GREENWOOD VILLAGE

STORM DRAINAGE CRITERIA MANUAL

OCTOBER 2022

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Acknowledgments

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The City of Greenwood Village acknowledges and recognizes Urban Drainage and Flood Control District's, also know as Mile High Flood District, many decades of investment in development and refinement of Volumes 1 through 3 of the U*rban Storm Drainage Criteria Manual* and supporting software, which are incorporated by reference to this Manual.

Record of Changes

Since the incorporation of the Village, there have been several adoptions and revisions of drainage regulations. Most of the revisions have been prompted by federal, state and regional regulations. Below is a summary of the history highlights. Many additional revisions have been adopted as a result of revised regulations but are not enumerated here because the revisions have not impacted policy. Future revisions to this Greenwood Village Storm Drainage Criteria Manual adopted by Council will be added to the history section regardless of impact to policy.

1950 Incorporation of the City Greenwood Village. Storm drainage was managed with currently accepted engineering drainage practices.

1970 Adoption of the Arapahoe County Subdivision Regulations. Stormwater management is included in the Subdivision Regulations of the Municipal Code because the Subdivision Regulations set the process and procedures for the development of land and it was through these processes that stormwater management can be effectively implemented. The purposes of Subdivision Regulations include:

a. Health and safety.

b. Secure safety from floodwater and other dangers.

c. Ensure that impacts of development are appropriately mitigated.

1986 Adoption of the Greenwood Village Storm Drainage Design and Technical Criteria Code (Code). The Code was developed in 1982 but was not adopted until 1986 because of the impacts of the Cherry Creek Reservoir Control Regulation No. 72. The current edition of the Urban Drainage and Flood Control District's Urban Storm Drainage Criteria Manual (UDFCD Manual) was adopted by reference.

1989 Adoption of the Greenwood Village Storm Drainage and Technical Criteria Manual, which included water quality with 50% phosphorus removal and the UDFCD Manual adopted by reference. The initial Flood Insurance Rate Maps were published and adopted.

1999 Adoption of the Greenwood Village Storm Drainage Criteria Manual which included flood attenuation and water quality with 60% phosphorus removal. The Village increased the required phosphorus reduction from 50%, as stated in Regulation No. 72, to 60% because the Village wanted to be more protective of water quality and determined that 60% phosphorus removal standard was necessary to meet the water quality standards for Cherry Creek Reservoir. The 60% reduction requirement was not adopted in Regulation No. 72. The UDFCD Manual was adopted by reference.

2003 Amendment to the Municipal Code and Greenwood Village Storm Drainage Criteria Manual regarding drainage violations, landscape permit, grading permits, wetland maintenance and redevelopment criteria as a result of the Colorado Discharge Permit System Municipal Separate Storm Sewer System (CDPS MS4) Phase II Permit.

2005 Amendment to the Greenwood Village Storm Drainage Criteria Manual and adoption of the Construction Site Management Manual as a result of the CDPS MS4 Phase II permit.

2019 Adoption of the Revised Greenwood Village Storm Drainage Criteria Manual to incorporate City Council direction as follows:

1. Apply the Cherry Creek Reservoir Regulations No. 72 only to the area of the Village that drains to Cherry Creek Basin.

2. Apply the Urban Drainage and Flood Control District's Urban Strom Drainage Criteria Manual methodology for full spectrum detention rather than the current 60% phosphorus removal standard.

3. Remove the requirement for water quality for single family residential lots where development or redevelopment disturbs less than an acre.

Other notable changes to the Greenwood Village Storm Drainage Criteria Manual included:

- Require water quality for commercial sites that disturb less than one acre.

- Adopt the Water Quality Capture Volume (WQCV) as the basis for stormwater quality treatment in accordance with the UDFCD Manual and the Village's MS4 Permit (rather than the 60% phosphorus removal standard). Alternative treatment approaches specified in the Village's MS4 permit are also allowed.

- General updates to the Village's Manual to be consistent with current regulatory requirements as described in the Cherry Creek Reservoir Control Regulated 72 (last updated October 9, 2012) and the Village's MS4 Permit (last updated December 1, 2016) and with currently applicable design criteria in the UDFCD Manual (including updates through August 2018).

2020 Adopted the September 4, 2020, FIS and FIRM and included a restriction for tents and makeshift structures, enclosures, or other shelters used for human habitation within the floodplain.

2022 Removed the dates of the FISs and FIRMs to state "latest version" to eliminate going to City Council each time any FIS and FIRM is updated.
Included new language in section 4.5.2 Floodplain Fringe and Encroachments. The new language adds "and drainage way" at the end of the sentence that states "Tents and makeshift structures, enclosures, or other shelters used for human habitation, shall not be permitted in floodplains and drainage ways.

Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACPA	American Concrete Pipe Association
ASTM	American Society for Testing and Materials
BFE	Base Flood Elevation
BMP	Best Management Practice
BOAA	Board of Adjustments and Appeals
BR	Bioretention
CAD	Computer Aided Design
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
CLOMR	Conditional Letter of Map Revision
CLOMR-F	Conditional Letters of Map Revisions Based on Fill
CMP	Corrugated Metal Pipe
CRS	Colorado Revised Statutes
CUHP	Colorado Urban Hydrograph Procedure
CWB	Constructed Wetland Basin
CWCB	Colorado Water Conservation Board
DFIRM	Digital Flood Insurance Rate Map
EDB	Extended Detention Basin
EGL	Energy Grade Line
EPA	U.S. Environmental Protection Agency
EURV	Excess Urban Runoff Volume
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FSD	Full Spectrum Detention
GI	Green Infrastructure
GIS	Geographic Information System
GSI	Green Stormwater Infrastructure
HDPE	High Density Polyethylene Pipe
HEC-RAS	Hydrologic Engineering Center’s River Analysis System
H:V	Horizontal to Vertical
LID	Low Impact Development
LOMR	Letter of Map Revision

LOMR-F	Letter of Map Revision Based on Fill
MDCIA	Minimized Directly Connected Impervious Area
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NAVD	North American Vertical Datum
NFHL	National Flood Hazard Layer
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PPD	Permeable Pavement Detention
PRF	Pollutant Reduction Facility
PVC	Polyvinyl Chloride Pipe
RCP	Reinforced Concrete Pipe
RP	Retention Pond
SCM	Stormwater Control Measure
SFB	Sand Filter Basin
SFHA	Special Flood Hazard Area
SWMM	Stormwater Management Model
SWMP	Stormwater Management Plan
TMAL	Total Maximum Annual Load
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UDFCD	Urban Drainage and Flood Control District (aka: Mile High Flood District)
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
WQCV	Water Quality Capture Volume

Abbreviations for Units of Measurement

cfs	cubic feet per second
fps	feet per second
lbs/sf	pounds per square foot
mg/L	milligrams per liter
sq. ft.	square feet

Definitions

Applicable Development Site - Development sites that result in land disturbance of greater than or equal to one acre, including sites less than one acre that are part of a larger common plan of development or sale, unless excluded below. Applicable development sites include all new development and redevelopment sites for which permanent water quality control measures are required in accordance with a Municipal Separate Strom Sewer System (MS4) permit.

Best Management Practice (BMP) - A technique, process, activity, or structure used to reduce pollutant discharges in stormwater. BMPs include source control practices (non-structural BMPs) and engineered structures designed to treat runoff.

Base Flood - The flood having a one percent (1%) chance of being equaled or exceeded in any given year. Also known as the 100-year flood.

Datum – Historically, the standard vertical datum in use for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the finalization of the North American Vertical Datum of 1988 (NAVD88), many FIS reports and FIRMs are being prepared using NAVD88 as the referenced vertical datum. All flood elevations in the FIS for Greenwood Village are referenced to NAVD88. New Construction - Structures for which the start of construction commenced on or after December 16, 1980, which is the date of publication of the initial FIRM map for the Village.

Energy Grade Line (EGL) - The total energy level of the water in a conveyance, being the sum of the depth of flow, the velocity head, and the elevation of the invert.

Excess Urban Runoff Volume (EURV) - The difference between urban and pre-development runoff volumes. The EURV is the basis of design for Full Spectrum Detention facilities.

Final Stabilization - The condition reached when all ground surface disturbing activities at a site have been completed, and for all areas of ground surface disturbing activities, a uniform vegetative cover has been established with an individual plant density of at least 70 percent of pre-disturbance levels, or equivalent permanent, physical erosion reduction methods have been employed.

Flood or Flooding - A temporary condition of partial or complete inundation of normally dry land from the unusual and rapid accumulation or runoff of surface water from any source.

Flood Insurance Rate Map (FIRM) - The official map on which the Federal Emergency Management Agency (FEMA) delineates Special Flood Hazard Areas.

Flood Insurance Study (FIS) - The official report prepared by FEMA that includes flood profiles, the Flood Boundary Map, and the water surface elevation of the base flood.

Flood Profile - A longitudinal profile showing the water elevation of a flood event.

Floodplain - The relatively flat or lowland area adjoining a creek, gulch, drainageway, or other body of standing water which has been or may be covered temporarily by floodwater.

Floodplain Easement - The area dedicated for the Special Flood Hazard Area.

Floodway - The channel of a creek, gulch, or other drainageway and the adjacent areas that must be preserved in order to discharge the base flood without cumulatively increasing the flood elevation more than 1 foot or the EGL elevation by more than 6 inches, whichever is less.

Full Spectrum Detention - A stormwater detention facility design that provides water quality and flood control benefits and reduces impacts on downstream channels by detaining the Excess Urban Runoff Volume (EURV) and releasing it over a 72-hour period.

Land Development - Any human-caused change to improved or unimproved real estate, including but not limited to buildings or other structures, dredging, filling grading, paving, excavation, or drilling operations.

Land Disturbing Activity - Any activity that results in a change in the existing land (both vegetated and non-vegetated). Land disturbing activities include, but are not limited to, clearing, grading, excavation, demolition, installation of new or improved haul roads and access roads, staging areas, stockpiling of fill materials, and borrow areas. Compaction that is associated with stabilization of structures and road construction is also considered a land disturbing activity.

Local Drainage System - The local drainage system consists of curb and gutter, ditches, swales, storm sewer inlets, storm sewers, culverts, bridges, detention areas, and all other drainage facilities used to convey the minor storm and major storm runoff to major drainageways.

Lowest Floor - The lowest floor of the lowest enclosed area (including basement).

Major Drainageway - Any channel with a tributary area of 130 acres or more.

One Hundred Year Flood - The flood having a one percent (1%) chance of being equaled or exceeded in any given year assuming ultimate development conditions throughout the tributary basis.

Pre-development Conditions - The condition of the land in a natural state prior to any development.

Regional Stormwater Detention Facility – Regional detention facilities serve an area of 130 acres or more and are usually publicly owned and maintained.

Special Flood Hazard Area - The land in the floodplain of a major drainageway subject to flooding during the Base Flood.

