[35] See *A Spreadsheet Tool for Defining Dangerous Flow Ranges of Low-Head Dams* for one potential method of evaluation (Wahl & Svoboda, 2023).

drop structure to avoid erosion. For higher drops, stilling basins may be required.

The design of vertical drop structures must follow the detailed design methodology and criteria outlined in the MHFD Manual.

8.3.4 Check Structures

Check structures consist of a vertical concrete wall with riprap placed on the downgradient side of the wall to dissipate energy and control erosion. Check structures are appropriate in the same settings as vertical drop structures. The same safety and access considerations and assessments required for vertical drop structures also apply to check structures.

The maximum allowable drop for check structures is 4 feet. Check structures must include riprap placed in the downstream side of the drop at a slope no steeper than 3:1 (horizontal [H]:vertical [V]). Concrete check structures must be formed reinforced concrete structures designed to not overturn when the channel bed has reached its stabilized slope. They must also be embedded sufficiently deep to resist undermining due to the piping of soils. Geotechnical and structural calculations demonstrating as much must be submitted for review during the civil plans (CPs) review.

8.4 PIPE OUTFALLS AND RUNDOWNS

Pipe outfalls represent a persistent problem due to concentrated discharges and the turbulence of flow as it transitions from pipe flow to open channel flow. Appropriate pipe end treatments and downstream erosion protection at pipe outfalls are critical to protect the structural integrity of the pipe and to maintain the stability of the adjacent slope.

The use of rundowns to convey storm runoff down a channel bank is discouraged due to their high rate of failure and the resulting maintenance and repair burden. Instead, pipes should be designed to convey runoff to a point just above the channel invert (normally 1 foot for small receiving streams or ponds, and up to 2 feet for large receiving channels).

See Volume 2, Chapter 10: Hydraulic Structures of the MHFD Manual for additional guidance and criteria related to pipe outfalls and rundowns. The design of pipe outfalls and/or rundowns must comply both with the criteria in this chapter and the criteria in the MHFD Manual.

8.5 RIPRAP

Riprap is used for a variety of applications in urban drainage. It is used to construct energy dissipation measures in open channels, form riffles or check structures, and provide erosion protection where outfalls enter channels. Riprap and boulder sizing criteria are included in Volume 1, Chapter 7: Open Channels of the MHFD Manual. MHFD criteria must be used for riprap and boulder sizing in the CoA unless otherwise specified in this chapter. When differences exist between CoA and MHFD criteria, the more conservative criterion (e.g., larger rock size) must be applied. When sizing riprap, the potential for vandalism and/or removal of riprap material should be considered.

When riprap is used for channel stabilization purposes, the CoA requires that soil riprap or void filled riprap be used instead of ordinary riprap without soil or smaller aggregate to fill the voids. Ordinary riprap may be used for outfall protection and similar applications. For ordinary riprap (i.e., not soil or void filled riprap), Type M riprap must be used at a minimum.

8.5.1 Soil Riprap

Soil riprap is intended for use in applications where vegetative cover can be established in the riprap. The following criteria apply to soil riprap:

- When soil riprap is used, Type L riprap is the minimum required size and must be mixed with a ratio of 30% soil to 70% riprap.

- When installed outside of the low-flow channel, 4 to 6 inches of topsoil shall be placed on top of the soil riprap to help establish vegetation. Soil placed in the voids and on top of the soil riprap should have characteristics that are compliant with MHFD's *Topsoil Management Guidance* (Mile High Flood District, latest edition).

- The criteria in the MHFD Manual for gradation and placement of both riprap and soil riprap must be followed.

- Refer to Volume 2, Chapter 13: Revegetation of the MHFD Manual for a staking detail that can be used where erosion control fabric or matting is specified over soil riprap. Where appropriate, a combination of straw and coir mat shall be used to help retain soil and seed (e.g., when topsoil is placed on top of soil riprap and then seeded).

- Specifications for mixing and installing soil riprap are addressed in the MHFD Construction Specifications (Mile High Flood District, latest edition).

8.5.2 Void Filled Riprap

Void-filled riprap contains a well-graded mix of cobbles, gravel, sands, and soil that fills all voids and acts as an internal filter. The following criteria apply to void filled riprap:

- In addition to specifying the D_{50} rock size, the design plans must specify the individual material components that will make up the mix. For each material component, the gradation must be defined by identifying a variety of particle sizes (from large to small) and the range of allowable "passing" percentages for each particle size.

- Volume 1, Chapter 8: Open Channels of the MHFD Manual notes typical mixes of various sized rock; however, the designer should specify any mix adjustments based on the site-specific requirements of a particular project.

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CHAPTER 9.0 CULVERTS AND BRIDGES

9.1 INTRODUCTION

This chapter establishes criteria for the design of culverts and bridges in the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD's) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 2, Chapter 11: Culverts and Bridges; the CoA's *Roadway Design and Construction Specifications* (RDCS); Aurora Water's (AW's) *Water, Sanitary Sewer & Storm Drainage Infrastructure Standards & Specifications*; the Colorado Department of Transportation's (CDOT's) *Bridge Design Manual*; Chapter 9: Culverts and Chapter 10: Bridges of CDOT's *Drainage Design Manual*; and any relevant details associated with the foregoing are hereby incorporated by reference. When conflicts exist in criteria between multiple documents, the most restrictive criterion must be applied.

Culverts and bridges are critical elements of urban drainage infrastructure that must function properly to avoid flooding, disruption of traffic, or other impacts to public safety. A culvert is defined as a conduit for the conveyance of water under a roadway, railroad, canal, or other embankment, and typically connects two open channel sections. In addition to serving hydraulic functions, culverts also must carry overhead loads from traffic and other activities, thereby serving a structural function and a hydraulic function. Proper culvert design is essential because culverts often significantly influence upstream and downstream flood risks, floodplain management, and public safety.

Bridges are typically designed to cross a waterway with minimal disturbance to the underlying flow. However, for practical and economic reasons, abutment encroachments and piers are often located within the waterway. Consequently, the bridge structure can cause adverse hydraulic effects and the potential for scour; these concerns must be evaluated and addressed as part of each design. Moreso than for culverts, the design of a bridge is particular to the site conditions, and numerous unique factors must be considered at each potential bridge location.

9.2 STRUCTURE SELECTION REPORT

For structures on major drainageways with a span greater than 20 feet, a Structure Selection Report (SSR) is required by the CoA to provide a rationale for the selection of a culvert versus a bridge for a specific site. The distinction between the two[36], as it pertains to hydraulic analyses, is as follows:

- In general, culverts are designed for submerged inlet conditions. The intent is to pass the design flow with the smallest barrel size that does not cause the allowable headwater elevation to be exceeded. Consequently, culvert design methodology typically assumes a zero-velocity condition both upstream and downstream of the culvert (Schall, Thompson, Zerges, Kilgore, & Morris, 2012).

- For structures that are on the main channel with a notable approach velocity and momentum, it is more appropriate to evaluate these types of structures as bridges and to consider pressure flow if there is overtopping.

[36] Note that the Federal Highway Administration (FHWA) defines bridges categorically as any crossing with a span greater than 20 feet. This Manual does not define bridges in this manner, and instead uses the more colloquial definition of the term "bridge."

Specific requirements for SSRs are included in Chapter 2 of this Manual.

9.3 GENERAL DESIGN AND HYDRAULIC EVALUATION

Volume 2, Chapter 11: Culverts and Bridges of the MHFD Manual provides detailed information on culvert hydraulics, culvert sizing and design, culvert inlets, and outlet protection. It also provides references for additional information, including the Federal Highway Administration's (FHWA's) *Hydraulic Design of Highway Culverts, Third Edition* (Schall, Thompson, Zerges, Kilgore, & Morris, 2012), and FHWA's *Hydraulic Design of Safe Bridges* (Zevenbergen, Arneson, Hunt, & Miller, 2012), among others.

Sizing of culverts and bridges depends on multiple site-specific factors, such as waterway hydrology and hydraulics, characteristics of the street and surrounding developments, stream geomorphology, the nature of wetlands and riparian areas, grade-separated crossing requirements, etc. Culverts and bridges must be designed to minimize impacts to waterways to the extent practical. In general, this means avoiding structural designs that will disrupt the hydrologic or sediment transport characteristics of the bankfull channel. This is typically accomplished by designing a culvert or bridge to span the bankfull channel when feasible. When spanning the bankfull channel is not feasible, impacts due to piers or abutments must be minimized.

For culverts, key design parameters include the culvert geometry, culvert material/roughness, and the allowable headwater depth. All culverts must be designed to convey the 100-year peak flow with a headwater depth no more than 1.5 times the diameter of the culvert (or culvert rise dimension for non-circular culverts; see Section 9.4.4 below).

All bridge structures must be designed to pass the 100-year peak flow with a minimum of 2 feet of freeboard between the 100-year water surface elevation (WSEL) and the low chord of the bridge (see Section 9.5.3 below). Bridge hydraulics must be evaluated to determine the effect of the structure on 100-year WSELs and sediment transport functions, including scour (see Section 9.5.2 below).

The hydraulic principles, criteria, roughness coefficients, entrance loss coefficients, culvert capacity charts, and other information provided in Volume 2, Chapter 11: Culverts and Bridges of the MHFD Manual must be used in the hydraulic evaluation, sizing, and design of culverts and bridges, except as modified herein.

The criteria in this chapter are considered minimum design standards. Site-specific characteristics may warrant higher design standards to address issues such as flooding of adjacent structures or private property, excessive channel velocities, and other factors identified based on a site-specific evaluation of the proposed bridge or culvert location and surroundings.

9.4 CULVERT DESIGN CRITERIA

All culverts in the CoA, including inlet and outlet structures, must be designed to convey runoff, sediment, and debris at all stages of flow. On the upper end of the flow spectrum, culverts must convey the 100-year peak flows without road overtopping, and on the lower end of the flow spectrum, culverts must be designed to be self-cleaning in frequent events to avoid excessive aggradation. The following sections describe design criteria specific to culverts.

9.4.1 Culvert Design Event

All culverts in the CoA must be designed to pass the 100-year peak flow, subject to the allowable headwater depth criteria stated below (see Section 9.4.4). No road overtopping is allowed up to and including the 100-year event.

Private Driveway Culverts

A variance to the 100-year peak flow design criteria may be considered for private, residential driveway culverts if it can be demonstrated that there are no adverse impacts to adjacent property and right-of-way (ROW), and that the 100-year flows are perpetuated downstream; if such is the case, a variance may be obtained to design the culvert for the 2-year peak flow instead. Private non-residential driveway culverts must still be sized for the 100-year peak flow.

Private driveway culverts must be maintained by the property owner.

9.4.2 Construction Material and Pipe Size

Within the CoA, culverts must be constructed from ASTM C76 Class III reinforced concrete or better (ASTM International, latest edition). All culverts must be designed to withstand H-20 loading in accordance with the American Association of State Highway and Transportation Officials' (AASHTO's) *Standard Specifications for Highway Bridges* (American Association of State Highway and Transportation Officials, latest edition) and the culvert manufacturer's design recommendations.

The minimum pipe diameter for culverts within the public right-of-way (ROW) is 24 inches. Roadside ditch culverts for private driveways must have a diameter of at least 12 inches. When box culverts reach or exceed a width of 8 feet, the minimum height must be 6 feet.

9.4.3 Inlets and Outlets

For the design of culvert inlets and outlets, the designer must consider compatibility with the upstream and downstream channels, including geometry, hydraulics, and aesthetics. All culverts must be designed with headwalls, wingwalls, and aprons, or with flared end sections at the inlet and outlet. Flared end sections may be used on pipes with diameters up to 3 feet; however, the length of the required headwall may be longer for larger diameter pipes. In these cases, wingwalls or boulders may be used to reduce the headwall length. A footing is required for headwalls of pipes with diameters larger than 4 feet. All culvert entrances must be designed to minimize head losses. Refer to Volume 2, Chapter 11: Culverts and Bridges of the MHFD Manual for criteria and details regarding the layout and configuration of culvert headwalls and wingwalls. Construction of headwalls and wingwalls must be in accordance with CDOT's *M Standards* (Colorado Department of Transportation, latest edition).

Outlet protection is required at all culvert outfalls to minimize the potential for erosion and scour immediately downstream of culverts. Outlet protection, such as riprap armoring or concrete aprons, helps to stabilize the transition from the culvert to the downstream channel. For culverts with supercritical exit flow, stilling basins may be required for energy dissipation.[37] When a stilling basin is used to dissipate energy, the downstream sill elevation for the basin must be at least 2 feet below the invert of the culvert outlet. The impact of tailwater conditions at the culvert must also be analyzed in the context of outlet protection. See Volume 2, Chapters 9: Hydraulic Structures and 10: Culverts and Bridges of the MHFD Manual, as well as Chapter 8 of this

[37] Stilling basins are typically required when the Froude number is 1.7 or greater.

Manual, for specific guidance and criteria on outlet protection. The MHFD-Culvert workbook may also be used for relevant calculations.

9.4.4 Allowable Headwater Elevation

Culverts must pass the 100-year peak flow with a headwater depth that is no more than 1.5 times the culvert diameter (or rise dimension, for non-circular culverts), as shown in Equation 9-1:

$$\frac{H_w}{D} \leq 1.5 \qquad \textbf{Equation 9-1}$$

where:

H_w = headwater depth (feet)

D = culvert diameter (circular culverts), or culvert rise (non-circular culverts) (feet)

Excessive ponding at culvert entrances will not be allowed if it is likely to cause damage to surrounding properties or the roadway.

9.4.5 Velocity and Slope

Culvert slopes and velocities must be designed to prevent sedimentation while avoiding excessive velocities that could cause scour and abrasion. The minimum culvert slope is 0.5%. The minimum allowable barrel velocity is 3 feet per second (fps) for the 2-year peak flow, to facilitate self-cleaning. The maximum allowable velocity for the 100-year peak flow is 12 fps.

9.4.6 Tailwater Effects

Any culverts that are located on or discharge to a major or minor drainageway must consider potential tailwater effects. For culverts located on major or minor drainageways, the 100-year WSEL of the drainageway downstream of the culvert shall be used as the tailwater elevation for evaluating maximum headwater elevations. When a culvert is located on a tributary and discharges into a major drainageway, the 10-year WSEL of the major drainageway may be used as the tailwater elevation for evaluating maximum headwater elevations, to account for differences in the timing of peak flows for the tributary and the major drainageway. For the design of energy dissipation measures, the design calculations should be performed without consideration of tailwater effects.

9.4.7 Safety Grates

Safety grates shall be implemented where required by MHFD criteria. The design of safety grates must be in accordance with all relevant MHFD criteria.

9.4.8 Emergency Overflow Path

An emergency overflow path must be provided above the opening of each culvert. The culvert emergency overflow discharge is dependent on the cross-sectional area of the culvert. For culverts with a cross-sectional area less than 20 square feet, Equation 9-2 shall apply:

$$Q_{Overflow} = Q_{100}$$ **Equation 9-2**

where:

$Q_{Overflow}$ = culvert emergency overflow discharge (cubic feet per second)

Q_{100} = 100-year peak discharge (cubic feet per second)

For culverts with a cross-sectional area greater than or equal to 20 square feet, Equation 9-3 shall apply:

$$Q_{Overflow} = Q_{100} * \frac{20 + 0.2 * (A_O - 20)}{A_O}$$ **Equation 9-3**

where:

$Q_{Overflow}$ = culvert emergency overflow discharge (cubic feet per second)

Q_{100} = 100-year peak discharge (cubic feet per second)

A_O = culvert cross-sectional area (square feet)

The emergency overflow path must provide a route that is free of structures or obstructions from the point of overtopping to the point where flow returns to the open channel. A drainage easement must be provided for the emergency overflow path (see Chapter 3). Emergency overflows must not negatively impact structures or properties along the flow path. The lowest point of entry[38] (LPE) of all structures along the emergency overflow path must have a minimum of one foot of freeboard above the emergency overflow WSEL.

9.4.9 Grade-Separated Trail Crossings

In some cases, a culvert may be combined with a grade-separated trail crossing. When a culvert is combined with a grade-separated trail crossing, the requirements included in the CoA's Parks, Recreation, and Open Space (PROS) Department's *Dedication and Development Criteria Manual* must be followed.

9.4.10 Allowable Sizing Methods

The MHFD Manual includes detailed instructions regarding the design procedure for culverts that must be followed for the design of culverts in the CoA. The MHFD also provides spreadsheet workbooks for drainage design; engineers are strongly encouraged to use the MHFD-Culvert workbook for culvert design. Other acceptable computer applications include the FHWA's HY-8 program (Federal Highway Administration, latest edition) and the United States Army Corps of Engineers' (USACE's) Hydrologic Engineering Center River Analysis System (HEC-RAS) software (United States Army Corps of Engineers, latest edition). Other programs

[38] The lowest point of entry (LPE) is the lowest elevation at which surface water may enter a structure, such as the elevation of the bottom of a door frame, or the elevation of the top of a basement window well. The LPE is distinct from the lowest floor elevation (LFE), though in some cases the elevations of each may be identical. See Chapter 3 for definitions of the LPE and LFE.

that implement the same FHWA equations are acceptable as long as a full listing of the program inputs and outputs is provided in an easy-to-review format with the drainage report (see Chapter 3). Capacity charts and nomographs may be used in accordance with guidance from the MHFD Manual or the *Hydraulic Design of Highway Culverts* (Schall, Thompson, Zerges, Kilgore, & Morris, 2012).