Structure - A walled and roofed building that is principally above ground.

Stormwater Control Measure - Any best management practice (BMP) or other method used to prevent or reduce the discharge of pollutants to waters of the state. Control measures include, but are not limited to, BMPs. The terms stormwater control measure and BMP are used interchangeably in this Manual.

Stormwater Management Plan (SWMP) – A plan that details the erosion, sediment and waste control plans required for applicable development sites.

Subregional Stormwater Detention Facility – Subregional detention facilities serve multiple landowners or lots and have a total watershed area of less than 130 acres. Most detention facilities located within residential communities are subregional, serving multiple individually owned lots. Subregional detention facilities are located off-line from the receiving stream.

Substantial Damage – 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 before the damage occurred.

Substantial Improvement – 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 improvement. This includes structures which have incurred substantial damage, regardless or the actual repair work performed. The term does not include any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications identified by the local code enforcement official which are the minimum necessary conditions or alteration of a historic structure, provided that the alteration will not preclude the structure's continued designation as a historic structure.

Village – the Village refers to the City of Greenwood Village. In the context of decision-making and appeals related to these criteria, the Village means the City Manager or his/her designee.

Violation - The failure of a structure or other development to be fully compliant with this Drainage Criteria Manual. A structure or other development without an approved Final Drainage Study, approved Construction Drawings, or other evidence of compliance with this Drainage Criteria Manual or NFIP standards is presumed to be in violation until such time as that documentation is provided.

Water quality capture volume (WQCV) - The volume equivalent to the runoff from an 80th percentile storm, meaning that 80 percent of the most frequently occurring storms are fully captured and treated and larger events are partially treated.

Water Surface Elevation - The height, in relation to the NAVD of 1988 (or other datum, where specified) of floods of various magnitudes and frequencies in floodplains or in any drainageway.

Wetlands - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas, though in the Village they can also include gulches, washes, major drainageways, and other areas that are not wet year-round. The federal regulations defining wetlands and limiting activities that affect wetlands are found in 33 CFR Parts 320 through 330 and 40 CFR Part 230.

1.0 Drainage and Stormwater Management Policies

1.1 Background and Purpose

The City of Greenwood Village (Village) has adopted a series of policies for the integration of its drainage and stormwater management systems into the overall planning policies of the Village. These policies are intended to protect the public health, safety and welfare and protect the environment. The Village's major drainageways incorporate an extensive parks and trails system that provides multiple benefits such as passive recreational opportunities through a series of pedestrian and equestrian trails, wetlands, terrestrial and avian wildlife protection areas, and aquatic habitat.

The purpose of this Storm Drainage Criteria Manual (Manual) is to establish criteria for the design, construction and maintenance of drainage and stormwater quality improvements in the Village. The Manual also provides planning and submittal requirements for land development projects in the Village, as well as describes the review and approval process for drainage and stormwater management plans. This Manual follows and incorporates by reference the design criteria in the Urban Storm Drainage Criteria Manual (UDFCD Manual) developed by the Urban Drainage and Flood Control District (UDFCD). Stormwater management requirements specific to the Village are also included in this Manual. Wherever conflicts exist among the criteria, the criteria described in the Village's Manual apply.

This Manual also serves as the cornerstone of the Village's post-construction and construction stormwater management programs that are required by the Colorado Department of Public Health and Environment (CDPHE) under several Colorado Water Quality Control Commission regulations related to stormwater quality management.

1.2 Land Development Classifications and Requirements

Storm drainage and stormwater quality management requirements vary based on land development classifications. Land development classifications, applicability and general requirements are summarized in this section. Land development classifications include both development and redevelopment.

1.2.1 Land Development Classifications

For purposes of this Manual, classifications for land development are defined in accordance with terminology used in the Colorado Water Quality Control Commission Cherry Creek Reservoir Control Regulation (5 CCR 1002-72, also known as Regulation 72). Although only a small portion of the eastern boundary of the Village is within the Cherry Creek Reservoir Basin, the Regulation 72 terminology provides consistency in describing land development and redevelopment thresholds throughout the Village. Classifications include:

1. Tier 1 development and redevelopment – any land disturbance less than one acre that is developed independently of a larger common plan of development or sale, and which results in less than 500 square feet of imperviousness for new development or less than 500 square feet of increased imperviousness for redevelopment.

2. Tier 2 development and redevelopment – any land disturbance less than one acre that is developed independently of a larger common plan of development or sale, and which results in more than 500 square feet but less than 5,000 square feet of imperviousness for new development, or more than 500 square feet and less than 5,000 square feet of increased imperviousness for redevelopment. For areas in the Cherry Creek Reservoir watershed, the total amount of disturbance also includes disturbances of existing impervious areas.

3. Tier 3 development and redevelopment – any land disturbance greater than or equal to one acre, or which results in more than 5,000 square feet of imperviousness for new development or 5,000 square feet of increased imperviousness for redevelopment. For areas in the Cherry Creek Reservoir watershed the total amount of disturbance also includes disturbances of existing impervious areas.

Integration of Water Quality and Flood Attenuation

When developments and redevelopments are required to implement stormwater quality and flood attenuation, these requirements can often be integrated. For example, full spectrum detention facilities address both flood attenuation and stormwater quality. Similarly, sites implementing runoff reduction practices can provide both flood attenuation and stormwater quality benefits, depending on site conditions. For example, when runoff reduction methods are used on small development and redevelopment sites that are required to implement flood attenuation, but not stormwater quality, benefits to stormwater quality also occur.

Tier 3 sites with land disturbance greater than or equal to one acre, including sites less than one acre that are part of a larger common plan of development or sale, are Applicable Development Sites regulated under the Village's Colorado Discharge Permit System Municipal Separate Storm Sewer (CDPS MS4) stormwater permit.

1.2.2 Applicability of Drainage and Stormwater Quality Management Requirements by Land Development Classification

All development and redevelopment within the Village is subject to drainage and stormwater management requirements based on its Land Development Classification and whether the land area is located in the Cherry Creek Reservoir Basin boundaries (Figure 1-1), as summarized in Table 1-1. Design professionals must perform analysis to verify if a site is within or outside of the Cherry Creek Reservoir basin. Stormwater quality requirements are also discussed in more detail in Chapter 15.

Figure 1-1. Portion of Greenwood Village Tributary to Cherry Creek Reservoir Basin

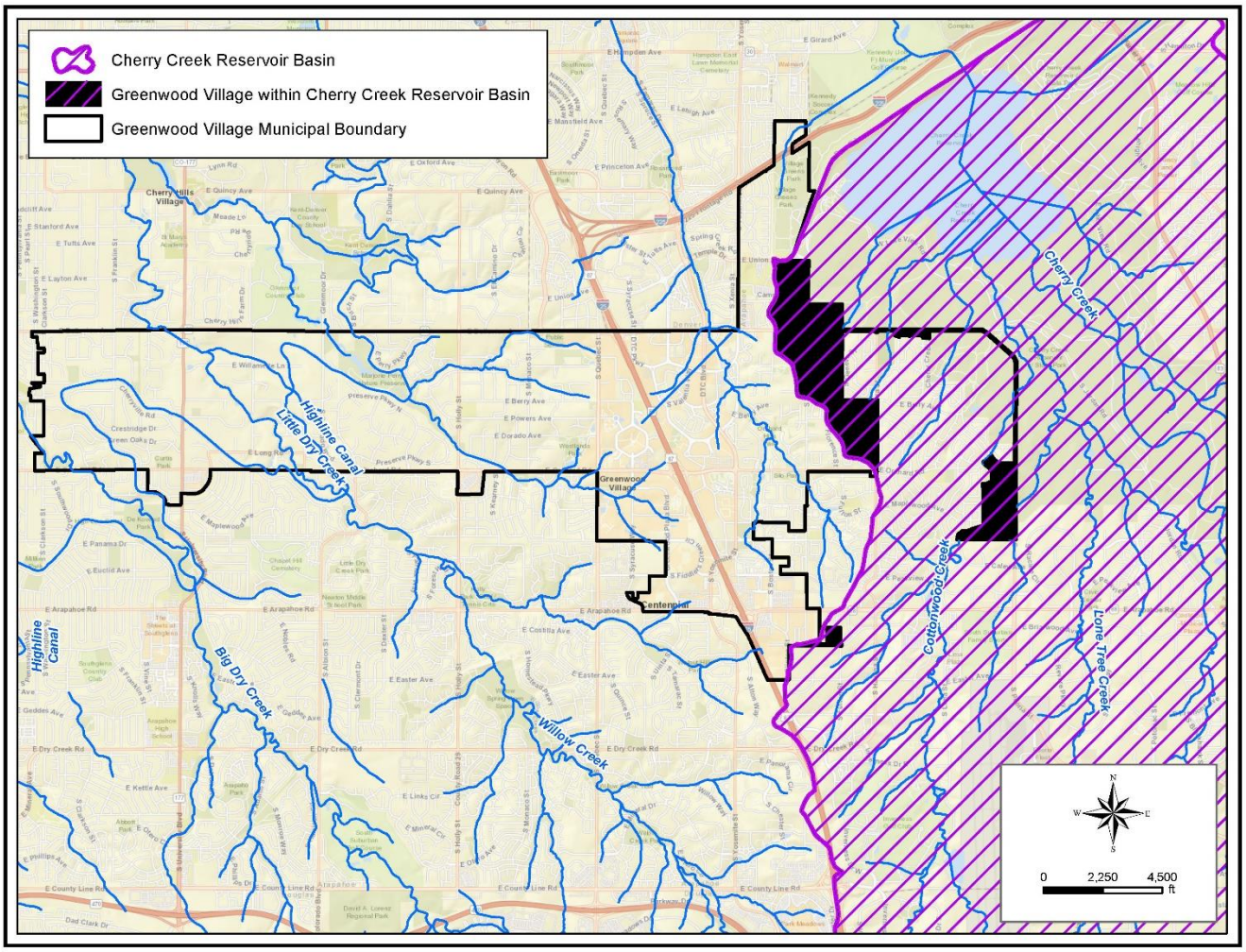


Table 1-1. Drainage and Stormwater Quality Management Requirements Based on Land Development Classification

Land Development Classification	Wetland and Floodplain Requirements	Flood Attenuation Requirements	MS4 Post-Construction Stormwater Quality Requirements	
			Outside of Cherry Creek Reservoir Basin[1]	Cherry Creek Reservoir Basin[2,3]
Tier 1 Development and Redevelopment (<500 sq. ft. imperviousness added)	**Wetlands** No net loss of wetland functions and values. **Floodplain** Development restricted in Special Flood Hazard Area (SFHA).	Flood attenuation not required.	Post-construction water quality not required.	Post-construction water quality not required.
Tier 2 Development and Redevelopment (<1-acre disturbance with impervious area increase > 500 sq. ft. and <5,000 sq. ft.)		Implement flood attenuation using UDFCD Manual runoff reduction practices and/or full spectrum detention for: 1) existing development to achieve release rates equal to discharge rates based on 1998 impervious area and 2) new development to achieve 90% of historic discharge rate.	Post-construction water quality control is not required for residential development/redevelopment. Post-construction water quality control is required for non-residential development/redevelopment.	Implement stormwater control measure that meets one or more of the following criteria: • WQCV does not leave the site. • Sheet flow over grass buffer area. • Grass swale and minimize directly connected impervious area (MDCIA). • Constructed wetland channel. • Grass buffer meeting certain criteria. • Hydrologic analysis showing adequate water quality protection. • Alternative control measures with comparable or better nutrient removal characteristics.
Tier 3 Development and Redevelopment (<1-acre disturbance with impervious area increase > 5,000 sq. ft.)				Implement stormwater quality control measure to provide the WQCV to treat, at a minimum, the 80th percentile storm event. Approved BMPs: • Extended Detention Basin (EDB) • Retention Pond (RP) • Constructed Wetland Basin (CWB) • Porous Pavement Detention (PPD) • Bioretention (BR) • Sand Filter Extended Detention Basin (SFB) • Runoff Reduction practices (MDCIA/LID) • Constructed wetland channel plus EDB, RP, CWB, PPD, BR or SFB • Grass swales plus PPD or BR • Constructed wetland channel preceded by modular block pavement • MDCIA plus EDB, RP, BR, SFB WQCV Alternatives: Other BMPs that do not use the WQCV or are in combination with WQCV with better or comparable nutrient reduction capabilities.
Tier 3 Development and Redevelopment (≥ 1-acre disturbance)			Implement stormwater quality control measures to meet one of the following base design standards: • Treat and/or infiltrate the Water Quality Capture Volume (WQCV). • Treat the 80th percentile storm event to remove pollutants • Infiltrate 60% of the WQCV to reduce runoff. • Provide regional WQCV control measure. • Provide a regional WQCV facility.	

Table Notes:

[1] A single-family residential lot greater than or equal to 2.5 acres with an impervious area of less than 10% is not required to provide water quality if a site-specific study demonstrating that runoff is controlled through pervious area infiltration is provided.

[2] Individual single-home construction disturbing less than one acre of land where the owner has a permit for one dwelling is not required to provide permanent stormwater quality treatment.

[3] Tier 2 and 3 land disturbances in Regulation 72 Stream Preservation Areas must implement BMPs that promote filtration or infiltration to treat the WQCV.

1.2.3 General Requirements

1. Any drainage study or drawing submitted by an applicant to the Village for approval must be stamped and signed by a Professional Engineer licensed in the State of Colorado.

2. The responsibility for compliance with the policies and criteria of the Village rests entirely with the applicant. Any review or approval by the Village of drainage studies or drawings submitted by an applicant does not relieve the applicant of the responsibility of meeting the requirements of this Manual.

3. Any development or redevelopment that adversely impacts off-site areas because of modifications to drainage patterns or facilities must mitigate the impacts to those areas.

4. Whenever work is being performed contrary to any provision of this Manual, the Village may order the work stopped by notice in writing served on any person engaged in doing or causing such work to be done. Any such person must forthwith stop such work until authorized by the Village in writing to proceed with the work. It is unlawful to do or perform any work in violation of such a stop work order.

5. The Village benefits from the creation and preservation of wetlands. The Village will approve only those development and redevelopment projects that fully preserve the function and values of wetlands. This is known as the "no net loss of wetlands" goal.

6. Drainage easements must be provided for all flood attenuation and stormwater quality facilities. The Village may require easements for other drainage improvements such as storm drains, inlets, roadside ditches, swales, culverts, floodplains, open channels, flow areas outside of streets, storage facilities, and stormwater quality treatment facilities. The easements must be sufficiently large to accommodate the 100-year flood and allow proper maintenance of the facilities. The drainage easements must be clearly shown in all drainage studies, construction drawings and other relevant documents.

7. Where this Manual and any other drainage criteria manual, ordinance, plat, or development plan overlap or conflict, the Village will determine the applicable requirements.

8. UDFCD has prepared major drainageway plans for most of the major drainageways within the Village showing recommended channel and bank improvements to stabilize the drainageways. The latest edition of the major drainageway plans and Flood Hazard Area Delineations (FHADs) are hereby adopted as guidelines for improvements to the major drainageways within the Village. Development and redevelopment projects that are located on properties adjacent to the major drainageways will be responsible for implementing the recommended improvements. Per Colorado Revised Statues 32-11-221(1), these improvements require UDFCD approval.

1.3 Floodplain Management Policies

1. The Village will not approve uses of or modifications to a Special Flood Hazard Area (SFHA) that could adversely impact the public health, safety, and general welfare of the Village.

2. The Flood Insurance Rate Maps (FIRMs) approved by the Federal Emergency Management Agency (FEMA) will be used to delineate floodplains. The Flood Hazard Area Delineation (FHAD) as provided in master plans prepared by UDFCD and adopted by the Colorado Water Conservation Board (CWCB) must also be considered. Whenever there is a conflict among sources in the delineation of the floodplain, the Floodplain Administrator will determine the most appropriate applicable delineation.

3. The applicant is responsible for securing the appropriate revisions to floodplain maps at its own expense for any alterations to the SFHA.

4. Appeals to decisions by the Village related to the regulation of the SFHA must follow the procedures outlined in Submittals (Chapter 3).

1.4 Flood Flow Attenuation Policies

1. Drainage systems must be designed to control flood discharges to protect people, property and the environment. The flood discharges from development or redevelopment in the Village must be managed to levels that will not cause or worsen drainage and flooding problems. Flood attenuation is required for all development and redevelopment activities that create 500 square feet or more of new impervious area. Flood attenuation practices must be designed in accordance with the criteria in this Manual and the UDFCD Manual.

2. For development and redevelopment sites that add 500 square feet or more of imperviousness or disturb one or more acres of land, flood attenuation requirements can be met through use of full-spectrum detention flood attenuation facilities and/or UDFCD Manual runoff reduction practices. Runoff reduction practices avoid the direct connection of impervious areas to the storm drain and instead, guide runoff from pavement and roofs to vegetated areas such as grass buffers and grass swales in a manner that maintains sheet flow conditions. Runoff is reduced by infiltration, depression storage, and evapotranspiration. Runoff reduction methods are generally only applicable as a stand-alone practice on small sites. Required release rates vary for redevelopment and development sites and must meet these criteria:

    i. For redevelopment of existing development, release rates must be equal to discharge rates based on 1998 impervious area.

    ii. For new development, release rates must achieve 90% of the historic discharge rate for the undeveloped area.

3. Flood attenuation requirements must be met prior to discharge of stormwater to a major drainageway, wetland, or across the property line of the applicant, unless a subregional or regional facility is provided.

4. If on-site detention or runoff reduction are impractical or if it is in the best interest of health, safety, and welfare, the applicant may apply for a waiver in accordance with Section 3.3 of this Manual.

1.5 Stormwater Quality Management Policies

The Village's general stormwater quality management policies are summarized below, followed by specific stormwater quality treatment requirements by land use classification and exemptions.

1.5.1 General Stormwater Quality Management Policies

1. Stormwater quality control is an integral part of any stormwater management system in the Village. The major drainageways, reservoirs, and wetlands in and near the Village are valuable resources, which must be protected against the potentially adverse water quality effects of stormwater discharges.

2. The Colorado Water Quality Control Commission has adopted use classifications and water quality standards for Cherry Creek Reservoir and streams in the Village, as summarized in Table 1-2. These standards are adopted to protect the aquatic life, recreation, and water supply resources of the Village. The criteria in this Manual are intended to manage stormwater runoff to achieve compliance with these classifications, standards and regulations.

3. This Manual provides the minimum requirements for controlling post-construction stormwater runoff to attain water quality standards to the maximum extent practicable.

4. All drainage studies and drawings for developments and redevelopments that require stormwater quality treatment must demonstrate compliance with the design criteria in this Manual.

5. Certain stormwater management facilities may impact water rights. The Village's policy is to preserve the integrity of water rights in the planning, design, and construction of stormwater drainage facilities in accordance with CRS 37-92-602(8) "Concerning a Determination that Water Detention Facilities Designed to Mitigate the Adverse Effects of Stormwater Runoff Do Not Materially Injure Water Rights."

6. If on-site stormwater quality post-construction control measures are impractical or if it is in the best interest of health, safety, and welfare, the applicant may apply for a waiver in accordance with Section 3.3 of this Manual.

Table 1-2. Summary of Colorado Water Quality Control Commission Regulations Related to Stormwater Management in Greenwood Village

Colorado Reg.[1]	Purpose	Implementation Related to Stormwater	Village Responsibilities to Implement Regulation
38	Establishes beneficial uses and numeric stream standards for water quality for streams/lakes in the South Platte River Basin.	If a waterbody is determined to be impaired based on stream standards, completion of a Total Maximum Daily Load (TMDL) may result in increased MS4 permit requirements to address pollutant loading.	Follow MS4 permit requirements for sites with disturbances ≥ 1 acre. Includes requiring implementation of post-construction BMPs, with design criteria specified in this Manual. Includes requiring erosion and sediment control during construction, following criteria specified in the Manual.
61	Establishes requirements for point source dischargers regulated under CDPS permits, including stormwater discharges.	Stormwater quality BMPs required according to MS4 permit.	
85	Establishes nutrient management controls for Colorado. Wastewater, stormwater and other sources are included. Nutrient controls address total phosphorus and total nitrogen.	Stormwater management practices implemented in the MS4 permit. Good housekeeping at municipal facilities. Develop and implement a municipal operations program that has the ultimate goal of preventing or reducing nitrogen and phosphorus in stormwater runoff associated with the MS4 permittee's operations. Public education and outreach on stormwater impacts associated with nutrients.	
72	Protects Cherry Creek Reservoir water quality. Establishes water quality standards and requirements for dischargers in the Cherry Creek Reservoir Basin.	Various stormwater management requirements to reduce pollutant loading to reservoir during construction and post-construction.	Follow MS4 permit requirements for the Cherry Creek Reservoir Basin for disturbances ≥ 1 acre. Implement additional Reg. 72 requirements for disturbances of < 1 acre that have > 500 sq. ft. of new impervious area.
93	Identifies Impaired Waters in Colorado (Section 303(d) List)	Streams identified as impaired require development of a TMDL resulting in additional MS4 permit requirements.	Comply with potential additional waterbody-specific requirements in MS4 permit.

[1]Colorado Water Quality Control Commission regulations can be accessed at: https://www.colorado.gov/pacific/cdphe/water-quality-control-commission-regulations.