9.5 BRIDGE DESIGN CRITERIA

Bridges are designed to carry pedestrian and/or vehicular traffic over a surface water drainageway with minimal disturbance to flow. This section includes criteria for the hydraulic design of bridges and is not intended to address structural design. For structural guidance, engineers are directed to AASHTO'S *Standard Specifications for Highway Bridges* (American Association of State Highway and Transportation Officials, latest edition) and CDOT's *Bridge Design Manual* (Colorado Department of Transportation, latest edition).

The design of a bridge is highly dependent on site-specific conditions, including the roadway classification and debris potential of the stream. Most bridges will create some localized disruption to flow which may result in constriction of the stream, backwater, increased flow velocity, and scour potential under the bridge. Given the array of unique site constraints that may be present at a bridge crossing, engineers are encouraged to consult with the CoA early in the design process.

9.5.1 Bridge Design Event

Bridges in the CoA designed to convey vehicular traffic must be designed to convey the 100-year peak flow beneath the bridge with at least 2 feet of freeboard between the 100-year WSEL and the low chord of the bridge (see Section 9.5.3 below). In some cases, a larger design event or additional freeboard may be appropriate for critical infrastructure.

Bridges designed to convey only pedestrian traffic (i.e., pedestrian bridges) must be designed to pass the 10-year peak flow without overtopping, and low water crossings must be designed to convey the 2-year peak flow without overtopping (see Section 9.5.5 below).

9.5.2 Scour

A scour analysis must be performed for all bridges to ensure the structure will withstand potential degradation of the channel during large flow events. The scour analysis must be performed following the methodology outlined in FHWA's Hydraulic Engineering Circular No. 18 (HEC-18): *Evaluating Scour at Bridges, Fifth Edition* (Arneson, Zevenbergen, Lagasse, & Clopper, 2012).

Bridges designed to convey vehicular traffic must be designed to resist scour in a 100-year storm event, and to account for the corresponding scour design flood and scour design check flood (which will be greater than the 100-year event) calculated per HEC-18 guidance (Arneson, Zevenbergen, Lagasse, & Clopper, 2012). Pedestrian bridges must be designed to resist scour in a 25-year storm event, and low water crossings must be designed to resist scour in a 10-year storm event. If utilities are incorporated beneath a crossing, the crossing shall be evaluated for scour as if it were a vehicular bridge (i.e., resist scour in a 100-year storm event and account for the corresponding scour design flood and scour design check flood).

The following publications may be consulted for additional guidance for evaluating bridge scour and implementing countermeasures:

- HEC-18: *Evaluating Scour at Bridges, Fifth Edition* (Arneson, Zevenbergen, Lagasse, & Clopper, 2012).

- HEC-20: *Stream Stability at Highway Structures, Fourth Edition* (Lagasse, Zevenbergen, Spitz, & Arneson, 2012).

- HEC-23: *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance, Volumes 1 and 2, Third Edition* (Lagasse, et al., 2009).

9.5.3 Freeboard

A minimum of 2 feet of freeboard is required between the low chord of a bridge and the 100-year WSEL to accommodate waves, debris, and ice. To account for possible backwater effects, the freeboard must be calculated based on the WSEL at the cross section upstream of the start of the contraction zone approaching the bridge.

9.5.4 Emergency Overflow Path

The evaluation of emergency overflow paths for bridges is dependent on the clear span of the bridge. Bridges with a clear span greater than or equal to 20 feet do not need to evaluate the emergency overflow path for the bridge. Bridges with a clear span less than 20 feet or with spans broken into multiple cells must evaluate the emergency overflow path in the same manner as for culverts (see Section 9.4.8 above).

9.5.5 Pedestrian Bridges and Low Water Crossings

Pedestrian crossings can vary from small low water crossings to large pedestrian bridges for regional trails. For all pedestrian crossings, consideration must be given to: floodplain impacts; debris accumulation and passage; sediment transport; potential blockage of other nearby conveyance structures and the cascading effects on the pedestrian crossing in question; structural design; clearance of structural members to various storm events' WSELs; maintenance responsibility and cost; and construction and replacement cost of the structure. Coordination with multiple CoA departments is typically required for pedestrian bridges and low water crossings, particularly the PROS department.

Pedestrian bridges must be designed to pass the 10-year peak flow without overtopping, and low water crossings must be designed to pass the 2-year peak flow without overtopping. Variances may be considered for major stream corridors (e.g., Sand Creek). Pedestrian bridges and low water crossings must comply with the scour criteria in Section 9.5.2 above. Pedestrian bridges should be designed to span the bankfull channel when feasible. The CoA reserves the right to prohibit pedestrian bridges and/or low water crossings on streams with significant sediment loads due to aggradation and degradation concerns upstream and downstream of the crossing, respectively.

All pedestrian crossings (including pedestrian bridges and low water crossings) must have adequate protection on both the downstream and upstream sides of path approaches to the crossing to avoid damage from overtopping flows. Flow which overtops a path can cause damage to the upstream path edge and scour along the downstream path edge. A thickened edge extending two feet below the path surface shall be applied to both the downstream and upstream edges of path approaches to a pedestrian crossing at any location where flow overtopping is anticipated. Soil riprap may also be implemented for added protection. See

Volume 2, Chapter 10: Stream Access and Recreational Channels of the MHFD Manual for additional guidance on path overtopping protection.

For low water crossings, see the PROS's *Dedication and Development Criteria Manual* for a standard low water crossing detail. This detail is a helpful starting place but must be modified to fit the site-specific conditions. Note that low water crossings are not an acceptable alternative for vehicular traffic, except to provide maintenance access.

Handrail impacts to hydraulic conditions should be evaluated. The hydraulic analysis must assume that the handrails are clogged during a storm event. Breakaway bridges and rails are not allowed in the CoA. Handrails shall be designed in conformance with PROS criteria.

9.5.6 Grade-Separated Trail Crossings

In some cases, a bridge may incorporate a grade-separated trail crossing. When a bridge incorporates a grade-separated trail crossing, the requirements included in PROS's *Dedication and Development Criteria Manual* must be followed.

9.5.7 Hydraulic Analysis Methods for Bridges

The guidance for the hydraulic analysis of bridges given in Volume 2, Chapter 11: Culverts and Bridges of the MHFD Manual must be followed. Additional references for bridge hydraulics include:

- Hydraulic Design Series No. 7 (HDS-7): *Hydraulic Design of Safe Bridges* (Zevenbergen, Arneson, Hunt, & Miller, 2012).
- HEC-18: *Evaluating Scour at Bridges, Fifth Edition* (Arneson, Zevenbergen, Lagasse, & Clopper, 2012).
- HEC-20: *Stream Stability at Highway Structures, Fourth Edition* (Lagasse, Zevenbergen, Spitz, & Arneson, 2012).
- HEC-23: *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance, Volumes 1 and 2, Third Edition* (Lagasse, et al., 2009).
- *Bridge Design Manual* (Colorado Department of Transportation, latest edition).
- *Highway Drainage Guidelines* (American Association of State Highway and Transportation Officials, latest edition).
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CHAPTER 10.0 DETENTION

10.1 INTRODUCTION

This chapter provides technical criteria for the planning and design of stormwater detention facilities in the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 2, Chapter 12: Storage are hereby incorporated by reference. Except as modified herein, all detention facility designs must be in accordance with the MHFD Manual.

Detention of flood flows for all development and redevelopment projects is required in accordance with these criteria for the purpose of reducing urban drainage problems. Detention facilities store excess stormwater runoff from increased watershed imperviousness and release this excess runoff at controlled rates to mimic predevelopment peak flow rates across a range of event frequencies.

10.2 RUNOFF REDUCTION AND DETENTION

Implementation of watershed-based runoff reduction practices, following Step 1 of the MHFD Four Step Process (Mile High Flood District, latest edition), is important in conjunction with detention because the watershed-based measures reduce the quantity of runoff that must be managed in more centralized detention facilities and slow the runoff response of the watershed. Runoff reduction practices use receiving pervious areas (RPAs) to infiltrate runoff by directing flow from impervious surfaces to pervious areas such as native grass buffers, native grass swales, and other landscape areas. Also known as low impact development (LID) and green infrastructure (GI), runoff reduction practices mimic natural hydrologic conditions (i.e., pre-development conditions) to minimize adverse in-channel impacts associated with increased imperviousness. CoA does not require, but encourages, runoff reduction on all development and redevelopment projects when feasible. Follow procedures in the MHFD Manual to calculate potential reductions in required storage volumes based on implementation of these measures.

10.3 DETENTION AND WATER QUALITY TREATMENT REQUIREMENTS AND APPROACHES

Detention, including the water quality capture volume (WQCV), excess urban runoff volume (EURV), and 100-year storage volume, are required for all development and redevelopment projects in the CoA, including construction of new roads, expansion of existing roads, and construction of large, paved multi-use paths. In areas with regional detention facilities, this requirement may be satisfied by demonstrating that the regional facility was designed to accommodate the area and imperviousness of the proposed development. Because it is impractical to implement detention ponds for small additions of impervious area, the CoA requires a tiered approach based on the amount of impervious area that is being created. The are described in detail below, and are shown in Table 10-1:

1. For development or redevelopment projects that create less than 1,000 square feet of new impervious area, formal detention and water quality facilities are not required. New impervious areas should be designed to drain to pervious areas to the maximum extent practicable.

2. For development and redevelopment projects[39] that add from 1,000 up to 5,000 square feet of new impervious area, detention and water quality requirements may be addressed by designing RPAs (such as linear trail projects or sidewalks with buffers) that will infiltrate sufficient runoff to meet water quality and detention requirements. For redevelopment projects, detention is only required for the additional impervious area; however, all water quality facilities must provide WQCV for the entire tributary area to the facility. To accomplish this, the following criteria apply:

    a. Runoff from the impervious area must be discharged to the RPA (i.e., buffer, swale, or other engineered pervious area) as sheet flow. For impervious areas larger than approximately 1,000 square feet, it may be necessary to have multiple RPAs treating runoff to effectively achieve sheet flow conditions. Level spreaders may be used to convert shallow concentrated flow to sheet flow.

    b. The RPA must be designed in accordance with the Receiving Pervious Area fact sheet from Volume 3 of the MHFD Manual and must incorporate a minimum of 6 inches of topsoil.

    c. The ratio of unconnected impervious area (UIA) to RPA must be 1:2 (UIA:RPA) or lower to achieve flood attenuation (e.g., the UIA must drain to a pervious area that is at least twice as large as the disconnected area).

    This approach also may be used for projects that add from 1,000 up to 5,000 square feet of impervious area only if the impervious area can be subdivided into smaller areas that can be managed through using RPA infiltration to provide water quality treatment and flood attenuation.

    This approach also may be used for linear projects such as multi-use paths or rural roadway widening projects when the runoff from the path or roadway can be directed to a RPA that runs parallel to the path with a ratio of UIA to RPA of 1:2 (UIA:RPA) or lower.

    If there is not sufficient pervious area on the site to achieve the necessary ratios, a small FSD bioretention facility or manufactured treatment device (MTD) meeting the criteria in Chapter 11 may be used.

3. For development and redevelopment projects[39] that add more than 5,000 square feet of new impervious area, Full Spectrum Detention (FSD) is required unless the impervious area can be subdivided and managed via RPA infiltration.

    a. When fewer than 2 acres of imperviousness drain to a FSD facility, the water quality component of the FSD facility must be an infiltration- or filtration-based stormwater control measure (SCM) such as bioretention or a sand filter. This is because an extended detention basin (EDB) with a surface release for a site of this scale requires orifice sizing that is highly susceptible to clogging.

    b. When 2 acres or more of imperviousness drain to a FSD facility, the water quality component of the FSD facility may be any of the storage-based or infiltration-based SCMs in Volume 3 of the MHFD Manual, including EDBs.

[39] Excluding roadway projects. For roadway projects, see Item 5.

4. For redevelopment projects only, if the impervious area is increased by less than 10% of the entire site area and the total new impervious area is less than 5,000 square feet, additional new detention is not required (i.e., the above tiered approach in Items 1 and 2 do not apply), provided there is no impact on existing infrastructure (i.e., storm drains; water quality and detention facilities; inlets, gutters, and streets; etc. have adequate capacity to receive the additional runoff from the new impervious area without violating the criteria in this Manual) and this has been demonstrated in the drainage report/letter submitted with the site plan. Note that stormwater quality treatment is required if the new impervious area exceeds the CoA's Municipal Separate Stormwater System (MS4) permit thresholds, even if it is less than 10% of the entire site area. See Chapter 11 for additional information on MS4 requirements.

5. For roadway construction projects (including roadway redevelopment/retrofit and off-site roadway construction) which add less than one acre of new impervious area, hydrodynamic separators[40] (HDSs) may be used to provide water quality treatment. (Note: HDSs do not provide significant flow attention.):

    a. For roadway redevelopment or retrofit construction (e.g., adding a lane to an existing roadway), HDSs meeting the requirements in Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual may be allowed if the added impervious area is less than one acre. If the added impervious area exceeds one acre, water quality and detention must be provided either via new facilities or modifications/improvements to existing facilities.

    b. For off-site roadway construction (e.g., roads that must be extended beyond the development parcel's boundaries) with an added impervious area of less than one acre, HDSs meeting the requirements in Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual may be allowed on an interim basis to provide water quality treatment until the property served by the off-site roadway develops and provides water quality and detention for the off-site roadway area as a part of the development's permanent water quality and detention facilities.

        If the added impervious area exceeds one acre, water quality and detention must be provided. In these instances, temporary drainage easements may be considered: temporary detention/water quality facilities for the added roadway impervious area may be constructed and held within a temporary easement until permanent detention/water quality facilities are constructed, at which point the area held in the temporary easement can be returned to the developer.

[40] Note that the use of hydrodynamic separators (HDSs) may be restricted by a future version of the CoA's MS4 permit.

Table 10-1. Detention and Water Quality Treatment Approaches

CoA Tier	Project Conditions	Runoff Reduction*	Detention and Water Quality Requirements	
1	< 1,000 SF of new impervious area	Implement to maximum extent practicable.	Not required.	
2	Between 1,000 SF and 5,000 SF of new impervious area	Runoff reduction approaches encouraged.	Direct runoff as sheet flow at ratio of 1:2 UIA:RPA or lower.‡ Design RPA per Receiving Pervious Area fact sheet from Volume 3 of MHFD Manual; minimum 6 inches of topsoil.	
3	≥ 5,000 SF of new impervious area	Runoff reduction approaches encouraged.	FSD required.	Impervious Area < 2 acres: water quality via infiltration/filtration SCM; no EDB.
				Impervious Area ≥ 2 acres: water quality via any appropriate SCM per Chapter 11.
4	Redevelopment if new impervious area both < 10% existing impervious area and < 5,000 SF	Runoff reduction approaches encouraged.	Numbers 1-2 of this table not applicable, provided existing infrastructure has adequate capacity for added flows.Δ	
5	Roadway construction with new impervious area < 1 acre and < 1 acre of disturbance	Runoff reduction approaches encouraged.	Roadway Redevelopment/Retrofit	HDSs may be allowed as described in Chapter 11. Note: HDSs provide only water quality treatment.Ω
			Off-site Roadway Construction	HDSs may be allowed on interim basis as described in Chapter 11. Note: HDSs provide only water quality treatment. Ω

* Runoff reduction must be implemented in a manner that does not cause adverse impacts to structures or adjacent property.

‡ If necessary ratio cannot be met, FSD bioretention or MTD per Chapter 11 may be used.

Δ MS4 permit thresholds may require water quality treatment even if new impervious area less than 10% of existing impervious area. See Chapter 11.

Ω HDSs may be restricted by future MS4 permits.

10.4 FULL SPECTRUM DETENTION

Full Spectrum Detention (FSD)

FSD is a storage-based approach to water quality, channel stability, flood control, and peak discharge attenuation. It is based on detaining the EURV and releasing it over approximately 72 hours (unless reduced time required in airport zone). The EURV is essentially the increase in runoff volume from undeveloped to urbanized conditions, as shown in Figure 10-1. The EURV includes the WQCV, which corresponds to the 80th percentile storm runoff event. FSD helps to offset some of the impacts that urbanization has on the downstream stream network.

All detention facilities must be designed to provide FSD in accordance with Volume 2, Chapter 12: Storage of the MHFD Manual. As such, three control volumes are integrated into the design: the WQCV, the EURV, and the 100-year storage volume.

In the CoA, the WQCV is a "nested" part of the EURV and the 100-year event volume. In other words, the WQCV is included as a part of the EURV, and the EURV is included within the 100-year volume. Therefore, it is not necessary to add a fraction of the WQCV or EURV to the 100-year volume. The 100-year event volume must be provided below the crest elevation of the emergency spillway, with peak discharges in excess of the 100-year storage capacity discharged via the spillway. The embankment height must be sufficient to pass emergency spillway flows with freeboard as described in Section 10.9.4. Figure 10-2 illustrates the nested WQCV, EURV, and 100-year volumes.