1.5.2 Construction Erosion and Sediment Control Requirements

1. During construction, erosion and sediment controls must be implemented in accordance with the most current versions of the Village's MS4 stormwater permit, Regulation 72, Chapter 16 Erosion and Sediment Control of this Manual, and the City of Greenwood Village Public Infrastructure Design and Construction Standards.

2. Any development or redevelopment that disturbs one acre or more of land must obtain coverage under the Colorado Discharge Permit System (CDPS) General Permit for Stormwater Discharges Associated with Construction Activities. In locations within the Cherry Creek Reservoir Basin, sediment control requirements apply for disturbances less than one acre.

3. Any development or redevelopment that disturbs less than one acre of land outside of the Cherry Creek Reservoir Basin must implement erosion and sediment control measures described in Chapter 16 of this Manual.

4. Construction-phase stormwater controls must be designed and implemented in accordance with Volume 3 of the UDFCD Manual unless justification is provided to the Village for use of alternate construction stormwater control design criteria.

1.5.3 Post-construction Stormwater Treatment Requirements by Land Use Classification

1. Permanent post-construction stormwater quality treatment is required under the Village's MS4 stormwater permits and Regulation 72. The post-construction stormwater treatment requirements vary based on a three-tiered land use classification system and whether the site is located in the Cherry Creek Reservoir Basin. These requirements are summarized in Table 1-1. All stormwater quality control measures must be designed in accordance with the criteria in this Manual and the UDFCD Manual.

2. Exemptions from post-construction stormwater quality treatment requirements are defined in the Village's stormwater MS4 permit. Representative exemptions include activities such as agricultural activities, trails, stream stabilization projects, emergency repairs and maintenance of underground utilities, certain types of roadway projects, and certain types of large-lot single-family developments employing runoff reduction practices.

1.6 Operation and Maintenance of Drainage Facilities

1. All drainage studies and drawings must include a maintenance plan designed to maintain the flood attenuation and water quality management requirements of this Manual. Adequate access must be provided to maintain the facilities.

2. The applicant and its successors and assigns are responsible for maintaining the drainage and water quality improvements.

3. The Village reserves the right to inspect the drainage and water quality facilities and determine whether or not the flood attenuation and water quality management requirements of this Manual have been maintained. If the Village notes any deficiencies, it

will notify the owner of the deficiencies and the owner must submit to the Village a proposal to correct the deficiencies within thirty days. The Village will review and comment upon the proposed plan and approve or reject the proposed plan in writing.

4. If an approved plan has not been completed within the proposed timeframe in the plan, the Village reserves the right to correct the deficiencies at its own expense and collect its expenses from the owner and to file a lien on the property which relies upon the drainage facilities and to use other lawful means of collection of its expenses if they are not paid by the owner in a timely manner.

5. Major drainageway improvements and regional detention or water quality enhancement facilities that are eligible for maintenance by UDFCD must meet the requirements of UDFCD's Maintenance Eligibility Program. Per Colorado Revised Statues 32-11-221(1), design, construction, and vegetation requirements for drainage facilities other than collection systems must be approved by UDFCD.

1.7 Stormwater Facility Reporting Requirements Related to Water Rights

In 2015, Colorado Revised Statute (CRS) §37-92-602(8) (also known as Senate Bill 15-212) became law. This statute provides water rights related legal protection for any regional or individual site stormwater detention and infiltration facility in Colorado, provided that the facility meets these criteria:

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.).
5. If it is in the Fountain Creek (tributary to the Arkansas River) watershed it must be required by or operated in compliance with an MS4 permit.

The 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 assignees), must not be released for subsequent diversion or storage by the owner/operator/overseer (or that entity's assignees), and must not be the basis for a water right or credit (UDFCD 2016).

Under this statute, new stormwater detention and infiltration facilities must complete certain reporting requirements facilitated by an on-line mapping system for Stormwater Detention and Infiltration Facility Notification (https://maperture.digitaldataservices.com/gvh/?viewer=cswdif). This information must be filed prior to operation of the facility and include the following:

1. Location.
2. Approximate surface area at design volume.
3. Data that demonstrate that the facility has been designed to comply with the release rates described in Items 2 and 3 above.

Not all stormwater facilities are required to complete filing requirements and certain types of facilities are not protected under this statute, as summarized in Table 1-3. Neither retention facilities nor constructed wetlands are protected under CRS §37-92-602(8); these facilities expressly require a water right. Temporary construction sedimentation basins should not be uploaded the on-line portal unless they will be used as permanent detention basins. In such case, the final detention configuration should be completed before uploading the record.

Table 1-3. Stormwater Facility Reporting Requirements under Senate Bill 15-212
(Source: UDFCD 2016)

BMP Type	Water Quality Only	Flood Control Included
Grass Buffers	Not Required	Not Required
Grass Swales	Not Required	Not Required
Bioretention (with or without an underdrain)	Not Required	Required
Green Roof	Not Required	Not Required
Extended Detention Basin	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	
Constructed Wetland Channel	N/A, Subject to Water Rights	
Retention Pond	N/A, Subject to Water Rights	

1.8 Other Policies

1. When foundation drains or sump pumps are required to protect structures, the outlet must discharge overland to promote infiltration prior to discharge offsite. Direct discharge to a sidewalk, gutter, street, roadside ditch or flood attenuation or water quality facility is prohibited. Additionally, common/community foundation drains installed in the right of way will be evaluated by the Village on a case-by-case basis and require a license agreement for long-term operation and maintenance.

2.0 Inventory of Resources for Drainage and Stormwater Projects

Table 2-1 summarizes commonly used resources needed for drainage and stormwater-related projects in the Village and provides weblinks to access the most current version of these references. Additional resources and references may be needed in addition to this selected list of frequently used resources.

The horizontal control for mapping is the Colorado State Plane Coordinate system, and the vertical control is NGVD 1929. This vertical datum is different from the NAVD 1988 that is used for floodplain mapping. Although the difference varies somewhat by location, the NGVD 1929 is approximately 3 feet lower than the NAVD 1988 for the Village. Each section-quarter-corner has a designated control point. The mapping is available electronically or in hard-copy form in quarter sections. Figure 2-1 is an index for the mapping system, and Figure 2-2 is the accompanying survey control diagram.

Table 2-1. Selected Resources to Support Stormwater and Drainage Improvements

Type	Reference/Resource	Description
Master Drainage Plans, Outfall Systems Plans and Floodplain Information	Urban Drainage and Flood Control District Master Drainage Plans, Outfalls System Plans, Floodplain Information and proposed drainage improvements. Find information: http://mapsearch.udfcd.org/ Access GIS information: http://udfcd.gisworkshop.com/	Current master plans for the perennial streams and their tributaries within the Village: 1) Big Dry Creek 2) Little Dry Creek 3) Greenwood Gulch 4) Goldsmith Gulch 5) Cottonwood Creek
FEMA Flood Maps	FEMA Flood Map Service Center https://msc.fema.gov/portal	Flood hazard information produced in support of the National Flood Insurance Program (NFIP).
FEMA National Flood Hazard Layer	FEMA National Flood Hazard Layer https://www.fema.gov/national-flood-hazard-layer-nfhl	Current FEMA data reflecting recent LOMRs available as kmz files to view in GoogleEarth or GIS.
Basic Arapahoe County GIS Mapping	Arapahoe County ArapaMAP https://gis.arapahoegov.com/ArapaMAP/	Online map service for geographic and spatial queries.
Greenwood Village Maps	Greenwood Village Maps http://www.greenwoodvillage.com/593/Village-Maps	Static PDF maps developed by the Village.
Stormwater MS4 Permit	Cherry Creek Reservoir Basin MS4 General Permit (COR080000) https://www.colorado.gov/pacific/cdphe/wq-municipal-ms4-general-permits	MS4 stormwater quality permit requirements specific to the Cherry Creek Reservoir Drainage Basin and for areas outside of the Cherry Creek Basin.

Type	Reference/Resource	Description
General Stormwater Construction Discharge Permit	Stormwater discharges associated w/construction activities (COR030000) https://www.colorado.gov/pacific/cdphe/wq-construction-general-permits	Construction-phase stormwater permit required by CDPHE for land disturbances ≥ 1 acre.
General Construction Dewatering Permit	Construction dewatering discharge permit (COG070000) https://www.colorado.gov/pacific/cdphe/wq-construction-general-permits	Construction dewatering source water can be groundwater, surface water, or stormwater that has commingled with the groundwater and/or surface water.
Colorado Water Quality Control Regulations	Regulation 72: Cherry Creek Reservoir Control Regulation Regulation 38: Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin https://www.colorado.gov/pacific/cdphe/water-quality-control-commission-regulations	Provides applicable water quality standards in the Cherry Creek Basin and for streams in the basin. Website also provides links to other potentially applicable control regulations.
Soils Mapping	USDA's Natural Resources Conservation Service (NRCS) Web Soil Survey https://websoilsurvey.nrcs.usda.gov/	Access to soil data information and soils maps based on user-defined project areas and/or areas of interest.
Wetland Mapping	U.S. Fish and Wildlife National Wetlands Inventory https://www.fws.gov/wetlands/data/mapper.html	Provides general information on potential wetland locations. Should only be used for planning purposes and does not constitute an official wetland delineation.
Clean Water Act Section 404 Permits	U.S. Army Corps of Engineers http://www.nwo.usace.army.mil/Missions/Regulatory-Program/Colorado/	Provides information on Section 404 permits required for the discharge of dredged or fill material into waters of the United States.
Detention Basin Notification Portal	Stormwater Detention and Infiltration Facility Notification under CRS §37-92-602(8) https://maperture.digitaldataservices.com/gvh/?viewer=cswdif	Mapping tool to provide the required notification for detention/infiltration to the stakeholders in the facility's watershed.
Stormwater and Drainage Facility Maintenance Eligibility	Urban Drainage and Flood Control District http://udfcd.org/maintenance-eligibility	Guidelines and requirements for UDFCD's Maintenance Eligibility Program for development-initiated floodplain modification projects.
Cherry Creek Basin Water Quality Authority	Provides consolidated information about water quality issues and activities in the Cherry Creek Basin http://www.cherrycreekbasin.org/	Resources available to manage the Cherry Creek Reservoir, tributaries, and surrounding lands.