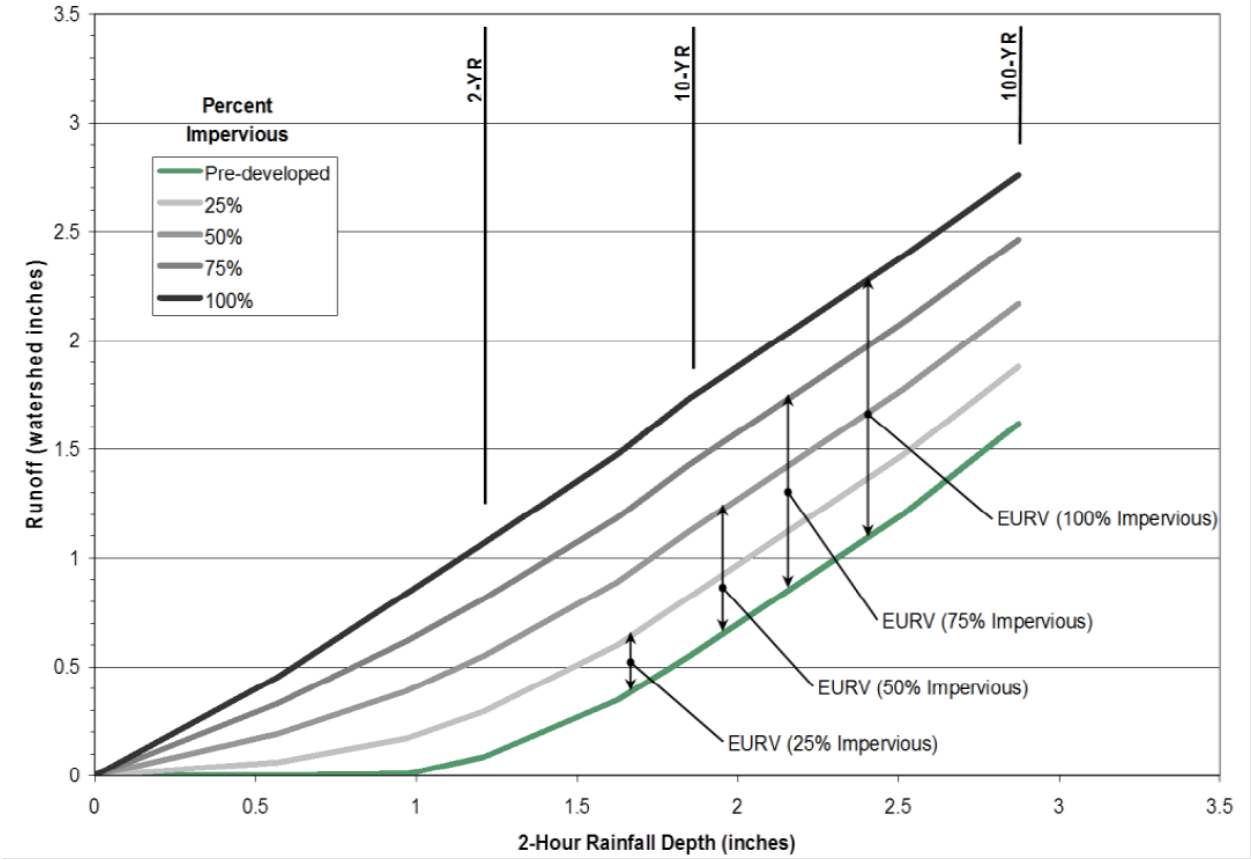

Figure 10-1. EURV Concept – Runoff versus 2-hour Rainfall Depth – Consistent Excess Urban Runoff Depth for Given Levels of Imperviousness (Mile High Flood District, latest edition)

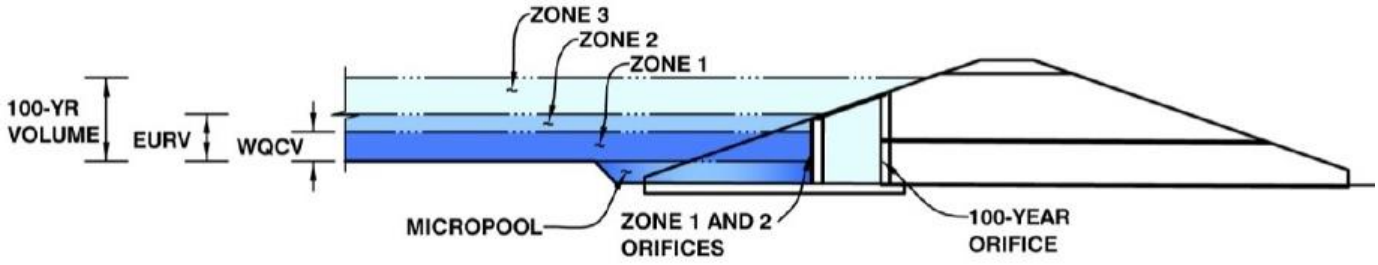

Figure 10-2. Illustration of "Nested" Water Quality and Detention Volumes and Freeboard Requirements for Detention Ponds, Extended Detention Basin Designed for FSD (Mile High Flood District, latest edition)

The three zones shown in Figure 10-2 include:

- Zone 1 provides the WQCV and is released over the drain time (12 to 40 hours) corresponding to the type of SCM.
- Zone 2 includes the portion of the EURV that is in addition to the WQCV and has a volume equal to the difference between the EURV and WQCV. The drain time for Zone

2 ranges from 12 to 32 hours depending on the type of SCM and must drain 97% of the EURV and WQCV within 72 hours, unless within an airport zone in which case shorter drain times are required as described in Section 10.14.

- Zone 3 has a volume equal to the 100-year storage volume minus the EURV. The maximum release rate for the 100-year storm event is based on 90 percent of the pre-development 100-year peak flow rate in accordance with MHFD criteria. The 100-year release rate must be calculated using methods in Volume 2, Chapter 12: Storage of the MHFD Manual.

Figure 10-3 illustrates typical steps for integrating FSD with SCMs that provide the WQCV or water quality peak flow (WQPF). References describing methods for integrating these three zones, calculating volumes, determining drain times, and calculating the 100-year release rate include:

- Chapter 11 of this Manual;
- Volume 2, Chapter 12: Storage of the MHFD Manual; and
- SCM fact sheets in Volume 3 of the MHFD Manual.

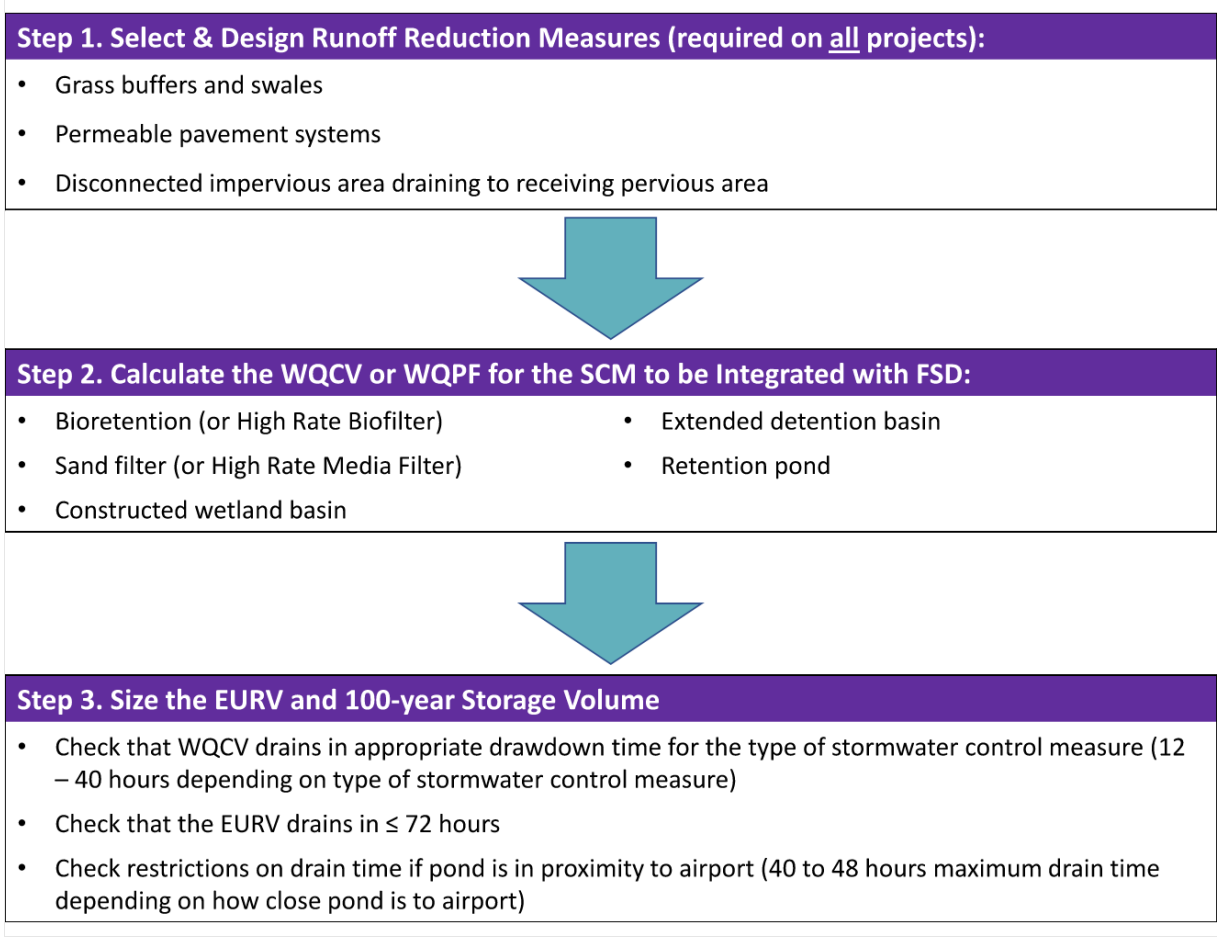

Figure 10-3. Steps to Integrate FSD and Water Quality in CoA

When using this approach, it is critical to select the appropriate type of SCM in Step 2. For example, EDBs are not suitable when the impervious area draining to the facility is less than 2 acres because of the very small orifice sizes required at this scale that are susceptible to plugging; instead; bioretention, sand filters, high rate biofilters, and high rate media filters are suitable SCMs to combine with FSD at this scale. Alternatively, infiltration-based SCMs may not be appropriate based on the underlying soil and proximity of buildings, roadways, retaining walls, or other structures with foundations vulnerable to seepage. Geotechnical analysis may be necessary to confirm the suitability of infiltration-based SCMs and determine if additional protection measures (e.g., lining) are necessary.

FSD may be omitted from an individual site when an existing downstream regional detention facility serves the development or redevelopment and there is adequate conveyance capacity between the site and the facility for developed flows. When a development or redevelopment site is served by an existing downstream facility, the applicant must verify that the downstream facility has adequate capacity for flows from the proposed development, meets current standards for spillways, emergency overflows, access, easements, and other criteria in this chapter, and has an approved and recorded Inspection and Maintenance (I&M) Plan. On-site water quality treatment is required unless the regional facility provides the WQCV.

10.4.1 On-site, Subregional, and Regional Detention

There are three basic approaches for locating FSD facilities in relation to their upstream watersheds. These include:

- **Regional Detention** – Regional detention basins are major detention facilities which benefit several adjacent parcels owned by different subdividers. By definition, these facilities provide detention of stormwater runoff generated from an area of greater than 130 acres and serve multiple property owners and/or subdividers (see Chapter 3). These facilities are typically identified in a drainage master plan. In some cases, regional detention is effective for watershed areas larger than one square mile and for multiple facilities arranged in series; however, due to the complexities associated with how facilities in series function within a large watershed, these types of configurations must be modeled and approved in the context of a formal CoA submittal as part of a master planning process. Note that while many regional detention facilities are publicly maintained, facilities of this scale also may be privately maintained, especially if they do not have a regional purpose beyond the immediate surrounding development.

- **Subregional Detention** – Subregional detention generally refers to facilities that serve multiple landowners or lots but have a total watershed of less than 130 acres. By definition, these are minor detention facilities (see Chapter 3). Many detention facilities located within residential communities are subregional because they serve multiple lots that are individually owned. Subregional detention facilities are located offline from the receiving stream. Like regional facilities, subregional detention facilities may be constructed to serve several landowners in the upstream drainage area but are more typically designed and constructed by a single developer to serve an area being developed. Unless otherwise approved, subregional facilities are privately owned and maintained.

Distributed Full Spectrum Detention

Distributed FSD refers to an approach using FSD in a way that preserves the headwater (low order) tributaries in a watershed. These small, usually dry tributaries are the "capillaries of the catchment" and provide multi-faceted benefits related to infiltration, groundwater recharge, aesthetics, and other community values. Distributed FSD facilities typically treat drainage areas from 10 to 30 acres. When this approach is used in conjunction with on-lot runoff reduction practices, benefits of smaller tributaries can be preserved instead of sacrificing these features to developed peak flow rates and heavily engineered conveyances.

- **On-site Detention** – On-site detention refers to facilities serving a single lot and is generally employed for commercial or industrial sites. On-site detention facilities typically serve small drainage areas up to approximately 20 to 30 acres. In some cases, on-site detention facilities may serve larger areas, but they are most effective at smaller scales where they can manage runoff near the source, thereby protecting smaller drainageways in the headwaters of the watershed that are often heavily impacted by developed flows when regional or subregional approaches are used. On-site detention facilities are privately owned and maintained.

Detention facilities with tributary drainage areas less than 130 acres may be considered "regional" if they serve regional objectives and have adequate assurances for long term

operation and maintenance. It is also important to recognize the schematic nature of master-planned detention facilities. Primary objectives at the master planning level are to identify the location, volumetric storage requirements, and allowable release rates for the detention facility. Polygons shown in master plans for detention facilities are schematic, and the design engineer for a particular facility must fit the design of the facility to the site, while meeting the requirements of the master plan and creating a facility that is compatible with surroundings. It is common for the design of a detention pond to evolve from the master planning phase to the preliminary design phase; as a result, storage volumes and release rates may change as plans are refined. In these cases, peak flows must be regulated to the master plan levels at downstream design points.

Note that for regional master planning and floodplain management, MHFD policy typically recognizes the effects of detention facilities on hydrology when these conditions are met:

- The facility serves a watershed area that is at least 130 acres or otherwise provides substantial flood reduction.
- The facility is owned or controlled by a public agency through a legal document, and maintenance is either performed or required by a public agency.
- The public agency has committed to ensure that the detention facility continues to operate in perpetuity as designed.

In some cases, detention facilities serving fewer than 130 acres may be recognized in regional master planning and floodplain management if they provide meaningful reductions in peak flows, serve regional purposes, and are contextual to the system.

10.4.1.1 Online and Offline Facilities

Detention facilities can be online or offline. Online facilities are constructed on major drainageways with watersheds of 130 acres or larger and are usually regional facilities. Online facilities that serve drainage areas larger than a square mile, or that will have perennial baseflows in the future, must be designed as detention-only facilities with the WQCV and EURV provided upstream and offline. This is to maintain sediment continuity in the stream and reduce the amount of sediment removal required to maintain the detention pond.

Offline facilities serve smaller drainage areas and typically are subregional or on-site facilities. Aside from seasonal irrigation return flows, these facilities generally do not have baseflow. Offline facilities are important because they provide treatment and detention of stormwater before runoff is

WQCV for Entire Contributing Watershed

WQCV facilities must be designed for the WQCV from the entire contributing watershed, and the tributary area to a single WQCV facility must not exceed one square mile. For this reason, WQCV facilities are commonly located offline since the most downstream facility in a series must treat the entire WQCV for the watershed regardless of upstream treatment facilities.

discharged to a water of the State[41] and help to protect stream stability by effectively managing stormwater in headwater areas of the watershed to the benefit of downstream infrastructure and waterways.

See Volume 2, Chapter 12: Storage of the MHFD Manual for additional information and illustrations of these approaches to detention.

10.4.1.2 Regional Detention Requirements

Regional detention is required when called for in a CoA-approved master plan. Regional detention facilities must meet the following requirements:

1. Regional detention facilities shall be designed based on fully developed flows from the upstream watershed. Effects of existing upstream regional detention facilities may be accounted for when the facilities are publicly maintained.

2. For the purposes of analyzing off-site runoff to regional detention facilities from undeveloped areas, engineers may assume that off-site flows will be attenuated to predevelopment levels if off-site areas will be managed via a publicly owned or quasi-publicly owned (e.g., metro district) regional or subregional detention facility.

3. Ownership and maintenance responsibilities must be clearly defined in an I&M Plan. For privately maintained facilities, the I&M Plan shall be recorded with the property to ensure the proper function of the facility in perpetuity.

4. There must be stable means to convey the fully developed flows from the site to the regional or subregional detention facility. When a regional or subregional facility provides the WQCV, and runoff from a development or redevelopment site discharges to a Water of the State[41,42] before reaching the regional or subregional treatment facility, then the applicant must provide sufficient justification in the Final Drainage Report (FDR) submittal to show that instream water quality between the site and the subregional or regional facility is adequately protected from adverse impacts from the stormwater discharge. See Chapter 11 for additional information. In addition, the stream channel between the discharge point of the development site and the regional WQCV facility must be stabilized.

5. When a regional detention facility is constructed in a phased manner, development in the tributary watershed must not exceed the level supported by the water quality and detention storage volumes and release rates provided by the facility. Otherwise, temporary on-site detention must be provided and designed to meet all CoA detention standards.

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[41] Per the Colorado Water Quality Control Act, a State Water is “any and all surface and subsurface waters which are contained in or flow in or through this state, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed” (Colorado Revised Statutes [CRS] §25-8-103).

[42] “Water of the State” as defined by the Colorado Department of Public Health and Environment (CDPHE) at the time of project design.

6. Design of the regional detention facility must be completed in accordance with the MHFD Manual and the requirements in Colorado Revised Statues (CRS) §32-11-221(1) for drainage facilities. All regional facilities must be designed to meet the MHFD's Maintenance Eligibility Program (MEP) requirements and must satisfy the design, construction, and vegetation criteria and requirements in the most current version of the MHFD Manual and Maintenance Eligibility Guidelines (Mile High Flood District, 2012). The design must also consider the following criteria:

    a. For regional detention basins, designers should consider compatibility with surrounding land uses as well as maintenance access. For example, a detention basin in a residential or open space area should consider potential aesthetic and/or recreational uses (as may be determined by the Parks, Recreation, and Open Space [PROS] Department), while a detention basin serving an industrial area would not likely include such considerations. If a regional detention basin is adjacent to a park, open space, or multi-use facility, early coordination with PROS is highly recommended.

    b. Detention ponds that are jurisdictional dams will only be allowed in rare circumstances. Alternatives such as expanding the pond footprint or using multiple ponds to achieve the same flow attenuation objectives should be considered. When good design can avoid creating embankment heights that trigger state dam safety regulations, this is desirable. See Section 10.8.1 for additional information on jurisdictional dams.

    c. Regional detention basins must be located on publicly owned lands whenever possible. At a minimum, a drainage easement allowing the CoA access to the basin for inspection and maintenance must be provided.

    d. If regional flood control detention facilities incorporate the regional WQCV for stormwater quality, developments upstream of the regional facility must provide on-site stormwater quality enhancement through runoff reduction practices.

Note that information on regional detention facilities in master plans is schematic in nature. Regional detention facilities must be designed to accommodate site-specific conditions and constraints while achieving the master plan release rates.

10.4.2 Sizing FSD Facilities

Several methods can be used to size FSD facilities; these are summarized in Table 10-2. The most common approach is the MHFD-Detention workbook, though other procedures may be more appropriate based on site and project conditions. The allowable release rates for a FSD facility shall be determined in accordance with Volume 2, Chapter 12: Storage of the MHFD Manual. For contributing catchment areas with less than 2 acres of impervious area, infiltration-based SCMs (e.g., bioretention facilities or sand filters) designed for FSD must be used instead of EDBs to avoid clogging of small orifices.

Table 10-2: FSD Sizing Methods

Detention Sizing Method	Appropriate Use
MHFD Simplified Equations	Primarily used for preliminary calculations and master planning. May be applied for simple catchments less than 10 acres in size. Should not be used when routing of hydrographs is required. Use simplified equations from Volume 2, Chapter 12: Storage of the MHFD Manual for EURV and 100-year volume calculations and follow MHFD criteria to calculate allowable release rates.
MHFD Detention Workbook	Can be applied to the full range of catchment sizes. The MHFD-Detention workbook implements CUHP* runoff procedures and SWMM‡ routing.
CUHP*/SWMM‡	Can be used as alternative to MHFD-Detention workbook if desired or if site-specific conditions do not meet the assumptions of the MHFD-Detention workbook.

* CUHP = Colorado Urban Hydrograph Procedure (Urban Drainage and Flood Control District (now Mile High Flood District), latest edition).

‡ U.S. Environmental Protection Agency's Stormwater Management Model (United States Environmental Protection Agency, latest edition).

10.4.3 Preliminary Pond Footprint

As a part of the master planning process, it is necessary to ensure that sufficient area is reserved for detention. Equation 10-1 may be used to approximate the area that should be reserved for each detention facility. This equation provides a simplified approach for determining the area that must be kept for detention based on the information that is typically available at a master planning level; a more detailed methodology may be used instead if sufficient information is available.

Equation 10-1 assumes the detention facility is a rectangular prism and divides the total volume by the assumed depth of the facility to determine the reserved area from the total volume; if the depth of the facility is not known at the master planning stage, use 5 feet. A 1.5 estimation factor is also included in the equation to account for maintenance access paths, pond embankments, and other features of detention facilities not otherwise included in the total volume. Note that this approximation is deliberately conservative; as the design of a detention facility progresses through the preliminary and final design processes, it is anticipated that the pond footprint shall be revised. Note also that underestimating the pond footprint at the master planning stage may lead to insufficient area being held for detention, thus resulting in significant rework of the overall site design during the site planning phase.

$$A_i = \frac{1.5 * V_T}{D_A}$$ **Equation 10-1**

where:

A_i = Initial detention area to be reserved (acres).

V_T = Total Pond Volume per master plan hydrologic calculations (acre-feet).

D_A = Assumed Depth of pond (feet). If unknown, use 5 feet.

The area to be reserved per Equation 10-1 or an alternate methodology shall be included in the master planning process.

10.5 CERTIFICATION OF PONDS AND WATER QUALITY FACILITIES

All detention and water quality ponds and water quality devices must be certified. A Professional Engineer licensed in the State of Colorado must ensure and certify that each stormwater detention pond and/or water quality SCM is built according to the approved plans and specifications, and that the required detention volume (including the WQCV, if applicable) is met. See Chapter 2 for additional information regarding the certification of ponds and water quality facilities.

10.6 RELATIONSHIP TO ADJACENT PROPERTIES AND STRUCTURES

Impacts to upstream and downstream properties relative to proposed detention facilities must be evaluated and minimized through appropriate facility design. Designs must consider the effects on structures and land uses near detention facilities and plan accordingly to avoid (1) impacts from backwater and emergency overflows; (2) nuisance conditions such as stagnant water, mosquitos, appearance, odor issues, etc.; and (3) seepage into basements or crawl spaces.
Aurora Water (AW) reserves the right to require any development or redevelopment to provide detention as necessary to avoid adverse impacts to other properties.

10.7 MAINTENANCE

All detention facilities must be designed with adequate maintenance access and in a manner that facilitates maintenance. The following criteria apply for maintenance access:

- Drainage easements must be provided for all detention facilities.[43] The easement must encompass all components of the pond, including the embankment (with toe of slope), spillway, inlets, outlet structure (including outfall pipe), and any other areas that would be inundated under spillway design conditions. Ponds must not be included on platted lots. An access easement must be provided between the pond drainage easement or tract and the public right-of-way (ROW). Provide maintenance access to detention ponds from local streets. Access from arterial streets is discouraged. A license agreement is

[43] Note that a drainage easement provides the CoA the right to maintain facility, but not the obligation to do so. It is the responsibility of the owner or other designated entity to maintain private facilities.

required for private infrastructure within a drainage easement or ROW, such as private retaining walls or other features that do not affect the function of the pond.

- Provide maintenance access to all pond components, including: the top of the outlet; the micropool, orifice plate, and screening/grating; the low flow channel; and the forebay(s). For smaller ponds, some components, such as the micropool, forebays, outlet trash rack, and orifice plate, may be accessed from the perimeter of the pond with a vacuum truck or other equipment without the need for additional maintenance access along the pond bottom. If maintenance access is provided from the pond perimeter (in lieu of access within the pond itself), the engineer must demonstrate that maintenance equipment can reach the necessary pond components from the pond perimeter. For larger ponds, the trickle channel may also be designed to provide maintenance access. A trickle channel which also provides maintenance access must be wide enough to accommodate maintenance equipment and be made of sufficiently strong material to support maintenance equipment loading (see next bullet).

- Use an all-weather, stable surface for maintenance access. Stable surfaces include concrete, articulated concrete blocks, concrete grid pavement, or reinforced grass pavement. Below the 5-year water surface elevation (WSEL), maintenance access must be a hardened surface (e.g., concrete or drivable aggregate surface).[44] When concrete is used, the minimum thickness is 6 inches. Asphalt is not allowed. Select a surface that will support the heaviest type of equipment expected for pond maintenance when the subgrade is saturated. The types of equipment required for maintenance vary by pond size. Small excavators typically have operating weights of 30,000 to 40,000 pounds, and large excavators may have operating weights of more than 100,000 pounds (Caterpillar, 2023).

- The minimum width of maintenance access is 12 feet with no recovery zones. If maintenance access is greater than 150 feet, a turn-around or drive through option must be provided.

- The minimum turning radius for maintenance access is 30 feet. When the turning radius is less than 50 feet, the maintenance access must be widened as necessary to accommodate the turning movement of maintenance vehicles (e.g., tandem axle dump truck or vacuum truck).

- The maximum longitudinal slope for maintenance access is 10% (10:1 horizontal [H]:vertical [V]). For on-site detention facilities that serve no more than 5 acres, the maximum longitudinal slope may be as steep as 25% (4H:1V). A cross slope of 2% is required.

- Avoid maintenance access across the low flow channel. In some cases, it may be necessary to cross the low flow channel to access pond components. When this is the case, use a rolled curb for the section of the low flow channel that must be crossed, and design the portion of the low flow channel that will be crossed to avoid settlement or damage to concrete under design loads for maintenance equipment.

[44] If the maintenance access material differs above and below the 5-year WSEL, the 5-year WSEL shall be noted on the relevant plan sheets.

- Maintenance access must provide storage and staging areas for sediment and debris removal during maintenance activities. These areas must be identified in the I&M Plan for a detention facility.

- Note that all regional facilities must be designed in accordance with the criteria established in this Manual and in the MHFD Manual, and must also be designed to meet the MHFD MEP requirements, including those regarding maintenance access (see Item 6 in Section 10.4.1.2 above).

- In instances where maintenance access is multi-use with a trail, maintenance access shall be coordinated with PROS to ensure all requirements are met.

- I&M Plans are required for all detention and water quality facilities (on-site, subregional, and/or regional) unless the facility is owned and operated by the CoA. I&M plans are legal documents recorded with the property defining ownership and maintenance responsibilities. A template for I&M Plans is provided on AW's website. It is the responsibility of the applicant to use the most up to date I&M Plan templates from the CoA's website.

10.8 STATE ENGINEER'S OFFICE REQUIREMENTS

The Office of the State Engineer (SEO, also known as the Colorado Division of Water Resources) administers Colorado's Dam Safety Program and water rights, among other functions. This section provides guidance on jurisdictional dam and water rights notification requirements of the SEO.

10.8.1 Jurisdictional Dam Requirements

Jurisdictional dams will be allowed only in rare cases. Any dam constructed for the purpose of storing water with a surface area, volume, or dam height as specified in CRS §37-87-105, as may be amended, requires the approval of the plans by the SEO. Those facilities subject to state statutes must be designed and constructed in accordance with the criteria of the State, in addition to the criteria in this Manual. To the extent that SEO criteria and requirements differ from the requirements in this Manual, the more restrictive requirements apply. Construction of jurisdictional dams for detention facilities is strongly discouraged due to the higher level of hazard posed by a jurisdictional dam. In some cases, depending on the size of the detention facility, creation of a jurisdictional dam may be unavoidable. In these cases, compliance with the Colorado Rules and Regulations for Dam Safety and Dam Construction (2 CCR 402-1) is required (Colorado Department of Natural Resources, latest edition).

The CoA will refer any pond designs with embankments that appear to be greater than or equal to 9.5 feet in height to the SEO's Dam Safety Branch for review. Additional review time should be anticipated.

10.8.2 Water Rights Reporting Requirements for Stormwater Facilities

CRS §37-92-602(8) provides water rights-related legal protection for any regional or individual site stormwater detention and infiltration facility in Colorado, provided the facility meets these criteria:[45]

1. It is owned or operated by a governmental entity or is subject to oversight by a governmental entity (e.g., required under an MS4 Permit).

2. It continuously releases or infiltrates at least 97% of all of the runoff from a rainfall event that is less than or equal to a 5-year storm within 72 hours after the end of the event.

3. It continuously releases or infiltrates as quickly as practicable, but in all cases releases or infiltrates at least 99% of the runoff within 120 hours after the end of events greater than a 5-year storm.

4. It operates passively and does not subject the stormwater runoff to any active treatment process (e.g., coagulation, flocculation, disinfection, etc.).

This statute specifies that runoff treated in stormwater detention and infiltration facilities must not be used for any other purpose by the owner/operator/overseer (or that entity's designees), must not be released for subsequent diversion or storage by the owner/operator/overseer (or that entity's designees) and must not be the basis for a water right or credit (MacKenzie, 2016).

Under this statute, new stormwater detention and infiltration facilities must complete certain reporting requirements facilitated by an online mapping system for Stormwater Detention and Infiltration (SDI) Facility Notification (https://maperture.digitaldataservices.com/gvh/?viewer=cswdif). This information must be filed prior to civil plan approval of the facility and include the following:

1. Facility Location. Fill in "Aurora."

2. Stormwater Facility Name – Platted Subdivision Name (and if more than one facility within subdivision unique identifier used on plans for the facility).

3. Surface area at design volume.

4. Data that demonstrate that the facility has been designed to comply with the release rate requirements described above. (The MHFD-Detention workbook available at www.MHFD.org can be used to demonstrate compliance with release rates.)

5. Other information that may be requested in the online mapping system.

Not all stormwater facilities have filing requirements, and certain types of facilities are not protected under this statute, as summarized in Table 10-3. Neither retention facilities nor constructed wetlands are protected under CRS §37-92-602(8). These facilities expressly require a water right. Temporary construction and sedimentation basins should not be uploaded to the online portal unless they will be used as permanent detention basins. The engineer of record

[45] Shorter drain times may apply in airport influence areas. This section only addresses water rights criteria. See Section 10.14 for additional information on drain times within airport zones.

shall complete the required information in the online portal, including uploading the SDI sheet or MHFD-Detention workbook, prior to submitting the civil plan signature set documents to CoA.

Table 10-3. Stormwater Facility Reporting Requirements under Senate Bill 15-212 (MacKenzie, 2016)[*]

SCM Type	Water Quality Only	Detention Included
Grass Buffers	Not Required	Not Required
Grass Swales	Not Required	Not Required
Bioretention (with or without underdrain)	Not Required	Required
Green Roof	Not Required	Not Required
Extended Detention Basin (EDB)	Required	Required
Sand Filter	Not Required	Required
Permeable Pavement Systems	Not Required	Required
Media Filter Drain	Not Required	Not Required
Underground Detention Vaults	Required	Required
Constructed Wetland Pond[‡]	N/A, Subject to Water Rights	
Retention Pond[‡]	N/A, Subject to Water Rights	

[*] New constructed wetland basins and retention ponds are not allowed in Aurora. Any modifications to existing constructed wetland basins and retention ponds will require demonstration of water rights as part of CoA development approvals.

[‡] Stormwater facility reporting requirements apply to modification of existing facilities, as well new facilities.

10.9 DESIGN STANDARDS FOR ABOVE GRADE DETENTION FACILITIES

Volume 2, Chapter 12: Storage of the MHFD Manual provides figures illustrating typical combinations of water quality facilities (such as EDBs, bioretention, sand filters, etc.) with FSD. Individual components of an above-ground detention facility are discussed in the subsections below.

10.9.1 Grading Requirements

Detention pond grading must meet the following requirements:

- Detention pond embankment and side slopes must not be steeper than 4:1 (H:V).
- The bottom of the detention pond must slope toward the low flow channel. The minimum slope of the pond bottom toward the low flow channel is 2%. The design shall be such that the pond bottom slopes can be feasibly constructed while not being less than 2%.
- All earthen embankments must be covered with a minimum of 6 inches of approved topsoil and revegetated with native grass in accordance with the CoA's Landscaping

Standards and the MHFD's *Topsoil Management Guidance* (Mile High Flood District, latest edition).

- The top width of the embankment must be at least 10 feet. If the top of the pond embankment is also used for maintenance access, see Section 10.7 above. For embankments that separate water quality functions from detention functions, lesser embankment top widths may be allowable (minimum of 5 feet) for smaller facilities.

- Groundwater inflow to detention facilities must be avoided. The bottom of the detention facility storage area must be at least 2 feet above the seasonal high groundwater elevation. If the geotechnical investigation for a site identifies shallow groundwater, install piezometers to monitor groundwater levels if ponds are planned in such areas.

- In general, stormwater quality and detention facilities should be located outside of the 100-year floodplain[46,47] so that they are not inundated by riverine flooding. In some cases, it may not be feasible to locate these facilities outside of the 100-year floodplain. Through a variance process, CoA may approve facilities within the 100-year floodplain provided they are located outside both the floodway and 10-year floodplain and above the 10-year WSEL as defined in the FEMA Flood Insurance Study (FIS), MHFD Flood Hazard Area Delineation (FHAD) study, or other floodplain study identified as the Best Available Data by the Floodplain Administrator (see Chapter 4). Under no circumstances will stormwater quality and detention facilities be permitted within the regulatory floodway.

10.9.2 Pond Inflows

Design the inverts of storm drain outfalls entering the detention facility to be higher than the WQCV WSEL to avoid problems with sedimentation in pipes entering the facility. All storm drains with outfalls into detention ponds must have adequate erosion protection and energy dissipation. The method of protection must be designed in accordance with Chapter 8 of this Manual and Volume 2, Chapter 9: Hydraulic Structures of the MHFD Manual.

10.9.3 Retaining Walls

The use of retaining walls within detention basins is highly discouraged. In no case shall retaining walls be allowed in publicly maintained facilities. For private facilities, if retaining walls are unavoidable, low-height walls less than 30 inches high may be permitted through a variance. Long-term maintenance access, safety, and aesthetics are important design considerations. Walls may not be continuous around a detention facility and must allow access for maintenance equipment. Maintenance equipment must be able to safely reach the bottom of the facility, including the forebay and outlet structure, and have adequate space to operate and turn. See the CoA's *Roadway Design and Construction Specifications* (RDCS) for design criteria for retaining walls and handrails.