Figure 2-1. City of Greenwood Village Mapping System Index

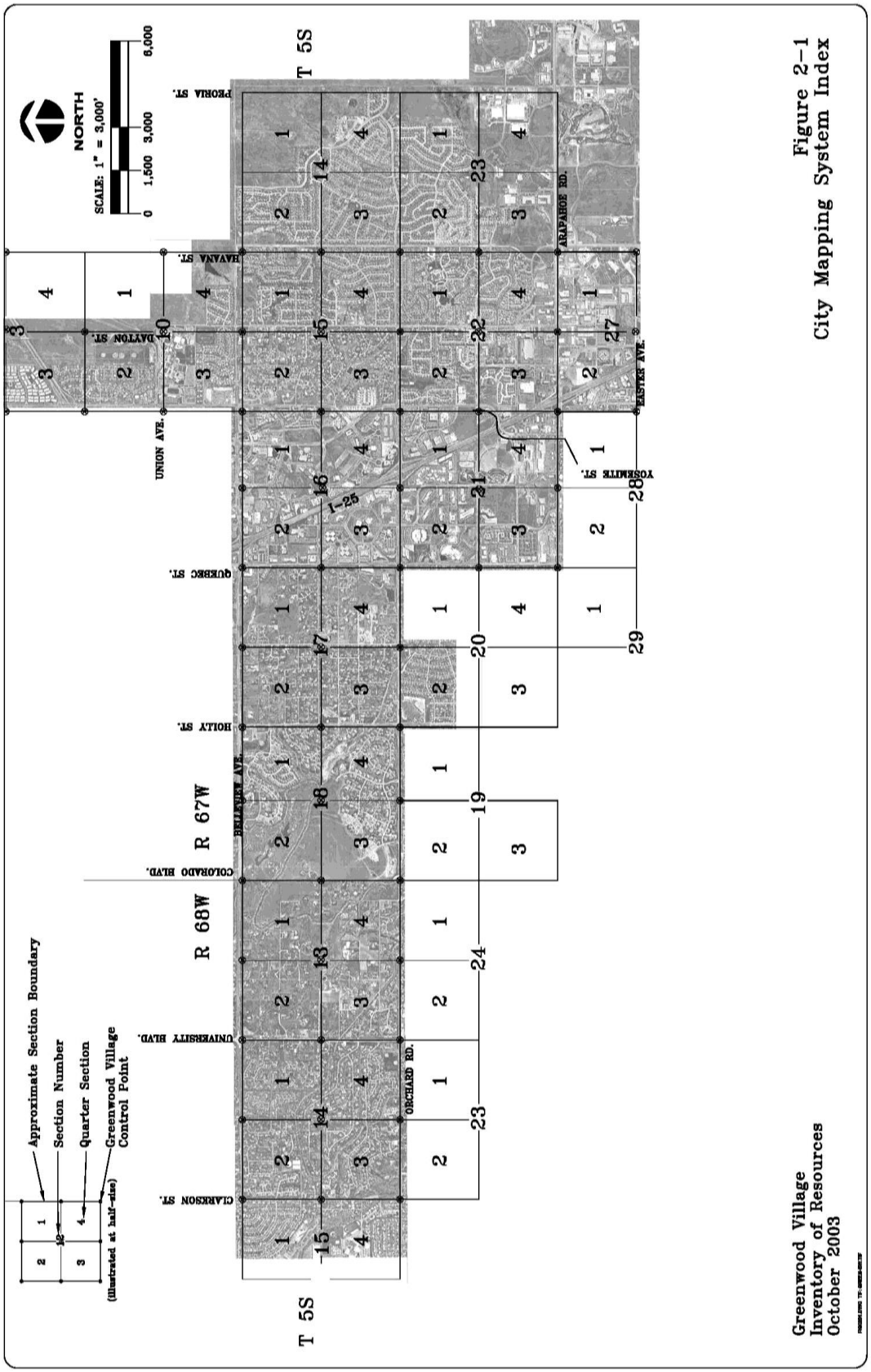
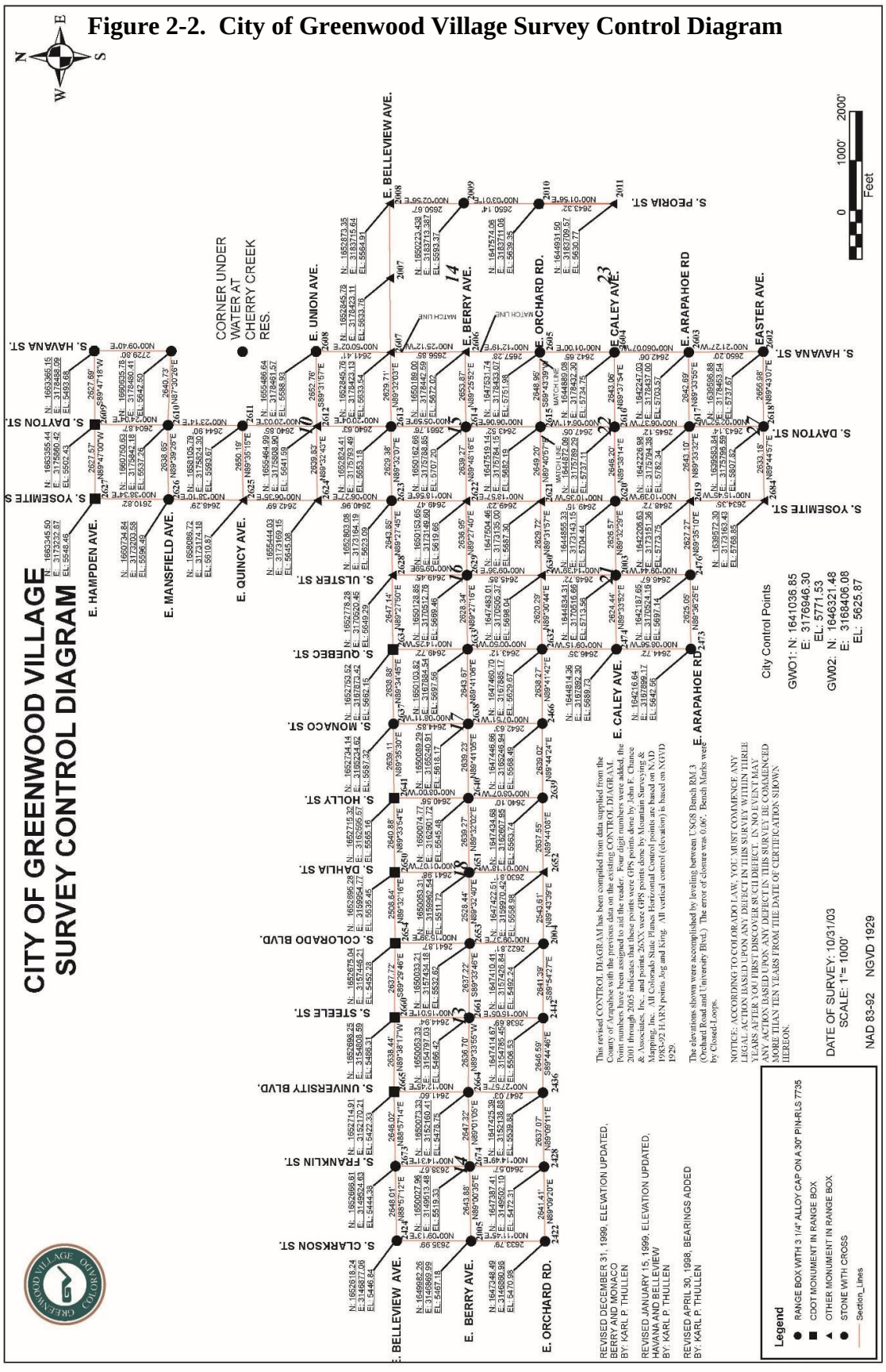


Figure 2-2. City of Greenwood Village Survey Control Diagram



3.0 Submittal Requirements

This chapter describes the Village's submittal requirements for drainage studies and the review, approval, waiver and appeals process for such studies.

3.1 Drainage Studies

Drainage study submittal requirements vary depending on the type of project, as summarized in Table 3-1. Drainage study submittal types include:

- **Conformance Letter:** A drainage conformance letter provides data and drainage analysis demonstrating that the project conforms to the most recently approved drainage report for the original site development and conforms to the Village's requirements for flood attenuation and water quality criteria. Where there is no previously approved drainage report, an analysis of existing drainage conditions must be provided. Conformance drainage studies are typically in the form of a letter report and are primarily allowed for minor and administrative amendments to various land development plans and as an initial step in Capital Improvement Projects and Community Development Permits.

- **Conceptual Drainage Study:** This type of drainage study is completed in the planning stages of land development projects and documents how drainage and water quality requirements will be met for a proposed development, but without completion of detailed design. A conceptual drainage study examines the feasibility of the project by providing the conceptual design, evaluating environmental site constraints, and demonstrating conformance with other planning documents and applicable regulations. The conceptual drainage study identifies and defines conceptual solutions to drainage problems that may occur on-site and off-site as a result of the development. Existing on-site drainage problems prior to development must also be addressed during the conceptual phase.

- **Preliminary Drainage Study:** Preliminary drainage studies build upon the requirements of the conceptual drainage study and provide more detailed calculations for the hydrologic basis of design, but without hydraulic analysis of storm sewers. When a conceptual drainage study has been previously approved by the Village, the preliminary drainage study will update the information in the conceptual drainage study.

- **Final Drainage Study:** The final drainage study addresses all drainage and water quality requirements for the site, including complete hydrologic and hydraulic analysis, design and construction drawings. Additionally, final drainage studies must include construction-phase stormwater management requirements (i.e., erosion and sediment control) and provide a long-term operation and maintenance plan for flood attenuation and stormwater quality facilities.

Specific requirements for each type of study are provided in checklists on the Village's website. The optional submittal of a conceptual or preliminary drainage study is allowed during the initial phases of the review by the Village for certain development types, as identified in Table 3-1; however, the project will not be approved until the final drainage study has been submitted and approved by the Village.

Table 3-1. Submittal Requirements

Type of Project	Type of Drainage Study			
	Conformance	Conceptual	Preliminary	Final
Land Development				
Annexation/Rezoning	No	Yes	No	No
Master Development Plan	No	Yes	No	No
Administrative Amendment	Yes	No	No	No
Site Development Plan	No	Optional	Optional	Yes
Major Amendment	No	Optional	Optional	Yes
Minor Amendment	Yes	No	No	No
Administrative Amendment	Yes	No	No	No
Planned Unit Development	No	Optional	Optional	Yes
Major Amendment	No	Optional	Optional	Yes
Minor Amendment	Yes	No	No	No
Administrative Amendment	Yes	No	No	No
Special Use Permit	No	Optional	Optional	Yes
Major Amendment	No	Optional	Optional	Yes
Minor Amendment	Yes	No	No	No
Administrative Amendment	Yes	No	No	No
Landscaping Plan				
Amendment for Water Conservation	Yes	No	No	No
Major Subdivision				
Final Plat	No	Optional	Optional	Yes
Preliminary Plat	No	Optional	Yes	No
Minor Subdivision 1. Vacation of Public Right of Way 2. Certified Survey Map 3. Lot Line Adjustment 4. Vacation of Interior Lot Line	Yes	No	No	No
Construction				
Capital Improvement Project[2]	Yes[1] (Sites <2,000 SF of increased impervious area)	Optional	Optional	Yes (Sites > 2,000 SF of increased impervious area)
Community Development Permits 1. Building Permit 2. Site Work 3. Floodplain[2] 4. Parking Lot 5. Accessory Structure	Yes (Sites < 2,000 SF of increased impervious area)	No	No	Yes (Sites > 2,000 SF of increased impervious area)

[1]May be used to justify exclusions.
[2]Floodplain permit requires a Final Drainage Report regardless of the amount of increased impervious area.

3.1.1 Drainage Study Submittal Requirements

All drainage study reports must be in a format approved by the Village. The study must be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that this (*type of study*) for (*name of site*) was prepared by me or under my direct supervision in accordance with the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The study must also be certified by the owner of the property using the following form:

> I hereby certify that the drainage facilities proposed for (*name of site*) will be constructed and maintained in accordance with the design presented in this (*type of study*). I understand that the City of Greenwood Village does not and will not assume liability for the proposed drainage facilities.
>
> _____
> Signature
>
> _____
> Date

3.1.2 Construction Drawing Submittal Requirements

Construction drawings must be submitted on 36" x 24" paper and submitted with the permit application for review and approval prior to construction. The construction plans must be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that these construction drawings for (*name of site*) were prepared by me or under my direct supervision in accordance with the approved Final Drainage Study and the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The construction drawings for the site must address all of the improvements required by the approved final drainage study. Requirements for construction plans are provided on checklists provided on the Village's website.

3.1.3 Record (As-Built) Drawing Submittal Requirements

An electronic set of as-built drawings for all drainage improvements must be provided in GIS format and must be certified by a professional engineer licensed in the State Colorado using the following form and submitted to the Village before the Village will accept the improvements:

> I hereby certify that these record drawings for (*name of site*) were prepared by me or under my direct supervision. The changes in the as-constructed conditions will not materially adversely affect the performance of the drainage facilities approved in the construction drawings and as required by the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

All submitted as-built drawings will be reviewed for compliance with the Village's requirements. After the as-built drawings have been approved by the Village, corrected electronic versions must be submitted.

3.2 Village Review and Approval

Village staff will review the drainage studies, construction drawings, record drawings, and applications for waivers and provide written review comments or approval.

The Village's review comments or approval of any studies or drawings does not relieve the applicant of their responsibility to comply with the requirements and regulations of the federal government, the State of Colorado, or the Village. The review and approval by the Village is offered only to assist the applicant's understanding of the applicable requirements.

Review and approval by other agencies, such as special districts, local governments, state or federal agencies and other referral agencies, may be required for some submittals. The applicant must address referral agency comments and obtain applicable approvals. Additionally, it is the applicant's responsibility to complete notification requirements for flood attenuation and stormwater quality facilities through the Colorado Division of Water Resources in accordance with CRS §37-92-602(8).

3.3 Waivers of Requirements

Under certain conditions, the requirements of this Manual may be waived. The applicant must initiate the waiver procedure by submitting an application for a waiver to Community Development. The applicant must provide an analysis, certified by a professional engineer licensed in the State of Colorado, in accordance with the following:

1. The applicant must include a description of conditions and/or constraints that prevent the applicant from meeting the requirements of this Manual. The application must provide specific reference to applicable sections of this Manual and/or the Village's CDPS MS4 permit relevant to the proposed waiver request.

2. The applicant must describe the cumulative impacts of the proposed waiver and similar potential waivers for similar properties in the same major drainage basin in the Village. Potential adverse impacts of the proposed waiver on major drainageways and downstream public and private drainage facilities and properties must be provided.

3. The applicant must provide alternatives to meet flood attenuation, water quality and other requirements of this Manual. If the analysis identifies the use of off-site and/or regional drainage facilities to meet the requirements of this Manual, the applicant must also include:

    a. Location of proposed facility.
    b. Owner of proposed facility.
    c. Analysis of available capacity of facility.
    d. Proposed modifications to the facility to accommodate proposed use (if applicable).
    e. Analysis of storm drain system capacity to convey flows to the facility.
    f. Agreement for use and maintenance of the facility.

Upon receipt of a complete application for a waiver, staff will prepare a rationale statement including an analysis of the application and either approve, disapprove, or request modifications of the proposed waiver.

3.4 Appeals

The applicant or any citizen of the Village materially affected by the proposed waiver may appeal to the Board of Adjustments and Appeals (BOAA). Any appeal from an order, requirement, decision, or determination of the Village made pursuant to this Manual will be taken within fifteen days following the date of such order, requirement, decision, or determination by the filing of a written notice of appeal with the Director of Community Development. The notice of appeal must state in detail the action appealed from, the grounds for the appeal, and the relief sought. The Director will forward the notice of appeal to the BOAA. The BOAA will hear such appeal within thirty days of the filing of the notice of appeal. At such hearing, both the appellant and the Director will have an opportunity to be heard and present evidence. The BOAA may affirm the decision, reverse the decision or affirm the decision with conditions. The ruling of the BOAA will be final, subject to judicial review.

4.0 Floodplain Criteria

4.1 Introduction

Floodplains in the Village are subject to periodic inundation that could result in loss of life and property, health and safety hazards, disruption of commerce and government services, extraordinary public expenditures for flood protection and relief, and impairment of the tax base. All of these impacts, singularly or collectively, have the potential to adversely affect the public health, safety, and general welfare of the Village. Flood losses may be due in part to the cumulative effects of obstructions in Special Flood Hazard Areas (SFHAs), which can increase flood heights and velocities.

SFHAs are defined based on areas inundated by the 1% annual exceedance probability flood event, also known as the "base flood" or 100-year event. The 100-year water surface elevations are called base flood elevations or "BFEs." Structures that are inadequately flood-proofed, inadequately elevated, or otherwise unprotected from flood damage also contribute to flood losses, and structures or other objects that are inadequately anchored can become flood debris and cause downstream damages.

The purpose of the floodplain management criteria is to promote the public health, safety and general welfare, and to minimize public and private losses due to flood conditions by providing criteria 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 that are generally undertaken at the expense of the public.
4. Minimize prolonged business interruptions.
5. Minimize damage to public facilities and utilities located in SFHAs.
6. Maintain a stable tax base by providing criteria for responsible development adjacent to SFHAs in order to minimize future flood blight areas.
7. Alert potential property buyers that a property is in a SFHA.
8. Ensure that those who occupy the SFHAs assume responsibility for their actions.
9. Protect the storage capacity of floodplains and ensure preservation of sufficient floodway area to convey flood flows that can reasonably be expected to occur.
10. Protect the hydraulic characteristics of small watercourses, including gulches, streams, and artificial water channels used for conveying floodwaters.
11. Reduce ongoing major drainageway operation and maintenance costs.

In order to accomplish these purposes, this section includes methods and provisions for:

1. Restricting or prohibiting uses that are dangerous to health, safety, and property due to water or erosion hazards, or which result in damaging increases in erosion, flood heights, or velocities.

2. Requiring that uses and facilities vulnerable to floods be protected against flood damage at the time of initial construction. All new and substantially improved critical facilities and new additions to critical facilities must be located outside of SFHAs. Critical facilities are structures or related infrastructure, but not the land on which the facilities are situated, that if flooded may result in significant hazards to public health and safety or interrupt essential services and operations for the community at any time before, during, and after a flood.

3. Controlling the alteration of natural floodplains, stream channels, and natural protective barriers that help accommodate or channel floodwaters.

4. Controlling filling, grading, dredging, and other development activities that may increase flood damage.

5. Preventing or regulating the construction of flood barriers that will unnaturally divert floodwaters, or which may increase flood hazards in other areas.

4.2 Floodplain Mapping

FEMA has published Digital Flood Insurance Rate Maps (DFIRMs) that delineate floodplains in the Village. In addition, the Urban Drainage and Flood Control District (UDFCD) has published Flood Hazard Area Delineation (FHAD) maps developed as part of major drainageway planning. These maps delineate areas inundated by the base flood (100-year flood), similar to FIRMs and DFIRMs. In many cases, FHADs that are completed by UDFCD provide the basis for DFIRM mapping that is adopted by the Colorado Water Conservation Board (CWCB) and FEMA.

Proposed development that may have an effect on or be affected by these floodplains must use the flood delineations adopted by the CWCB or the DFIRM, whichever are more restrictive. Floodplain maps should be obtained on-line at the FEMA Map Service Center at www.fema.gov. Applicants also should consult UDFCD and/or FEMA's National Flood Hazard Layer (NFHL) (https://www.fema.gov/national-flood-hazard-layer-nfhl) to determine if there have been any Letters of Map Revision (LOMRs) since the effective date of the FIRM.

Floodplain limits must be determined by evaluating the FIRM. Applicants also should compare floodplain mapping with available topography for existing conditions to verify that the mapping is representative of current conditions. Where a conflict exists between this information and actual field conditions, the Village will make the necessary determination regarding the floodplain limits.

Whenever a development alters a major drainageway, the developer is responsible for revising the floodplain maps at their expense. All plans, details, calculations, and other requirements must be submitted through the Village to UDFCD in accordance with FEMA criteria. The Village will

notify the CWCB as required. In areas where the floodplain has not been mapped by FEMA or CWCB, the applicant will be required to provide mapping of approximate floodplain boundaries prior to beginning any work.

The Village will issue building permits based on approval of drainage design plans as well as compliance with all other Village requirements. For projects that will modify the SFHA, a Conditional Letter of Map Revision (CLOMR) must be issued by FEMA prior to the Village issuing a building permit. CWCB regulations require a LOMR when the base flood elevations (BFEs, i.e., 100-year water surface elevations) change by 0.30 feet or more relative to pre-project conditions. In such cases, the Village will also require a CLOMR. For changes in BFEs of less than 0.30 feet, a simplified permitting process known as a CLOMR/LOMR based on Fill (CLOMR-F/LOMR-F) may be used. Ultimately, the local Floodplain Administrator has discretion over whether a CLOMR or CLOMR-F is required for a project.

"As-Built" surveys must be submitted for construction in or near the floodplain prior to issuance of a certificate of occupancy. For alterations to the floodplain that modify the boundaries of the SFHA or BFEs (100-year water surface elevations), a LOMR will be required. The Village Floodplain Administrator must approve all necessary documentation for submittal of a CLOMR or LOMR prior to submittal to UDFCD. All expenses for preparation and submittal of CLOMRs and/or LOMRs will be borne by the applicant.

4.3 General Provisions

4.3.1 Special Flood Hazard Areas

The SFHAs prepared by UDFCD and adopted by the CWCB, and the flood areas identified in the latest version of the FEMA report titled "The Flood Insurance Study Report for Arapahoe County, Colorado and Incorporated Areas," with accompanying DFIRMs are hereby adopted by reference as part of this Manual. The effective dates of FIS and DFIRMs differ depending on when the drainage basin was studied and approved. The FISs and DFIRMs are available at FEMA's online Map Service Center (www.fema.gov). Areas not included in the FEMA or CWCB designated floodplains, but within the major drainageways, will be considered as SFHAs if the base flood inundates these areas under the projected ultimate developed conditions in the watershed. Major drainageways are defined as drainageways with at least 130 acres of tributary drainage area.