[46] Also known as the 1% annual chance (1PAC) floodplain.

[47] As defined by the Federal Emergency Management Agency (FEMA), MHFD, or other floodplain study identified as the Best Available Data by the Floodplain Administrator. See Chapter 4 for additional information on floodplain designations.

10.9.4 Emergency Spillway, Overflow Path, and Freeboard

An emergency spillway must be provided to convey runoff in the event that the pond is full at the time the peak design discharge occurs, due to a plugged outlet or otherwise. An emergency overflow path must be provided to convey the discharge from the spillway to the public ROW or receiving stream. The following criteria apply to emergency spillways and emergency overflow paths:

Freeboard Considerations

Designers may want to allow additional freeboard in facility designs to ensure that minimum volume requirements and freeboard criteria are met to obtain a pond certificate, which is based on as-built conditions rather than design plans. In cases where as-built conditions deviate slightly from design conditions, allowing for additional freeboard in the design can be beneficial for avoiding construction modifications at a late stage in a project.

- The spillway design discharge is the 100-year peak inflow to the pond for fully developed conditions. This is the peak of the inflow hydrograph coming into the pond when using the MHFD-Detention workbook or SWMM, and should **not** account for attenuation effects of the pond. Plans must clearly show the emergency overflow and detained release rates and directions of flow, and the applicant must provide calculations to establish the width and depth of the emergency overflow path by means of MHFD-Detention workbook or other comparable methodology.

- An emergency overflow path must be provided that is free of structures or obstructions to convey the spillway design discharge to a downstream ROW or drainageway with adequate capacity for the discharge. No impediments to flow are allowed within the emergency overflow path, such as fences, trees, parking areas, buildings, etc. If a fence around a detention facility is needed to restrict access, the bottom of the fence must be elevated to provide a minimum of one foot of freeboard above the emergency overflow WSEL where the fence crosses the spillway. Nevertheless, fences across spillways should be avoided whenever possible; even if the fence is elevated to the freeboard elevation, there is still the potential for the fence to catch debris floating on the water surface.

- When an emergency overflow discharges to a receiving stream, the tailwater condition of the emergency spillway shall be assumed to be the 100-year WSEL of the receiving stream for the hydraulic analysis of the emergency overflow spillway.

- All emergency overflow paths on a site must be within drainage easements until reaching public ROW or a major drainageway.

- Emergency overflows must not negatively impact structures or properties along the flow path. The lowest point of entry[48] (LPE) of all structures along the emergency overflow path must have a minimum of one foot of freeboard above the emergency overflow WSEL.

[48] The lowest point of entry (LPE) is the lowest elevation at which surface water may enter a structure, such as the elevation of the bottom of a door frame, or the elevation of the top of a basement window well. The LPE is distinct from the lowest floor elevation (LFE), though in some cases the elevations of each may be identical. See Chapter 3 for definitions of the LPE and LFE.

- In cases where the emergency overflow path crosses an off-site property before reaching public ROW or a major drainageway, the following apply:

    - Existing historic flow patterns must be maintained.

    - If the emergency overflow discharges on to an adjacent developed property, the applicant must demonstrate at least one foot of freeboard to the LPEs of all existing structures.

    - If the emergency overflow discharges on to an adjacent undeveloped property, the plans must include a note indicating that the downgradient property owner must perpetuate the historic flows and emergency overflows.

- For on-site or subregional facilities, the emergency overflow path must be analyzed and meet the above requirements until flows reach a public ROW or major drainageway. For regional facilities, the emergency overflow path must be analyzed until flow reaches a major drainageway.

Freeboard is required above the spillway's design WSEL to avoid potential overtopping of the pond embankment and to protect nearby structures. The following criteria apply to the embankment freeboard to the spillway design WSEL:

- For contributing drainage areas of 5 acres or more, the elevation of the top of the embankment must be a minimum of one foot above the spillway design discharge WSEL. Figure 10-4 illustrates this freeboard requirement.

- For contributing drainage areas of less than 5 acres, the elevation of the top of the embankment must be above the spillway design discharge WSEL Figure 10-5 illustrates this freeboard requirement.

- The lowest floor elevations (LFEs) of structures on lots adjacent to detention ponds must be at least one foot above the top elevation of the embankment. The LFEs of all structures (both existing and proposed) near the detention basin shall be verified to ensure that adequate freeboard is provided.

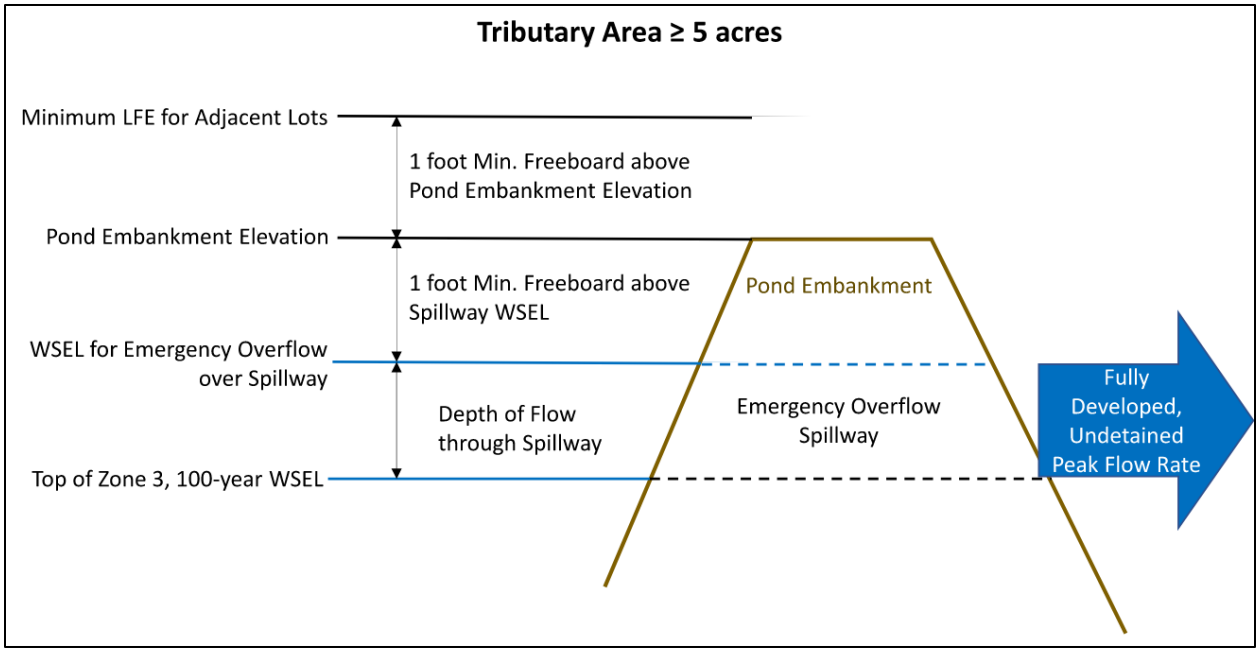

Figure 10-4. Freeboard Requirements for Ponds Serving 5 Acres or More

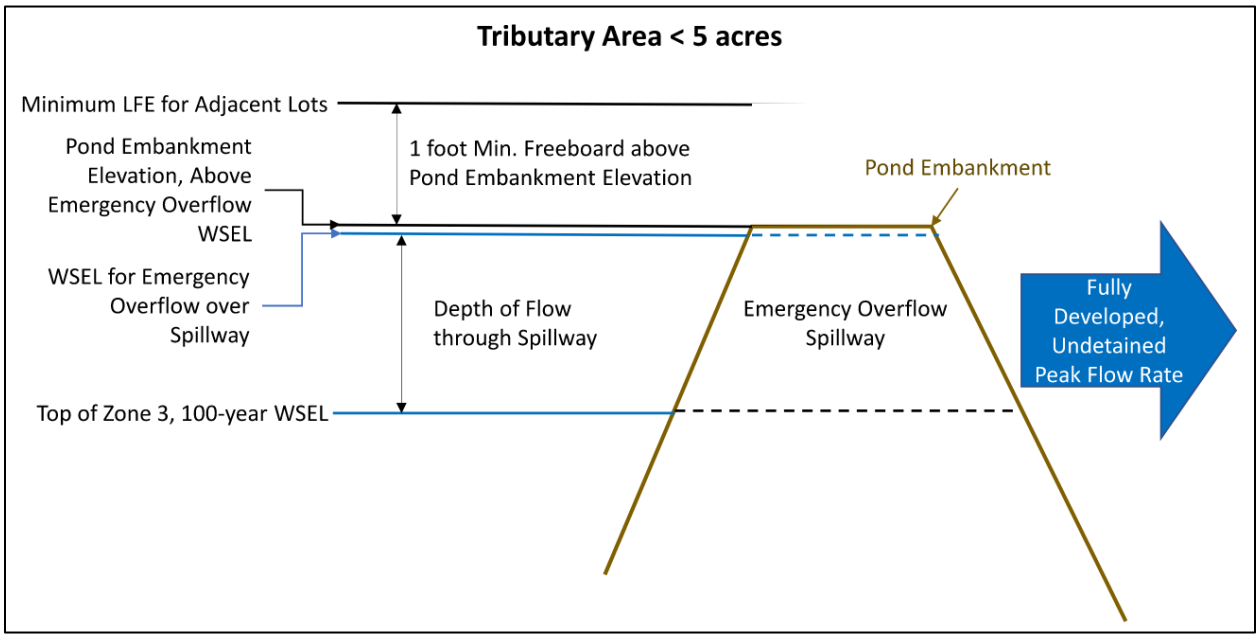

Figure 10-5. Freeboard Requirements for Ponds Serving Less Than 5 Acres

Some situations may require more stringent emergency spillway or freeboard criteria than presented in this Manual or in Volume 2, Chapter 12: Storage of the MHFD Manual. When a storage facility falls under the jurisdiction of the SEO as a dam, the spillway's design storm is prescribed by the SEO (Colorado Department of Natural Resources, latest edition). At the CoA's discretion, larger spillway design flows and/or greater freeboard may be required depending on potential risks to downstream and surrounding areas.

When multiple upgradient water quality or detention ponds drain through a downgradient pond, the spillway for the downgradient pond must be sized for the 100-year inflow to the pond, including the detained, 100-year releases from upgradient ponds. If separate detention facilities are hydraulically connected (e.g., by an equalizer pipe), they should be considered to be a single facility for the purpose of determining emergency overflow discharges.

10.9.5 Sediment Forebays

Sediment forebays for pond inflow locations must be sized in accordance with the MHFD Manual. The intent of the forebay is to reduce loading of sediment and debris to the main body of a detention facility and facilitate maintenance. Alternative pretreatment, such as HDSs designed in accordance with the MHFD Manual, may be considered on a case-by-case basis in lieu of forebays. Similar to forebays, pretreatment via HDSs can help reduce the maintenance required for a detention facility: some HDS systems utilize a screen that can help remove trash and debris that would otherwise clog trash racks and outlet orifices. In any case, forebays or equivalent pretreatment measures are required for all water quality and detention facilities. Table 10-4 summarizes sediment forebay sizing criteria based on the impervious area of the contributing watershed.

Table 10-4. Forebay Sizing Criteria

<table>
<tr><th rowspan="2">Forebay Sizing Criteria</th><th colspan="5">Watershed Impervious Area (IA)
acres (ac)</th></tr>
<tr><th>IA < 2 ac</th><th>2 ac ≤ IA < 5 ac</th><th>5 ac ≤ IA < 10 ac</th><th>10 ac ≤ IA ≤ 20 ac</th><th>IA > 20 ac</th></tr>
<tr><td>Forebay Release Rate and Configuration</td><td rowspan="3">Concrete sediment pad with dense grasses surrounding, concrete pad with slotted metal edge, or similar design.</td><td colspan="4">Size to drain in 4 to 5 minutes using Equation 4-1 in MHFD Manual.</td></tr>
<tr><td>Minimum Forebay Volume*</td><td colspan="4">1% of WQCV</td></tr>
<tr><td>Maximum Forebay Depth*</td><td>12 to 15 inches</td><td>15 to 18 inches</td><td>18 to 24 inches</td><td>24 to 30 inches</td></tr>
</table>

* Appropriate volume and depth should consider maintenance and access needs. The values provided are approximate and provide a starting point for design.

10.9.6 Low Flow Channel

All detention basins must include a low flow (trickle) channel designed according to the MHFD Manual. Volume 3 of the MHFD Manual provides criteria for soft-bottom and concrete-bottom low flow channels:

- Vegetated Low Flow Channels – When designed and maintained properly, vegetated low flow channels enhance water quality treatment by slowing and filtering stormwater runoff, and promoting infiltration and wetland treatment processes. Design vegetated low

flow channels with sinuosity and varied grading to emulate a natural stream channel. Select riparian grasses, sedges, and rushes to thrive with frequent and prolonged inundation. Design vegetated low flow channels with a consistent longitudinal slope between 1 to 2% from the forebay to the micropool with a minimum depth of 18 inches and a 6-foot bottom width. Side slopes for the low flow channel may be as steep as 2:1 (H:V) provided that the side slopes are designed with appropriate soils and groundcover to resist erosion from anticipated design flows. The low flow channel must be stable and non-erosive. Provide consistent longitudinal slope and depth and periodic concrete or boulder sills to demarcate the design grade and facilitate restorative maintenance when sediment removal in the low flow channel is necessary.

When soft-bottomed low flow channels are selected, follow MHFD criteria to avoid maintenance problems. For online detention ponds that do not include the WQCV or EURV, soft-bottom low flow channels are preferred.

- Concrete Low Flow Channels – A low flow channel with a concrete pan establishes the bottom of the basin for routine maintenance. Design a concrete pan with a longitudinal slope between 0.4% and 1%; the flatter slopes reduce flow velocities, and the steeper slopes help avoid low points due to construction tolerances. Provide a bottom width of at least 6 feet, a concrete pan depth of 6 inches, and a total low flow channel depth of approximately 18 inches from the bottom of the pan to the top of the low flow WSEL. Concrete curbs may be used for the sidewalls of the low flow channel. Side slopes for the low flow channel above the concrete pan must be 4:1 (H:V) or milder for regional facilities, but greater than 2% for all facilities.

Riprap and soil-riprap lined low flow channels are not allowed. See the MHFD Manual for additional information on soft-bottom and concrete-lined low flow channels, including representative cross sections.

When using either vegetated or concrete low flow channels, the bottom of the basin outside the limits of the low flow channel should be graded to slope at 2% or more to encourage drainage. Consider shaping the basin bottom to create zones of varied depths and hydrology. At least 6 inches of suitable topsoil should be provided in the basin bottom and side slopes; see MHFD's *Topsoil Management Guidance* for information on texture and nutrients for suitable topsoil (Mile High Flood District, latest edition). Consider using sandier-textured soils (loamy sand, sandy loam) from on-site or imported sources in the low flow channel and bottom benches to promote higher infiltration capacity, quicker dewatering, and improved stability compared to clayey soils.

10.9.7 Outlet Configuration and Outfalls

The MHFD Manual and website provide design guidance, design details, and examples for several detention facility outlet configurations. See Volume 2, Chapter 12: Storage and the EDB fact sheet in Volume 3 of the MHFD Manual for criteria related to outlet structure design, including criteria for orifice plates, micropools, trash racks, and safety grates.

The outlet configurations for all detention facilities in the CoA must incorporate the following:

1. All mounting hardware for the orifice plate and trash racks must be stainless steel.

2. Orifice plates must be stainless steel.

3. The WQCV and/or EURV orifice plate must have a neoprene gasket between the plate and outlet structure to prevent leakage.

4. The configuration of the orifice plate openings must be in accordance with Volume 3 of the MHFD Manual. The 100-year orifice control is typically located at the entrance to the outlet pipe. The MHFD-Detention workbook may be used to size the openings of the orifice plate and other outlet hydraulic controls.

5. If orifices are 2.5 inches in diameter or larger, fabricated bar grating with nominal openings of 1 by 4 inches is recommended in lieu of a well screen. For orifice openings in the range of 1.25 – 2.5 inches, the engineer should evaluate the potential nature of debris draining to the facility to determine if well screen or bar grating is appropriate. For orifices with a diameter of less than 1.25 inches, well screen is required. See the EDB fact sheet of the MHFD Manual for additional information on when well screen, bar grating, or both are needed to minimize potential for orifice clogging.

6. Outlets must incorporate micropools in conformance with the EDB fact sheet in Volume 3. Additionally, the well screen (or bar grating as appropriate) must extend to the bottom of the micropool.

7. All outlets must be designed to minimize unauthorized modifications that affect proper function. A sign with a minimum area of 1.5 square feet must be attached to the outlet or posted nearby (if unable to be posted to the outlet) with the following message:

WARNING
Unauthorized Modification of
this Outlet is a Code Violation

8. When an outlet structure discharges to a receiving stream, the tailwater condition of the outlet structure shall be assumed to be the 100-year WSEL of the receiving stream for the hydraulic analysis of the outlet structure.

10.9.8 Public Safety Considerations

All designs must consider public safety. Safety grates for detention and water quality pond outlets must be designed in accordance with the MHFD's safety grate criteria. The MHFD's safety grate criteria are designed to enhance public safety and minimize clogging.