4.3.2 Compliance

No structure will be constructed, extended, converted, or altered within a SFHA without full compliance with the requirements of this Manual and Chapter 16 of the Village Land Development Code.

4.3.3 Abrogation

Where this Manual and another ordinance, plat, or other approved plan conflict or overlap, whichever imposes the more stringent restrictions as determined by the Village will prevail.

4.3.4 Interpretation

In the application of this chapter, all provisions will be considered minimum requirements, liberally construed in favor of the Village, and deemed neither to limit nor repeal any other powers granted under the State of Colorado Revised Statutes.

4.3.5 Disclaimer

The degree of flood protection required by this Manual is considered reasonable for regulatory purposes and is based on scientific and engineering considerations. Larger floods can and will occur on rare occasions. Flood heights may be increased by man-made or natural causes. This Manual does not imply that land outside the SFHAs or uses permitted within such areas will be free from flooding or flood damages. This Manual must not create liability on the part of the Village, any officer or employee thereof, for any flood damages that result in reliance on this Manual or any administrative decision made thereunder.

4.4 Administration

4.4.1 Floodplain Permit Application

Approval from the Village is required for all permit applications for floodplain revisions before construction or development begins within a SFHA. Application for a permit must be made on forms furnished by the Village and must include, but not be limited to, plans drawn to scale and certified by a Professional Engineer licensed in the State of Colorado showing the following minimum requirements:

1. Ensure that any changes within the SFHA comply with FEMA requirements.
2. Location, dimensions, uses, and elevations of the area in question.
3. Existing and/or proposed structures.
4. Existing and proposed contours and drainage facilities.
5. Elevation in relation to mean sea level of the lowest floor (including basement) of all structures. All elevations must be in the North American Vertical Datum of 1988 (NAVD 88) for compatibility with Village floodplain mapping. If elevations are in a different datum, the datum should be converted to NAVD 88 for all submittals related to floodplains.
6. Elevation in NAVD 88 to which any non-residential structure has been flood-proofed and the method of such flood-proofing.

Energy Grade Line Criteria for Flood Fringe and Floodway

The Village regulates rises due to fill in the floodplain fringe (the area within the SFHA but outside of the floodway) based on a maximum rise of 0.5 feet in the energy grade line (EGL). The change in the EGL is equal to the change in water surface elevation plus the change in the velocity head.

Any work within the floodway must meet no-rise criterion (0.00 feet) for the 100-year water surface elevation and the EGL.

7. Description of the extent to which any watercourse will be altered or relocated as a result of proposed development.

8. Evaluation of the cumulative effect of the proposed development, when combined with existing and anticipated development within the floodplain, on the energy grade line (EGL) elevation of the base flood.

4.4.2 Duties and Responsibilities of the Village's Floodplain Administrator

The Village will implement and administer this Manual by granting or denying permit applications in accordance with the provisions of this chapter. In the Village, the Community Development Engineer acts as the Floodplain Administrator, under the authority of the City Manager. Duties of the Floodplain Administrator include, but are not limited to, the following:

1. Permit Review

    a. Review all permit applications to determine that the requirements of this Manual have been satisfied.

    b. Review all permit applications to determine that all necessary permits have been obtained from those federal, state, or local governmental agencies.

    c. Review all permit applications to determine if the proposed development is located in the SFHA.

2. Use of Other Base Flood Data

    a. When BFEs have not been established (for example when the floodplain is approximate, Zone A), the applicant must provide accurate BFE and floodway data to the Village in order for the Village to administer permits under Section 4.5.

3. Information to be Obtained and Maintained

    a. Obtain and record the actual elevation in NAVD 88 of the lowest floor (including basement) of all new or substantially improved structures located within SFHAs.

    b. For all new or substantially improved flood-proofed structures:

        i. Verify and record the actual first floor elevations in NAVD 88.

        ii. Maintain the flood-proofing certifications required in Section 4.5.3.

    c. Maintain for public inspection all records pertaining to the provisions of this Manual and in accordance with the provisions of the current edition of the International Building Code and Uniform Plumbing Code as referenced by the Village.

4. Alteration of Watercourses

    a. Notify adjacent communities and the CWCB prior to any alteration or relocation of a watercourse and submit evidence of such notification to the UDFCD.

    b. Require that maintenance be provided within the altered or relocated portion of said watercourse to preclude diminishing the flood carrying capacity.

5. Interpretation of Flood Boundaries

    a. Make interpretations where needed, as to the exact location of the boundaries of the SFHAs (e.g., where there appears to be a conflict between a mapped boundary and actual field conditions). The person contesting the location of the boundary will be given a reasonable opportunity to appeal the interpretation as provided in Section 3.4.

4.4.3 Nonconforming Uses

The existing lawful use of a structure or premises that does not conform to the provisions of this Manual may be continued subject to the following conditions:

1. No such use will be expanded or enlarged except in conformity with the provisions of this Manual.

2. No structure alteration, addition, or repair to any nonconforming structure over the life of the structure can exceed 50 percent of its assessed value at the time of it becoming a nonconforming use unless it is permanently changed to a conforming use.

3. If such use is discontinued for 12 consecutive months, any future use of the building or premises must conform to this chapter.

4. Any alteration, addition, or repair permitted to any non-conforming non-residential structure must be protected by flood-proofing measures in accordance with Section 4.5.3.

4.5 Permitted Uses within SFHAs

The following sections identify the two areas within the SFHA floodplains with BFEs that are defined for regulatory purposes and discuss additional issues related to development adjacent to floodplains.

4.5.1 Floodway

The floodway is defined as the stream channel and that portion of the floodplain that must be preserved in order to discharge the peak flow of the base flood without increasing the EGL by more than 0.5 feet. The EGL is computed as the water surface elevation plus the velocity head. The floodway limits are typically generated through hydraulic modeling by assuming an equal loss of conveyance on both sides of the floodplain due to encroachments. The floodway cannot be identified by visual inspection on a specific site or stream reach. The floodway is defined for regulatory purposes, and development in or use of the floodway is severely restricted. In most cases, projects that encroach upon the floodway require a “no rise” in water surface elevation

certification for existing structures, and conveyance improvements are needed to balance fill activities so that there are no rises in BFEs or the EGL that adversely affect insurable structures.

4.5.2 Floodplain Fringe and Encroachments

The floodplain fringe is the portion of the SFHA that is not within the floodway. Although development and other forms of encroachment may be considered in the floodplain fringe, developers do not have an inherent right to fill in the floodplain fringe. Encroachments into the floodplain fringe reduce beneficial floodplain storage areas, and the cumulative effect of such encroachments can have significant impacts on downstream properties. Reduction of floodplain storage areas can increase peak flow rates and associated BFEs downstream, even though theoretically there may be limited impact at the site where the encroachment occurs. For this reason, encroachment into the floodplain fringe is contrary to the objective of minimizing damage to life and property and to the objective of maintaining floodplains as open space. Therefore, encroachments into the floodplain fringe are discouraged and will be considered on a case-by-case basis. When considering requests involving floodplain fringe encroachment, at a minimum, the following will be considered:

- Impacts to adjacent properties. If the encroachment creates a rise in the BFE on properties other than that of the applicant, the applicant will be required to obtain floodplain easements for the additional floodplain property. FEMA typically will not allow any encroachment that causes a rise on an existing habitable structure.

- Channel hydraulics and design. If the encroachment creates a significantly narrow channel with steep side slopes and undesirable velocities, mitigating channel improvements will be required; otherwise, the floodplain encroachment will not be allowed.

- Channel stability, aesthetics and land use. If the fringe encroachment significantly impacts the functions, stability or aesthetics of the natural drainageway and the resulting channel improvements create a drainageway that is not deemed compatible with the surrounding land uses, the floodplain fringe encroachment will not be allowed.

- Threatened and Endangered Species. FEMA requires that the U.S. Fish and Wildlife Service (USFWS) sign-off for threatened and endangered species for CLOMRs. If there is no effect on threatened and endangered species, the USFWS provides a letter of concurrence of "no taking."

Any structure that is proposed within the SFHA must have a lowest floor elevation that is at least one foot above the BFE based on the proposed development conditions. This must be verified through a LOMR or LOMR-F based on "As Built" conditions.

Tents and makeshift structures, enclosures, or other shelters used for human habitation, shall not be permitted in the floodplain and drainageways.

4.5.3 Provisions for Flood Hazard Reduction

Within the SFHA, the following standards are required:

1. Anchoring

    a. All new construction and substantial improvements must be anchored to prevent flotation, collapse, or lateral movement of the structure and to withstand hydrodynamic loads. Fences, logs, railroad ties, and the like are included in this requirement.

2. Construction Materials and Methods

    a. All new construction and substantial improvements must be constructed with materials and utility equipment resistant to flood damage.

    b. All new construction and substantial improvements must be constructed using methods and practices that minimize flood damage.

3. Utilities

    a. All new and replacement water supply systems must be designed to minimize or eliminate infiltration of floodwaters into the system.

    b. New and replacement sanitary sewage systems must be designed to minimize or eliminate infiltration of floodwaters into the system and discharges from the system into floodwaters.

    c. On-site waste disposal systems must be located to avoid impairment to them or contamination from them during flooding.

    d. Electrical, heating, ventilation, plumbing, and air-conditioning equipment and other service facilities must be designed and/or located to prevent water from entering or accumulating within the components during flooding.

4. Subdivision Proposals

    a. All subdivision proposals must be consistent with the requirement to minimize flood damage.

    b. All subdivision proposals must have public utilities and facilities located and constructed to minimize flood damage.

    c. All subdivision proposals must have adequate drainage provided to reduce flood damage.

    d. BFE data must be provided for all subdivision proposals and other proposed developments that contain at least forty lots or five or more acres.

5. Residential Construction

    a. New construction and substantial improvement of any residential structures must have the lowest floor, including the basement, elevated at least one foot above the BFE.

6. Nonresidential Construction

    a. New construction and substantial improvement of any commercial, industrial, or other nonresidential structure must either have the lowest floor, including the basement, elevated to one foot above the BFE or meet these requirements:

        i. Be flood-proofed so that the structure is watertight below the BFE with walls substantially impermeable to the passage of water and,

        ii. Have structural components capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy and,

        iii. Provide that where a non-residential structure is intended to be made watertight below the BFE, these requirements are met:

            1. A licensed Professional Engineer or architect must develop and/or review structural design, specifications, and plans for the construction, and certify that the design and methods of construction are in accordance with accepted standards of practice for meeting the applicable provisions of Section 4.5.3 and

            2. A record of such certification that includes the specific elevation (in NAVD 88) to which such structures are flood-proofed must be maintained with the Village.