When ponds are designed that incorporate permanent water surfaces (e.g., constructed wetland basins), provide a shallow, mildly sloped safety bench to allow for self-rescue of people or animals that enter the water unintentionally. See the Retention Pond and Constructed Wetland Pond fact sheet in Volume 3 of the MHFD Manual for criteria regarding safety benches.

Detention ponds must be maintained frequently enough to prevent public nuisances from developing (e.g., unpleasant odors or aesthetics). These nuisances, if left unaddressed, can create public health hazards from mosquitos (e.g., West Nile Virus). Therefore, design features that facilitate maintenance and an effective I&M Plan are important for public safety.

10.9.9 Landscaping Requirements

Detention areas and embankments should be designed and constructed to blend in with their

surroundings, creating site amenities rather than eyesores. In open space or natural areas, techniques to be considered include the creation of topographic changes that mimic natural conditions (such as introducing a variety of slope changes along an embankment) and using natural materials such as stone or other materials that match the local environment. Existing drainage patterns should be preserved whenever possible. Landscaping must be done so as not to hinder maintenance access or activities.

Vegetate all above-ground detention basins in accordance with the CoA's Landscaping Standards and the MHFD's *Topsoil Management Guidance* (Mile High Flood District, latest edition). Landscaping improvements should enhance the aesthetics of the detention facility. When determining landscaping, long-term maintainability of the facility should be a high priority. Where native vegetation is required as a part of the function of a SCM, an irrigation plan and Lawn, Seed, and Irrigation Permit are required. The irrigation plan must show information for establishing vegetation on a short-term basis. The irrigation submittal will be reviewed by the CoA conservation team.

The use of wood mulch in detention facilities is not allowed because of its potential to be displaced and clog outlet structures. The use of rock mulch within detention facilities is also prohibited because it is difficult to remove sediment from the rock.

Typically, runoff is conveyed to detention facilities via a storm drain pipe. When runoff is conveyed to the detention facility via a swale, or when the storm drain pipe discharges above the toe of the pond embankment, rundowns may be needed to minimize erosion at inflow points. When rock or concrete rundowns are used, they should be attractive and compatible with the overall landscape design. Follow the criteria for rundowns in Chapter 8 of this Manual and Volume 2, Chapter 9: Hydraulics Structures Chapter of the MHFD Manual.

When detention facilities are located in CoA parks and open space, consult with the CoA PROS Department on landscaping requirements. See also the Unified Development Ordinance (UDO; City Code Chapter 146) Section 4.7.5.M for additional landscaping requirements for detention and water quality ponds.

10.9.10 Multiple Use Guidance

Multiple uses (i.e., multi-uses) of detention facilities are encouraged; however, it is critical that these types of facilities be designed carefully so that the functionality of a particular use is not impeded by another. In areas of residential development, park and detention multi-use facilities may provide benefits related to aesthetics, wildlife, and recreation; however, consideration should be given to the time required for the detention area to drain and dry out, safety in areas used for child play, and the potential for standing water to develop and thereby contribute to mosquito-borne illness concerns (e.g., West Nile virus).

The following criteria apply for multi-use facilities:

- Only major, regional, and/or subregional detention facilities may be considered for multiple uses due to size limitations of on-site facilities. Water quality facilities may not be multi-use facilities, and water quality facilities may not be located within park facilities.

- Detention facility design and aesthetics must be compatible with the surrounding land uses. The detention facility shall be integrated with the surrounding landscape.

- For recreational uses, the anticipated level of organized and informal activity in a park must be defined, as along with passive versus active recreation objectives. Recreational uses must be planned around the required drain times for a detention facility. Areas within the footprint of the WQCV are not appropriate for recreational uses due to the frequent inundation and accumulation of pollutants in this area.

- Assess the need for irrigation. For facilities that support recreational uses that require turf grass, irrigation will be required.

- Evaluate the requirements for maintenance and operations as they relate to the multiple uses the facility will provide. For example, if the portions of a detention facility above the EURV are used for recreational purposes, more frequent mowing and maintenance may be required. For multiple use facilities that provide habitat for wildlife, the timing of maintenance may need to be adjusted to avoid critical times of the year when wildlife depend on the vegetation in the facility.

- Consider all potential safety hazards related to having the public in close proximity to a facility with potentially large and abrupt WSEL changes. Discourage recreational activities in the lower portions of the pond that are susceptible to frequent inundation, and design side slopes for self-rescue (i.e., 4:1 H:V or flatter).

- Multi-use facilities must not directly or actively use the water impounded in or passing through the facility. For example, water may not be pumped out of the facility for irrigation purposes.

- Early coordination with AW and PROS for all multi-use facilities is strongly encouraged.

- Multiple use areas within ponds that are intended for public access should be at or above the 10-year WSEL to limit the frequency of inundation, potential for nuisance conditions to develop, and level of maintenance required for the area. Applicants shall denote the 10-year WSEL on all plans for multi-use facilities to demonstrate that areas intended for public access are not below the 10-year WSEL.

10.10 DESIGN STANDARDS FOR PARKING LOT DETENTION

Detention in parking lots is discouraged and allowed only at the discretion of the CoA through a variance. However, for redevelopment sites where there may not be adequate pervious area for construction of an FSD facility, detention may be integrated with parking areas. Parking lot detention may be allowed if the following minimum criteria are met:

1. The outlet from the parking lot detention area is designed to achieve the required drawdown times for the EURV and the WQCV and detains design flows to the levels specified for other types of detention facilities in this chapter.

2. The maximum ponding depth for the 100-year design storm is no more than 12 inches at the deepest point.

3. Inlets are designed with pipes having a minimum diameter of 12 inches for private facilities or 18 inches for public facilities. Weir outlets are designed with a minimum width of 3 inches.

4. The outlet is designed to minimize modifications that affect detention functions. The applicant must evaluate potential future resurfacing activities for impacts to detention volumes and release rates.

5. Ponding water in frequently used portions of parking lots must be avoided. At least two signs are required for all parking lot detention areas. The signs must have a minimum area of 1.5 square feet and contain the following message:

WARNING
This area is a detention basin and is subject to periodic flooding to a depth of (provide design depth).

Sign materials, geometry, and location are subject to approval by AW.

10.11 DESIGN STANDARDS FOR UNDERGROUND DETENTION

Underground detention is highly discouraged because of the potential for deferred maintenance, the difficult and potentially hazardous nature of access for maintenance, issues related to anaerobic conditions and pollutant mobility for devices that retain water between events, and the uncertain design life for materials subject to corrosion. Nevertheless, the CoA may allow underground detention in certain cases and only through a variance. Underground detention and water quality treatment practices **are not** allowed solely for purposes of increasing density of development; the need for underground facilities must be justified by other site constraints. Moreover, underground detention and water quality treatment practices generally **are not** allowed for "greenfield" development (e.g., development of previously undeveloped land). The CoA may allow underground 100-year detention and water quality treatment in limited high-density urban developments or redevelopments, space-constrained redevelopment projects, and in airport zones on a case-by-case basis through the variance process. In any instance where underground detention is contemplated, thorough consideration must be given to the concerns described above to ensure ongoing inspection, maintenance, and functionality. Care should be taken to address material selection for underground detention due to the potential for adverse soil conditions to inhibit the system from functioning properly. Acceptable materials include plastic, concrete, or corrugated metal. A geotechnical engineer should be consulted to ensure soil and conditions are appropriate for the selected detention material.

When underground detention or water quality treatment practices are allowed, the following criteria apply:

1. Pretreatment to remove coarse sediments and floatables is required for underground detention. HDSs may be used for pretreatment but may not be used as stand-alone water quality treatment facilities in most cases. All underground pretreatment MTDs must comply with the criteria in the fact sheets in Volume 3 of the MHFD Manual.

2. A surface emergency overflow path that is free of obstructions must be provided for all underground detention facilities for the 100-year peak inflow to the underground detention facility for fully developed conditions. This is the peak of the inflow hydrograph coming into the underground detention facility, and should **not** account for any attenuation effects from the facility. A minimum of one foot of freeboard is required between the emergency overflow WSEL and the LPEs of any structures on lots adjacent to the overflow path. Note that the criteria for emergency overflow paths for surface

detention facilities denoted in Section 10.9.4 above also apply to underground detention facilities.

3. Outlets from underground detention must consist of a pipe that can convey 120% of the 100-year outflow, with a minimum diameter of 12 inches. The invert of the outlet pipe must be at the lowest point in the detention facility to ensure that it fully drains. If an orifice plate is required to control the release rates, the plate must be firmly bolted or secured to the wall with a gasket to prevent leakage around the edges.

4. Underground MTDs for water quality must be third-party verified and meet the CoA's MS4 permit requirements to be considered for use. Underground MTDs must comply with the criteria in the fact sheets in Volume 3 of the MHFD Manual.

5. Detention vaults must be designed to be effectively maintained by jetting and/or rodding.

6. Detention vaults must use full circular pipe sections to facilitate maintenance; no half-pipe sections are allowed.

7. If an underground vault has multiple chambers, access openings must be provided for each chamber.

8. Underground facilities must be located to enable safe access for maintenance and minimize disruption of aboveground uses during maintenance. Do not locate access openings in areas that are routinely used for parking.

9. Easements must be provided for all underground detention facilities. Such easements must include an additional 4 feet from the perimeter of underground detention facilities/devices if bound by private property.

10. Underground detention and water quality facilities are prohibited underneath buildings or other structures.

11. The I&M Plan for underground detention and water quality facilities must include quarterly inspection and maintenance as well as inspection and maintenance following any rainfall event of 0.5 inches or more. The inspection and maintenance frequency may be reduced after 5 years of operation if the owner demonstrates that a lesser frequency is appropriate.

10.12 DESIGN STANDARDS FOR PUMPED DETENTION

In extreme cases, when gravity drainage is not feasible, detention ponds with pumped outflows may be allowed on a case-by-case basis with a variance. Such detention ponds must be designed to be pumped dry between storm events. Discharges from pumped detention ponds must be conveyed to an acceptable outfall location within 72 hours unless water rights are obtained for the facility or if the facility is located within an airport zone where the drain time may be reduced (see Section 10.14 below). Stormwater pump stations must be in compliance with CoA pumping station, electrical, and supervisory control and data acquisition (SCADA) specifications as denoted in the CoA's *Stormwater and Wastewater Lift Station Design and Engineering Guidelines* (Aurora Water, latest edition). An emergency spillway and overflow path that is free of obstructions must be provided for all pumped detention facilities for the 100-year peak inflow to the pumped detention area for fully developed conditions. This is the peak of the

inflow hydrograph coming into the pumped detention facility, and should **not** account for any attenuation effects from the facility. A minimum of one foot of freeboard is required between the emergency overflow WSEL and the LPEs of any structures on lots adjacent to the overflow path. Note that the criteria for emergency overflow paths for non-pumped detention facilities denoted in Section 10.9.4 above also apply to pumped detention facilities.

Pumped detention ponds will only be allowed when there are adequate assurances for lifecycle costs of the pump system's operation, maintenance, repair, and replacement. In cases where pumped detention is needed only on a temporary basis until a future gravity outfall is available, the applicant must commit financial resources for a later retrofit of the facility to a gravity-based outlet. Ponds that rely on pumped drainage will only be allowed through a variance.

10.13 RETENTION PONDS

The CoA prohibits the use of retention ponds for flood control, including infiltration basins that do not have a gravity-based surface outflow mechanism. Retention may be used as a water quality treatment practice in accordance with criteria in the Retention Ponds and Constructed Wetland Ponds fact sheet in Volume 3 of the MHFD Manual, but water rights are required for such facilities (see also Section 0 above). Retention ponds used for water quality have a permanent pool that remains between storm events and a surcharge volume that fills and drains during periods of runoff.

10.14 SPECIAL REQUIREMENTS FOR DETENTION FACILITIES NEAR AIRPORTS

Within airport zones, integration of the WQCV and EURV with the 100-year flood control volume presents challenges to meeting drain time requirements, which are reduced in proximity to airports. Detention facility drain times for sites adjacent to air operations areas are limited by Federal Aviation Administration (FAA) recommendations contained in Advisory Circular 150/5200-33C (Federal Aviation Administration, 2020) and by additional guidance specific to Denver International Airport (DEN). These drain time limitations are intended to minimize wildlife attractants and potential interference with air traffic. The CoA requires all new development and redevelopment to comply with the FAA and DEN guidelines. The drain time limitations preclude pond designers from obtaining the full drain times recommended by the MHFD for the EURV and the WQCV. To maximize water quality treatment (e.g., drain time) while satisfying FAA criteria, the WQCV and/or EURV may need to be decoupled from flood control detention and provided as separate facilities upgradient of a flood control detention facility.

The FAA recommended maximum time to fully drain the design event from ponds is 48 hours. FAA drain time limitations apply to Buckley Air Force Base, Centennial Airport, and Front Range Airport to a distance of 10,000 feet from air operations surfaces. Mapping of these areas is provided at https://arcg.is/1j8eH0 and is identified as the "10,000-foot critical zone." Refer to the FAA circular for definitions and additional details.

DEN has a more stringent requirement within or immediately adjacent to the airport. Within 10,000 feet of DEN, the total drain time must be limited to 40 hours. This drain time is shorter than the FAA recommendation with the intent of allowing 8 hours for pumping should an outlet structure become plugged or otherwise fail. In areas beyond 10,000 feet but still within 5 miles of DEN, ponds must be designed to drain within 48 hours. DEN mapping of the 10,000 feet (40-hour drain time) and 5 miles (48-hour drain time) is also provided at the ArcGIS link above. The applicant is responsible for checking for current FAA and DEN requirements at the time of design.

Retention ponds and constructed wetland ponds are prohibited within the 10,000-foot critical zones around airports.

10.14.1 Regional Detention Facilities Near Airports

For regional detention facilities in airport zones the following criteria apply:

- Newly planned regional detention ponds within airport zones must not incorporate the WQCV. Instead, provide the WQCV in separate private facilities that serve one or more sites. Using separate facilities for the WQCV will generally allow longer WQCV drain times than would be possible if combined with the EURV and detention. WQCV drain times in separate private facilities still must comply with FAA drain time requirements, and release rates from upgradient WQCV facilities must be accounted for when evaluating the drain time for a downgradient, regional detention facility.

- Newly planned offline regional detention ponds located within airport zones may incorporate the EURV. Offline ponds are located on ephemeral tributaries to the mainstem of a stream system. The total drain time for EURV and flood detention storage must be 40 or 48 hours as dictated by FAA and/or DEN requirements. Note that where the WQCV has been provided in upgradient facilities, the EURV to be included in the downstream detention pond need only consist of the difference between the WQCV and the total EURV volume (i.e., Zone 2 in Figure 10-2; see also explanations in Section 10.4 above).

- Newly planned online regional detention ponds must be designed so that the WQCV and EURV are provided offline and upstream to maintain sediment continuity in the stream system and limit sediment removal costs for the online pond. The upstream WQCV/EURV pond(s) should be designed with a minimum drain time of 24 hours for the WQCV and an additional 12 hours for the remainder of the EURV, for a total drain time of 36 hours.

The configuration and design of any regional detention facility within an airport zone must be coordinated with the MHFD, and the facility must be designed to satisfy the requirements of MHFD's MEP.

10.14.2 Subregional and On-site Detention Facilities Near Airports

Subregional and on-site ponds typically combine the WQCV, EURV, and 100-year volume in a combined facility. Within airport zones, use a minimum drain time of 24 hours for the WQCV and an additional 12 hours or more for the remainder of the EURV. The total drain time must be no more than 40 or 48 hours depending on applicable criterion (FAA or DEN). As a part of hydraulic design of the outlet, extend the release time for the remainder of the EURV beyond 12 hours to the extent practical while staying within the FAA or DEN guidelines to optimize treatment.

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CHAPTER 11.0 STORMWATER QUALITY

11.1 INTRODUCTION

This chapter provides technical criteria for providing stormwater quality within the City of Aurora (CoA). Design criteria in the Mile High Flood District's (MHFD's) *Urban Storm Drainage Criteria Manual* (MHFD Manual), Volume 3 are hereby incorporated by reference. Except as modified herein, all stormwater quality designs must be in accordance with the MHFD Manual.

Permanent Stormwater Control Measures (SCMs), also known as Best Management Practices (BMPs), are required on development and redevelopment projects to comply with state and federal regulations and to protect the water quality of the CoA's streams, lakes, and wetlands. These stormwater requirements are necessary to comply with the CoA's Municipal Separate Storm Sewer System (MS4) discharge permit.[49]

Construction-phase SCMs are also required for development and redevelopment projects in the CoA but are not discussed in this chapter. See the CoA's *Rules and Regulations Regarding Stormwater Discharges Associated with Construction Activities* for more information on the CoA's construction SCMs (Aurora Water, latest edition).

Because water quality and detention requirements are typically integrated using full spectrum detention (FSD) facilities on most development sites within the CoA, water quality requirements in this chapter should be reviewed in conjunction with the criteria in Chapter 10.

11.1.1 Terminology

Common terminology used within this chapter are defined below. Note that the definitions below may differ slightly from those included in Chapter 3 to emphasize aspects relevant to water quality.

Full Spectrum Detention (FSD) – FSD is a water quality and detention design approach intended to reduce flooding and stream degradation impacts associated with urban development by controlling peak flows in the stream for a range of events. FSD is focused on controlling peak discharges over the "full spectrum" of runoff events, from small, frequent storms up to the 100-year flood.[50] FSD produces outflow hydrographs that, other than the small release rate of the Excess Urban Runoff Volume (EURV), replicates the shape of pre-development hydrographs.

State Waters – State Waters means any and all surface and subsurface waters which are contained in or flow in or through this state, but does not include waters in sewage systems,

[49] The CoA is covered under a Phase 1 individual stormwater MS4 permit issued by the Colorado Department of Public Health and Environment (CDPHE), which has been administratively extended since 2014 (Colorado Department of Public Health & Environment, 2011). Permanent stormwater quality requirements in this permit are mostly narrative, with the exception of the requirement to provide permanent stormwater quality treatment when one acre or more of disturbance occurs. This chapter includes concepts that meet the requirements of the existing applicable permit at the time this Manual was adopted, and incorporates some requirements and approaches found in more recently renewed MS4 permits in Colorado. See https://cdphe.colorado.gov/wq-municipal-ms4-individual-permits for the most current version of the CoA's MS4 permit.

[50] Also known as the 1% annual chance (1PAC) flood.

waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed (Colorado Revised Statutes 25-8-103). Also known as Waters of the State.

Stormwater Control Measure (SCM) – A SCM is any BMP or other method used to prevent or reduce the discharge of pollutants to Waters of the State. SCMs include, but are not limited to, BMPs, Green Infrastructure (GI), Green Stormwater Infrastructure (GSI), and Low Impact Development (LID).

Water Quality Capture Volume (WQCV) – The WQCV is a storage volume intended to attenuate and treat runoff from the Water Quality Event (WQE). The WQCV is calculated using a regression equation that relates the mean storm depth, imperviousness, and SCM drain time to the WQCV. The WQCV represents the 80th percentile runoff-producing event.

Water Quality Event (WQE) – MHFD defines the WQE as a design storm representing a rainfall depth equal to the 80th percentile runoff-producing storm event for the Denver metropolitan region (Mile High Flood District, latest edition). The design storm depth corresponding to the WQE is 0.60 inches for the Denver metropolitan region. This regional design storm depth is used to calculate the WQCV and the Water Quality Peak Flow (WQPF).

Water Quality Peak Flow Rate (WQPF) – The WQPF is the design flow rate for SCMs that are designed based on a flow rate for the WQE instead of a volume (Zivkovich & Piza, 2022).

11.2 APPLICABILITY

All development and redevelopment projects with added impervious area or disturbance area meeting certain thresholds must implement SCMs as follows:

- If the project is located outside of the Cherry Creek Reservoir basin, comply with Section 11.2.1 and Table 11-1.

- If the project is located within the Cherry Creek Reservoir basin, comply with Section 11.2.2 and Table 11-2.

The Cherry Creek Reservoir basin is shown in Figure 11-1. A digital map version of the Cherry Creek Reservoir basin can be accessed here.[51]

[51] From the link, select Aurora Water Maps, then Wastewater and Stormwater Assets. Select "OK," and then activate the Storm Basin layer from the "Layer List" in the upper right-hand corner of the window.

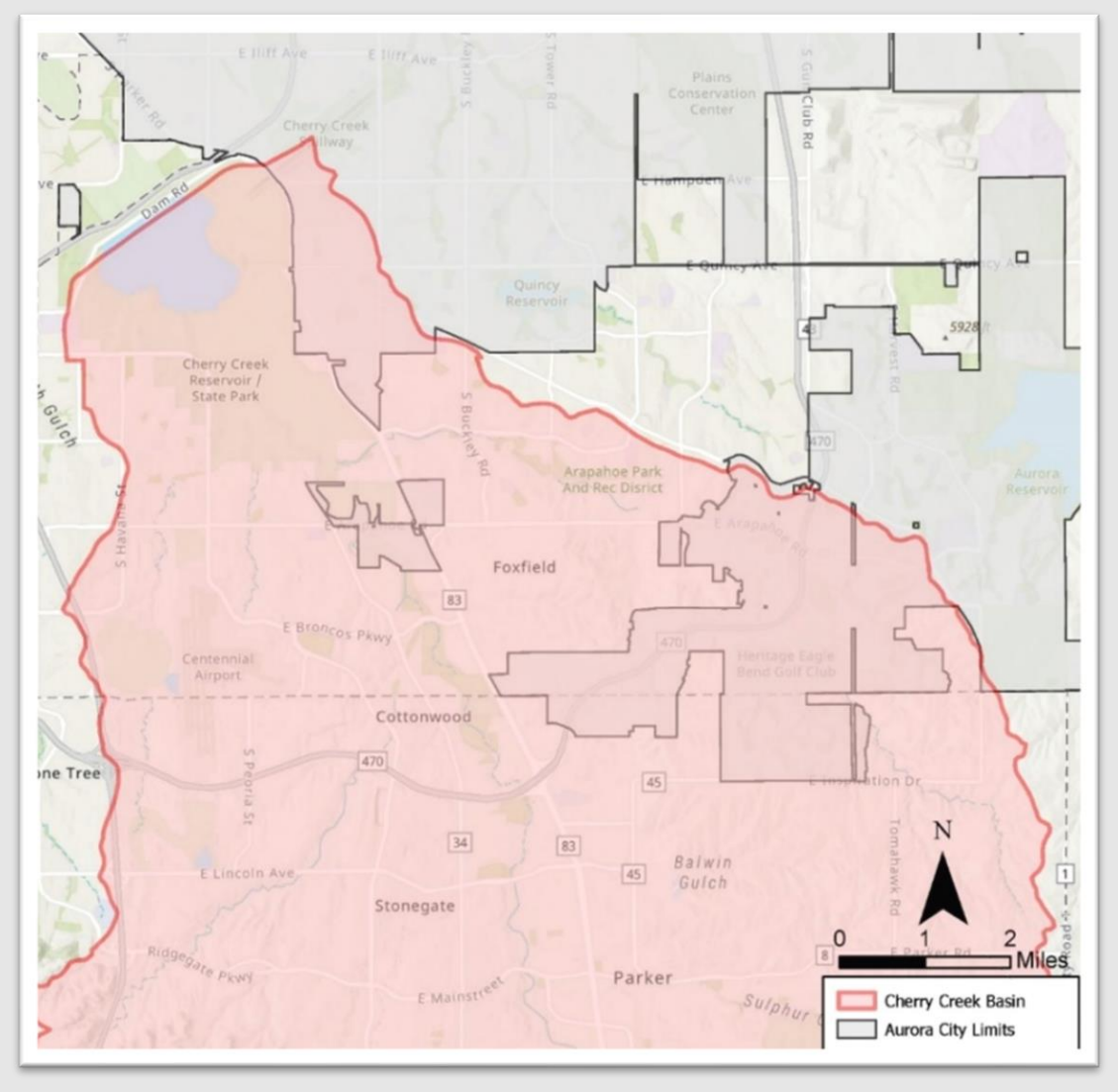

Figure 11-1. Cherry Creek Basin and Aurora City Limits Overlap Area

11.2.1 Stormwater Quality Requirements Outside Cherry Creek Reservoir Basin

The CoA requires water quality treatment SCMs for all development and redevelopment sites with an area of disturbance greater than or equal to one acre or over 5,000 square feet (SF) of new impervious area in accordance with Table 11-1. If a proposed development or redevelopment is part of a **larger common plan of development or sale** that meets these thresholds, these requirements also apply. CDPHE defines a larger common plan of development or sale as:

> "*A contiguous area where multiple separate and distinct construction activities may be taking place at different times on different schedules, but remain related. The Division has determined that 'contiguous' means construction activities located in close proximity to each other (within ¼ mile). Construction activities are considered to be 'related' if they share the same development plan, builder or contractor, equipment, storage areas, etc.*" (Colorado Department of Public

Health & Environment, 2016)

Table 11-1. Permanent Stormwater Quality Control Measure Requirements Outside of the Cherry Creek Reservoir Basin

Project Conditions	**Permanent SCM Requirements**	
< 5,000 SF of new impervious area.*	Treatment SCMs not required; runoff reduction approaches encouraged. See Chapter 10 for additional criteria for detention.	
≥ 5,000 SF of new impervious area,* or 1 acre or more of disturbance, unless exception condition met.	FSD (including Water Quality) required.	Impervious Area < 2 acres: water quality via infiltration/filtration SCM; no EDB.Δ Use bioretention, sand filter, or permeable pavement
		Impervious Area ≥ 2 acres: water quality via any SCM in Table 11-3 that can provide FSD.
Exceptions		
Redevelopment if new impervious area: • < 10% existing impervious area • < 5,000 SF total • < 1 acre of disturbance	Treatment SCMs not required; runoff reduction approaches encouraged.	
Roadway construction with new impervious area < 1 acre and < 1 acre of disturbance	Roadway Redevelopment/Retrofit	HDSs may be allowed, see Table 11-3.‡
	Off-site Roadway Construction	HDSs may be allowed on interim basis see Table 11-3.‡

* New impervious area for SCMs means all surface types in Table 5-6 of this Manual that are 60% impervious or higher (e.g., packed gravel, roads, concrete, rooftops).
‡ HDSs may be restricted by future MS4 permits.
Δ Extended detention basin.

11.2.2 Stormwater Quality Requirements in the Cherry Creek Reservoir Basin (Regulation 72)

In addition to complying with the criteria in Section 11.2.1, all developments and redevelopments within the Cherry Creek Reservoir Basin must comply with the most current stormwater requirements of the *Cherry Creek Reservoir Control Regulation* (5 CCR 1002-72, latest edition). These requirements are more stringent than requirements outside of the Cherry Creek Basin and vary based on three development tiers. Thresholds and specific requirements for SCMs in the Cherry Creek Reservoir Basin are summarized in Table 11-2.

Table 11-2. Permanent Stormwater Quality Control Measure Requirements within the Cherry Creek Reservoir Basin under Regulation 72

Land Development Classification	MS4 Post-Construction Stormwater Quality Requirements Cherry Creek Reservoir Basin[*,‡] (2022 Regulation 72)	
	Definition	**Reg. 72 Water Quality Requirement with CoA Requirements Added**
Reg. 72 Tier 1 Development and Redevelopment	≤ 500 SF of impervious area added, disturbs less than 1 acre, and is not part of a larger common plan of development or sale that disturbs 1 acre or more.	Post-construction water quality not required.
Reg. 72 Tier 2 Development and Redevelopment	> 500 SF of impervious area added, disturbs less than 1 acre of land, and is not part of a larger common plan of development or sale that disturbs 1 acre or more.	Implement SCM(s) that meet one or more of the following criteria: • Comply with Tier 3 requirements. • Incorporate receiving pervious areas (RPAs) that are designed to infiltrate at least 60% of the WQCV for the added or increased impervious area. • Demonstrate that an alternative control measure or site condition provides nutrient load reduction that is at least as protective as the criteria allowed in the first two options listed in Tier 3. **CoA Requirement**: If new impervious area > 5,000 SF, provide FSD per Table 11-1.
Reg. 72 Tier 3 Development and Redevelopment	Land disturbance of 1 acre or more or land disturbance that is part of a larger common plan of development or sale that disturbs 1 acre or more.	Implement SCM(s) that meet one or more of the following criteria: • Install SCM that treats the WQCV. • Implement runoff reduction practices using SCMs designed to infiltrate, evaporate, or evapotranspire at least 60% of the WQCV if all impervious area for the development site discharged without infiltration. • Implement other performance-based SCMs allowed in the CoA's MS4 permit provided they are at least as protective as the above two options. • Demonstrate that an alternative SCM or site condition provides nutrient load reduction comparable to or better than the above three options. **CoA Requirement:** If new impervious area > 5,000 SF, provide FSD per Table 11-1 unless exception condition met.
Additional Requirements for Reg. 72 Tier 2 and Tier 3 in Stream Preservation Areas	Stream Preservation Areas include: Cherry Creek Reservoir; all of Cherry Creek State Park; drainage and discharges to the park within 100 feet of the park boundary; lands overlying the Cherry Creek 100-year floodplain; and all lands within the 100-year floodplain of Cherry Creek tributaries, as defined by the MHFD.	Select and implement SCMs that promote filtration and/or infiltration processes to treat the WQCV or meet runoff reduction design standards for all Tier 2 and Tier 3 new development and redevelopment within the Stream Preservation Area. See Regulation 72 for authorized exclusions.[‡]

[*] Individual single-home construction disturbing less than 1 acre of land where the owner has a permit for one dwelling is not required to provide permanent stormwater quality treatment. See Regulation 72 for additional exclusions.

[‡] Tier 2 and 3 land disturbances in Regulation 72 Stream Preservation Areas must implement SCMs that promote filtration or infiltration to treat the WQCV. See Regulation 72 for a complete list of exclusions from Stream Preservation Area requirements. One such exclusion includes construction of roadway, highway, and underground utility crossings, provided construction SCMs are implemented as required.

11.3 STORMWATER QUALITY DESIGN

This section describes various aspects related to the design of stormwater quality facilities, including the design approach and criteria, safety considerations, and maintenance concerns.

11.3.1 Design Approach and Criteria

This section provides the design criteria for various permanent SCMs, as well as a discussion on implementing runoff reduction practices.

11.3.1.1 Runoff Reduction Opportunities

On some small sites, it may be possible to fully meet stormwater quality management requirements using runoff reduction, relying on draining impervious surfaces as sheet flow to receiving pervious areas (RPAs). On larger sites, the size of WQCV and FSD facilities may be reduced through the use of RPAs. Runoff reduction practices are also effective at providing stormwater quality along trails. To effectively reduce runoff volumes using RPAs, opportunities for disconnection must be considered early in the land development planning process. Volume reduction quantification methods are described in Volume 3 of the MHFD Manual, including in the MHFD-SCM design workbook (Mile High Flood District, latest edition).

11.3.1.2 Permanent Stormwater Quality Control Measures

Table 11-3 lists SCMs that may be used in the CoA, along with the design basis and tools, notes on site suitability and design, and comments regarding the use of a SCM. Table 11-4 provides additional considerations for EDBs based on the contributing drainage area. Finally, Table 11-5 notes organizations with testing protocols for manufactured treatment devices (MTDs) accepted by the CoA.

In general, SCM design criteria from Volume 3 of the MHFD Manual apply, along with the latest versions of MHFD's Detention and MHFD-SCM design workbooks (Mile High Flood District, latest edition). Other SCM types with demonstrated performance will be considered on a case-by-case basis with a variance.

Volume 3 of the MHFD Manual provides guidance for selecting permanent SCMs, considering factors such as watershed size, soils, depths to groundwater and bedrock, baseflows, watershed conditions, and targeted pollutants. This selection guidance is incorporated by reference and is not repeated in this chapter.

To successfully plan, design, and construct infiltration-based SCMs, data related to soil characteristics, infiltration rates, depth to groundwater, and other related information are needed. The CoA incorporates the criteria in Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual regarding geotechnical investigations and data collection for infiltration-based SCMs.

If a development or redevelopment site discharges to a State Water upstream of a subregional or regional facility without water quality treatment on-site, then the applicant must provide sufficient justification in the Final Drainage Report (FDR) submittal to show that instream water quality between the site and the subregional or regional facility is adequately protected from adverse impacts from the stormwater discharge. Examples of measures that minimize adverse effects of runoff prior to off-site treatment may include, but are not limited to, the use of RPAs

such as swales or buffers, proprietary devices, or other water quality treatment practices.

The use of multiple SCMs in series, otherwise known as a “treatment train” approach, can also be used to meet water quality requirements. When WQCV-based stormwater controls are used to meet MS4 permit requirements, the WQCV must be sized for the entire upgradient watershed, assuming future detained developed conditions.

Table 11-3. SCMs Allowed in Private Developments in CoA[52]

SCM Type	Design Basis/Tools	Site Suitability and Design	Comment
Runoff Reduction Practices (non-WQCV)			
Buffers and Swales	• MHFD Vol. 3 Ch. 4 • MHFD's SCM Design workbook (Runoff Reduction, Grass Buffer & Grass Swale workbooks) • CUHP or Rational Method for Swale Design	• Can be used to disconnect impervious area and provide volume reduction. • If used as a stand-alone SCM, these should be designed to achieve a 60% volume reduction for the WQCV. • Must be native turf grass or approved active turf grass with a uniform density of at least 80% that complies with the CoA's landscaping and turf ordinances (Unified Development Ordinance Section 4.7; Aurora City Code Section 138-191). • Temporary irrigation may be required to establish vegetation.	• Provides runoff reduction and some filtering/sedimentation. • Applicable to small impervious areas and linear projects with sheet flow conditions, such as multi-use paths, sidewalks, and small impervious areas < 5,000 SF (e.g., patios, decks) where runoff can be distributed as sheet flow (buffers) or shallow, low-velocity concentrated flow (swales). • Can be used in a treatment train.
Storage-based Practices: WQCV or FSD			
Bioretention	• WQCV or FSD • MHFD Vol. 3 Ch. 4 • MHFD-Detention workbook	• Well suited for smaller sites (typically < 20 acres), infill, and redevelopment. • Do not use for subregional or regional applications unless a pretreatment forebay following EDB sizing criteria is provided and bioretention depth and surface area criteria in MHFD Volume 3 are strictly followed. • Select full-infiltration, partial-infiltration, or no-infiltration configuration based on the criteria in MHFD Vol. 3 Ch. 4. • Closely follow media specification in MHFD Vol. 3 Ch. 4. • Do not use partial- or full-infiltration configurations where soil or groundwater contamination may exist or is known to exist. • Temporary irrigation may be required to establish vegetation.	• Provides filtration, sedimentation, runoff reduction, and biologically-mediated pollutant removal. • Where phosphorus reduction is targeted, media amendments allowed to provide enhanced removal.

[52] EDBs are the only SCM type eligible for public maintenance by the CoA, and only when such facilities are both major and regional (i.e., more than 130 acres of tributary area and serving multiple property owners).

SCM Type	Design Basis/Tools	Site Suitability and Design	Comment
Extended Detention Basin (EDB)	• WQCV or FSD • MHFD Vol. 3 Ch. 4 • MHFD-Detention workbook	• Not allowed for drainage areas with less than 2 impervious acres. Maximum drainage area is 1 square mile. • See Table 11-4 for additional design criteria and selection considerations. Can be designed as a subregional or regional facility. • Adjust drain time in airport zones (see Chapter 10).	• Primarily provides sedimentation. • Eligible for public maintenance on private development if major regional facility with FSD. See Footnote 52.
Sand Filter	• WQCV or FSD • MHFD Vol. 3 Ch. 4 • MHFD-Detention workbook	• Most suitable for small sites (less than approximately 20 acres). • Do not use partial- or full-infiltration configurations where soil or groundwater contamination may exist or is known to exist. • Underground sand filters are prohibited unless unique circumstances limit use of other SCMs. Underground sand filters require a variance and additional review time will apply. See Chapter 10 for more information.	• Provides filtration and sedimentation. • Subsurface conditions must be considered to protect roadways and foundations. See MHFD Volume 3 Chapter 4, Table 4-3.
Permeable Pavement	• WQCV or FSD • MHFD Vol. 3 Ch. 4 • • MHFD-SCM Design workbook (for WQCV) or MHFD-Detention (FSD) workbook	• Suitable for parking areas, alleys, and low-use areas. Enables use of SCM surface area for other purposes. • Must meet loading requirements for traffic and fire access. • Select full-infiltration, partial-infiltration on no-infiltration configuration based on criteria in MHFD Vol. 3 Ch. 4. • Do not use partial- or full-infiltration configurations where soil or groundwater contamination may exist or are known to exist.	• Provides filtration and runoff reduction.

SCM Type	Design Basis/Tools	Site Suitability and Design	Comment
Manufactured Treatment Devices (MTDs)			
High rate media filtration (HRMF)	• WQPF for WQE • MHFD Vol. 3, Ch. 3 & 4 • Follow manufacturer's design method	• Performance must be verified through Technology Assessment Protocol–Ecology (TAPE) with the HRMF having achieved a General Use Level Designation (GULD) for Basic Treatment. If discharging in the Cherry Creek Basin, the HRMF must have TAPE GULD verification for Phosphorus Treatment. Comparable certifications under the STEPP or ASTM programs accepted. See Table 11-5 and the MHFD MTD fact sheet for additional information. • Do not exceed the verified hydraulic loading rate (HLR) in TAPE verification letter. The HLR is the rate at which pollutant removal was verified. • Only allowed when no above-ground alternatives are feasible. Not allowed for greenfield development. • If used as regional water quality facility, then pretreatment is required.	• HRMFs provide similar functions to sand filters but are designed based on peak flow rate for the WQE (i.e., the WQPF) rather than the WQCV.
High rate biofiltration (HRBF)	• WQPF for WQE • MHFD Vol. 3, Ch. 3 & 4 • Follow manufacturer's design method	• Performance must be verified through TAPE with the HRBF having achieved a GULD for Basic Treatment. If discharging in the Cherry Creek Basin, the HRBF must have TAPE GULD verification for Phosphorus Treatment. Comparable certifications under the STEPP or ASTM programs accepted. See Table 11-5 and the MHFD MTD fact sheet for additional information. • Systems accessible from the surface are allowed. • If used as regional water quality facility, then pretreatment is required. • HRBFs may provide proprietary media blends that target phosphorus removal.	• HRBFs provide similar functions as bioretention but are designed based on the peak flow rate for the WQE (i.e., the WQPF) rather than the WQCV.

SCM Type	Design Basis/Tools	Site Suitability and Design	Comment
Hydrodynamic Separator (HDS)	• WQPF for WQE • MHFD Vol. 3, Ch. 3 & 4 • Follow manufacturer's design method	• Currently allowed for space-limited urban sites and roadway widening projects, as well as for interim treatment for roadway sites until long-term water quality is installed for the development (see Table 11-1 and Chapter 10). • Otherwise, only allowed as pretreatment as part of a treatment train (i.e., sequence of SCMs) approach. See Table 11-5 and the MHFD MTD fact sheet for additional information. • May be used in lieu of a forebay for an EDB.	• Can be used to provide pretreatment in a treatment train. • When used in a treatment train with other SCMs, use the HDS as first step. • Use of HDSs in series is not recommended; instead, use an HDS followed by an infiltration or filtration SCM.

Table 11-4. Contributing Impervious Area Considerations for EDBs

Contributing Impervious Area (acres)	SCM Selection Criteria and Considerations
0-2	• EDBs not allowed; use filtration-based SCM such as bioretention, sand filter, HRBF, or HRMF instead.
2-20	• Consider sand filter, bioretention, or other filtration or infiltration SCM as an alternative to EDB. • Limit EDB outlet to 2 WQCV orifices to maximize orifice size while still providing a second orifice in case one clogs. • Protect orifices less than 1.25 inches in diameter with well screen and consider additional measures such as standard bar grating upstream of well screen to reduce the frequency of maintenance of the well screen.
20-50	• Limit EDB outlet to two WQCV orifices to maximize orifice size while still providing a second orifice in case one clogs. • Protect orifices with standard bar grating unless orifice dimensions are less than 1.25 inches in diameter. Well screen is not advised unless it is needed to protect small orifices (i.e., less than 1.25 inches), in which case, use a well screen.
> 50	• Evaluate baseflow under current and fully developed conditions (with consideration for irrigation return flows). Design outlet to pass baseflows without affecting the storage provided by the WQCV. Baseflows may change seasonally and year to year; therefore, if observed baseflows are used in design, be sure to consider antecedent precipitation and effects on flows at the time of observation. • Consider using multiple subregional EDBs throughout the watershed instead of designing one EDB for the entire tributary area. • EDB tributary drainage areas must not exceed 1 square mile. • EDB must provide WQCV for entire upgradient watershed.

Why Limit Contributing Drainage Area for SCMs?

The contributing drainage area is an important consideration for SCM selection and design at both at the site level and at the regional level. At the site level, there is a practical minimum size for certain SCMs, largely related to the ability to drain the WQCV over the required drain time. For example, it is theoretically possible to size the WQCV for an EDB for a half-acre site; however, designing a functional outlet to release the WQCV over a 40-hour drain time is practically impossible due to the very small orifices that would be required. For this size watershed, a bioretention or sand filter SCM would be more appropriate.

Conversely, there must be a limit on the maximum drainage area for a regional facility to ensure adequate treatment of rainfall events that may produce runoff from only a portion of the area draining to the SCM. If the overall drainage area is too large, events that produce runoff from only a portion of the contributing area will pass through the outlet (sized for the full drainage area) without adequate residence time in the SCM. As a practical limit, the maximum drainage area contributing to a water quality facility should be no larger than one square mile.

Table 11-5. Organizations with Testing Protocols for MTDs Accepted by CoA*

Organization/ Protocol	Description
TAPE	Technology Assessment Protocol–Ecology (TAPE) is the stormwater quality treatment certification program implemented by the Washington State Department of Ecology for evaluating the performance of emerging technologies to treat polluted stormwater (State of Washington Department of Ecology). The TAPE protocol is recognized in dozens of states and municipalities across the country to assist with approving MTDs and innovative stormwater treatment technologies.
NJDEP HDS Protocol	New Jersey Department of Environmental Protection (NJDEP) published the *Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation (HDS) Manufactured Treatment Device* in 2023 (New Jersey Department of Environmental Protection, 2023). Additionally, NJDEP certifies performance using the HDS or filter protocol, as opposed to "verifying" manufacturer claims.
STEPP	The National Municipal Stormwater Alliance (NMSA) established the National Center for Stormwater Testing and Evaluation for Products and Practices (STEPP) to promote development of a national testing and verification program for MTDs and public domain stormwater practices. STEPP will provide a program for third-party testing and verification of pretreatment MTDs, primary treatment MTDs, and traditional surface-based SCMs that will be a useful reference for designers and reviewers once the program is launched.
ASTM	ASTM International (formerly American Society for Testing and Materials [ASTM]) is currently developing a national standard for the performance of MTDs under ASTM Committee E64 on Stormwater Control Measures. The standard is consistent with the NJDEP laboratory testing protocol and, once published, can be used to evaluate the performance of MTDs. Additionally, a field-testing protocol is under development similar to the TAPE protocol.

* Organizations across the country provide testing protocols for MTDs. More details about individual testing protocols associated with the organizations in Table 11-5 can be found in Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual.

In addition to the criteria in the MHFD Manual, the following requirements apply:

- Where native vegetation is required as part of a functional SCM, irrigation plan submittals must show how irrigation will be provided to establish vegetation on a short-term basis. The CoA water conservation team will review this plan.

- Variances are required for SCMs located in the right-of-way (ROW) or in other areas where the CoA is responsible for maintenance.

- For infiltration-based practices, a geotechnical report is required. The applicant must consult with a geotechnical engineer to evaluate the suitability of soils for various infiltration-based SCMs and establish minimum distances between infiltration SCMs and structures. At a minimum, the geotechnical report must include:
    - A description of soil type and texture, including soil gradation data.
    - Results from infiltration tests in accordance with Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual. Infiltration tests must be representative of the subgrade of the SCM.
    - The depth to groundwater and an estimate of the seasonal high groundwater elevation.
    - Recommendations for whether the SCM should be designed for no infiltration (i.e., fully lined), partial infiltration, or full infiltration.
    - The minimum required setbacks between building foundations, road embankments, and/or other structures and infiltration-based SCMs.
    - The elevation of soils with shrink-swell potential.
    - Geotechnical recommendations for over-excavation or soil amendments needed to achieve the required infiltration rates.
- Infiltration-based practices are generally not appropriate for subregional or regional water quality facilities due to the large surface area and shallow depth requirements. If subregional or regional infiltration practices can strictly adhere to these design requirements, additional pre-treatment must be provided to reduce sediment loading; otherwise, the effectiveness of the SCM will be reduced over time due to clogging.
- Infiltration-based practices are not allowed at sites where the potential for groundwater or soil contamination is known to exist unless a no-infiltration (i.e., fully lined) configuration is utilized. See Volume 3, Chapter 4: Stormwater Control Measures of the MHFD Manual for additional information. It is incumbent upon the designer to ensure that the selected SCM does not result in additional contamination or cause the spread of existing contamination if a partial- or full-infiltration configuration is utilized.
- Underground SCMs are not allowed in greenfield development areas. See Chapter 10.
- For EDBs, reduced drain times are necessary in proximity to airports to reduce the potential for bird strikes. See Chapter 10.
- SCMs must comply with water rights reporting requirements as Chapter 10.

11.3.2 Safety

SCMs must be designed and maintained in a manner that protects the safety of both the public and maintenance personnel. Design criteria in Volume 3 of the MHFD Manual incorporate safety considerations and must be adhered to in the CoA. At a minimum, the following specific requirements must be met:

- Safety rails must be provided for facilities with vertical drops greater than 2.5 feet.

- Trash racks and safety grates on outlet structures must be provided in accordance with MHFD criteria.

- Bottom grading of the SCM must be designed to avoid standing water to prevent nuisance conditions and mosquitoes.

- Mild slopes (i.e., 4:1 horizontal: vertical [H:V]) or flatter are required for safe egress.

- Plan landscaping to discourage illicit activity. Avoid walled-in, remote basins that could provide a haven for illicit activities.

- Locate maintenance access outside of traffic areas to provide for the for safety of maintenance workers and to minimize traffic disruptions when maintaining SCMs.

- For EDBs, follow the public safety considerations described in Chapter 10 and in the MHFD EDB fact sheet.

Additional safety requirements may be identified based on site-specific conditions.

11.3.3 Maintenance

All SCMs must be maintained by the property owner, metropolitan district, or other non-COA entity unless a facility is accepted for public maintenance by the CoA. Facilities accepted by the CoA for maintenance must be designed in accordance with CoA and MHFD standards.

Maintenance requirements and costs are important considerations in SCM selection. All SCMs must be designed with adequate maintenance access provisions and in a manner that facilitates maintenance. The CoA requires that an Inspection and Maintenance (I&M) Plan be completed for all permanent SCMs. The I&M Plan shall be submitted to the CoA as described in Chapter 2 and must be signed by the owner of the facility or facilities to which it applies. In addition to maintenance requirements included in Volume 3 of the MHFD Manual, the following requirements apply:

- Dedicated drainage easements must be provided to allow operation and maintenance of SCMs. Maintenance access must be provided from public ROW. A drainage easement is required for portions of the maintenance access between the ROW and a SCM. Easement(s) must be documented on the plat or submitted by separate document, and must be recorded prior to civil clan (CP) approval. See Chapter 3 for additional requirements for easements.

- RPAs including grass swales and grass buffers must be included in a drainage easement if used to meet MS4 permit or Regulation 72 runoff reduction requirements.

- For EDBs, comply with the maintenance criteria in Chapter 10.

- Easements must be provided for all underground SCMs. Such easements must include an additional 4 feet from the perimeter of underground detention facilities/devices if bound by private property. SCMs may not be located underneath structures. Underground SCMs serving private property are not allowed in public ROW.

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CHAPTER 12.0 COMPUTER PROGRAMS

12.1 COMPUTER PROGRAM CRITERIA

There are many computer programs on the market for the analysis and design of storm water infrastructure. To assist in the efficient review of design computations and to promote consistent design methods, the City of Aurora (CoA) adopts the following policies and procedures:

1. Publicly available modeling platforms are preferred (i.e., models that do not require a license fee for the CoA to be able to open and run).

2. The most current available versions of models must be used for analysis. In some cases, it may be preferable to run a model in the software version in which the original was created for consistency of results (e.g., recreating master plan results for proposed development, or creating a duplicate effective model for floodplain analysis). The CoA may allow the use of previous versions of models for analysis on a case-by-case basis with justification provided by the engineer.

3. The CoA encourages applicants to use design spreadsheets developed by the Mile High Flood District (MHFD) (Mile High Flood District, latest edition), including the following:

    - UD-Rational – Peak runoff calculations via the Rational Method.
    - MHFD-Inlet – Street capacity and inlet sizing.
    - MHFD-Detention – Detention design including full spectrum detention (FSD).
    - MHFD-Culvert – Culvert design and hydraulics.
    - MHFD-SCM Design – Sizing procedures for stormwater control measures.

    The most current version of the MHFD spreadsheets must be used. Other spreadsheets are not accepted unless previous approval has been granted by the CoA.

4. The Federal Highway Administration's (FHWA's) Hydraulic Toolbox (Federal Highway Administration, latest edition) provides computational hydraulic tools for channels, channel linings, weirs (including irregular weirs), curb and gutter sections, storm drain inlets, detention basins, bridge scour, riprap countermeasures, sediment gradations, and culvert assessments. These tools can be applied for design in the CoA so long as the inputs and methods selected are consistent with the criteria in this Manual.

5. For rainfall-runoff modeling beyond the Rational Method, the Colorado Urban Hydrograph Procedure (CUHP) (Urban Drainage and Flood Control District (now Mile High Flood District), latest edition) and Environmental Protection Agency's (EPA's) Stormwater Management Model (SWMM) (United States Environmental Protection Agency, latest edition) must be used. Note that the most recent version of CUHP and SWMM should be used, but, on a case-by-case basis, the CoA may allow older versions to be utilized (see Item 2 above). SWMM also can be used to design storm drain networks, including hydraulic grade line (HGL) calculations. In most situations, using SWMM in kinematic wave mode is appropriate for design.

6. The United States Army Corps of Engineers' (USACE's) Hydrologic Engineering Center River Analysis System (HEC-RAS) (United States Army Corps of Engineers, latest edition) must be used for hydraulic modeling of open channels. In areas where the existing effective models are in the HEC-2 format, they must be converted to the latest version of HEC-RAS through a duplicate and corrected effective model analysis (see Chapter 4). When two-dimensional (2D) modeling is performed, the HEC-RAS 2D software must be used.

7. Commonly used proprietary models such as StormCAD, FlowMaster, and similar programs that implement the methods specified in this Manual may be approved by the COA for hydrologic and hydraulic design on a case-by-case basis. Model inputs and outputs must be summarized and clearly presented in all drainage submittals. If a proprietary model is used, all inputs and outputs must be shared with the CoA in an easily reviewable format, such as in the Portable Document Format (PDF). Reports that simply attach the input and output listings without preparing a concise summary of the inputs and outputs will not be accepted for review.

8. Any proprietary or non-proprietary software or program not listed above requires the approval of the CoA prior to its use in drainage analysis and design. This approval should be obtained before analysis or design based on the software is included in a drainage submittal (i.e., in a Master Drainage Report [MDR], Preliminary Drainage Report [PDR], or Final Drainage Report [FDR]).

12.2 REFERENCES

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