7. All new and substantially improved critical facilities and new additions to critical facilities must be located outside the SFHA.

5.0 Rainfall

5.1 Introduction

Rainfall depth, duration, intensity, and frequency data are necessary to develop hydrologic analyses used to calculate runoff for storm drainage planning. Rainfall patterns have a strong influence on the volume and rate of stormwater runoff in a drainage system. The best available data source for rainfall characteristics along the Front Range of Colorado and within the Village is the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 8, Version 2. Data from NOAA Atlas 14, as presented in this chapter, must be used as the source of rainfall data in the preparation of any drainage study or drawings submitted to the Village.

The stormwater management policies of the Village strongly encourage the use of local on-site detention, grass-lined swales, and stormwater infiltration systems to attenuate peak flood discharges and improve stormwater quality. As a result, many facilities are designed for drainage basins smaller than 10 acres with times to the peak rate of discharge that are less than 30 minutes. These types of systems are typically sized using the Rational Method, which requires rainfall intensity for a duration equivalent to the time of concentration. In almost all cases, the rainfall duration for use with the Rational Method will be less than one hour.

Applicability of Rational Method

While much of the development and redevelopment in the Village is at a scale that can be analyzed using the Rational Method and UDFCD spreadsheets, there are cases where more sophisticated analysis using hydrologic and hydraulic models is needed. These include sites where routing of hydrographs is necessary to account for timing of peak flows, regional water quality and detention facilities, and hydrology and hydraulics for major drainageways. See Chapter 6 Runoff for additional information on when to use the Rational Method and when to use hydrograph-based methods.

5.2 Intensity-Duration-Frequency Data

Given the size of typical development sites in the Village, much of the hydrologic analysis will use the Rational Method, which requires rainfall intensity for a duration equivalent to the time of concentration as an input. To facilitate the use of the Rational Method, Table 5-1 presents intensity-duration-frequency data for a central location in the Village from NOAA Atlas 14 that must be used as the basis for rainfall-runoff calculations throughout the Village.

Table 5-1 provides rainfall intensity data for a range of return periods and durations. For drainage design, it may only be necessary to perform calculations for the minor (2-year or 5-year) and major (100-year) events. Data for other return periods are provided for reference and may not be needed for most projects. Data are provided at 5-minute increments up to a duration of 30 minutes. If the time of concentration calculated falls between increments presented in Table 5-1, use linear interpolation to find the appropriate value. As an example, the 100-year rainfall intensity for a time of concentration of 17 minutes can be determined as follows:

- Rainfall intensity for 100-year with time = 15 minutes is 5.52 inches/hour (Table 5-1)
- Rainfall intensity for 100-year with time = 20 minutes is 4.64 inches/hour (Table 5-1)

- Rainfall intensity for 100-year with time = 17 minutes is interpolated:

$$I_{17\ minutes} = I_{15\ minutes} + (I_{20\ minutes} - I_{15\ minutes}) \times \frac{(17\ minutes - 15\ minutes)}{(20\ minutes - 15\ minutes)}$$

$$I_{17\ minutes} = 5.52\ \frac{in}{hr} + \left(4.64\frac{in}{hr} - 5.52\frac{in}{hr}\right) \times \frac{(2\ minutes)}{(5\ minutes)}$$

$$I_{17\ minutes} = 5.17\ \frac{in}{hr}$$

Table 5-1. Intensity-Duration-Frequency Data for Greenwood Village

Duration (minutes)	Rainfall Intensity (inches/hour) Corresponding to Return Period (year)						
	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5	3.36	4.46	5.44	6.88	8.05	9.29	12.48
10	2.46	3.26	3.98	5.03	5.89	6.78	9.12
15	2.00	2.66	3.24	4.08	4.80	5.52	7.40
20*	1.68	2.23	2.72	3.43	4.03	4.64	6.22
25*	1.49	1.98	2.41	3.04	3.57	4.11	5.51
30	1.36	1.81	2.20	2.78	3.26	3.76	5.04
60	0.85	1.12	1.35	1.71	2.01	2.33	3.15
120	0.51	0.67	0.81	1.02	1.20	1.39	1.90
180	0.38	0.48	0.58	0.74	0.87	1.01	1.39
360	0.23	0.29	0.35	0.44	0.51	0.59	0.81

* Interpolated from 15-minute and 30-minute values from NOAA Atlas 14.

5.3 Flood Control Design Storms

For some types of facilities, especially full spectrum detention storage facilities, it may be necessary to perform hydrologic calculations to generate a design inflow hydrograph. When this is required, the applicant must develop a design rainfall hyetograph for use in the hydrologic model. A hyetograph for a given storm return period and duration can be generated by combining the dimensionless temporal hyetographs in the Rainfall Chapter of the UDFCD Manual with point rainfall depths found in Table 5-2, below. For example, if a 100-year, 2-hour design storm

hyetograph is needed, each of the ordinates (percentages) of the dimensionless 2-hour temporal distribution from the UDFCD Rainfall Chapter (Table 5-2 in the UDFCD Manual) would be multiplied by the 100-year, 1-hour point rainfall depth of 2.33 inches from Table 5-2, below, to provide a 2-hour rainfall hyetograph that is scaled to the 100-year, hourly point precipitation depth. This hyetograph can then be used as input in a software program such as the Colorado Urban Hydrograph Procedure (CUHP) that calculates runoff from rainfall to generate runoff hydrographs for the selected event.

UD-Detention and CUHP-SWMM

Full spectrum detention, which provides flow regulation over a range of events from water quality events to major flood events, can be sized using UDFCD's UD-Detention spreadsheet or the Colorado Urban Hydrograph Procedure (CUHP) and the Stormwater Management Model (SWMM). The UD-Detention spreadsheet can be used for sizing on-site facilities that do not involve complex routing and for preliminary design of sub-regional and regional facilities. For final design of sub-regional and regional full spectrum detention facilities, CUHP-SWMM should be used. See Chapter 6 Runoff for additional information.

Table 5-2. One-hour Point Rainfall Depths for Greenwood Village for Developing Design Storm Hyetographs

Return Period (year)	1-hour Point Rainfall Depth (inches)
2	0.85
5	1.12
10	1.35
25	1.71
50	2.01
100	2.33
500	3.15

5.4 Stormwater Quality Design Storm

The stormwater quality design storm in the Village is based on the Water Quality Capture Volume (WQCV) calculated for the 80th percentile runoff-producing event. The depth of the 80th percentile runoff-producing event is 0.6 inches in the Village. This means that capturing and treating a WQCV based on 0.6 inches of rainfall will fully treat 80% of the runoff-producing events. Chapter 15 Stormwater Quality provides additional information and criteria for calculating the WQCV, as well as other water quality requirements for disconnection of impervious area.

For most sites, the user does not need to perform rainfall-runoff and routing calculations to determine the WQCV. UDFCD has developed charts and spreadsheets that perform these calculations, as discussed in Chapter 15 Stormwater Quality. In cases where a hyetograph is needed for water quality calculations (atypical circumstances), the 80th percentile depth of 0.6 inches can be used in conjunction with the 2-hour dimensionless hyetograph in the Rainfall Chapter of the UDFCD Manual (Table 5-2 in the UDFCD Manual) to generate a 2-hour water quality design storm hyetograph.

6.0 Runoff

6.1 Introduction

Primary considerations for designing drainage and water quality facilities include the timing, peak rate of discharge, and volume of stormwater runoff. The purpose of this chapter is to provide a dependable and consistent methodology for estimating storm runoff in the Village. Extensive additional information on the Rational Method and the Colorado Urban Hydrograph Procedure (CUHP), the two methods discussed in this chapter, is available in the UDFCD Manual, Chapter 6 Runoff. The methods for estimating storm runoff described in this chapter must be used for all drainage studies submitted to the Village.

Rational Method versus CUHP

Most development and redevelopment projects in the Village are of a size where the Rational Method is applicable as long as complex routing is not involved. However, because on-site water quality and detention are required for most projects in the Village, it is necessary to use CUHP or UD-Detention for detention facility sizing.

While there are some methods for approximating detention volumes using the Rational Method such as triangular hydrographs or the Federal Aviation Administration (FAA) "Bowstring" method, these methods are not recommended by UDFCD and are not allowed in the Village.

6.2 Calculating Runoff

The Rational Method and CUHP are the preferred methods for estimating runoff in the Denver metropolitan region. The Rational Method is a simplified approach that has proven to be reliable for the design of storm drain systems and for determining runoff from small drainage basins since the late 1800's. CUHP is a more sophisticated approach and is generally recommended for larger basins with more complex design needs. For smaller basins without complex routing, the Rational Method is appropriate. Table 6-1 summarizes appropriate uses of these methods.

Table 6-1. Methods for Calculating Runoff

Watershed Size (acres)	Is the Rational Method Applicable?	Is CUHP Applicable?
0 to 90	Yes	Yes
90 to 160	No	Yes
160 to 3,000	No	Yes[1]
>3,000	No	Yes (subdividing into smaller catchments required)[1]

[1] Subdividing into smaller subcatchments and routing the resultant hydrographs using SWMM may be needed to accurately model a catchment with areas of different soil types or percentages of imperviousness.

A distinguishing factor between the Rational Method and CUHP is that the Rational Method provides only a peak discharge rate, while CUHP calculates a hydrograph, including the peak discharge rate, the time to peak, and the runoff volume. Therefore, if a hydrograph is needed for

subsequent analyses, such as detention sizing or routing to combine with hydrographs from other subcatchments, the Rational Method is not appropriate.

The Rational Method is primarily used for sizing inlets and determining required capacities for storm drains in relatively small, homogeneous watersheds, while CUHP, in conjunction with the Stormwater Management Model (SWMM) or as a part of the UD-Detention workbook, is used for runoff and routing in more complex watersheds and for sizing detention facilities. Water quality facilities are sized using empirical equations to determine the water quality capture volume (WQCV). Detention sizing is presented in Chapter 13 Flood Attenuation, and equations and tools for calculating the WQCV are presented in Chapter 15 Stormwater Quality.

6.2.1 Application of Design Methods

The first steps in applying the Rational Method or CUHP are to obtain a representative topographic map of the area, define design points where runoff rates or hydrographs are needed, and delineate the boundaries of all the relevant drainage areas tributary to design points. Drainage areas should be defined for on-site and off-site drainage basins. Field checks must be completed for the study area and all off-site basins to verify topography, land use, imperviousness and other physical characteristics needed for model input. In some cases, a survey may be required if topographic data of sufficient resolution (2-foot contour intervals or finer for hydrologic calculations) are not available.

At the preliminary stage of planning, the possibility of run-on into the study area from off-site drainage areas should be investigated. Potential sources of run-on could be a result of drainage modifications/improvements by others or overflows from irrigation ditches such as the Highline Canal. At this stage, the applicant also should evaluate the capability of downstream drainage systems to adequately convey runoff from proposed improvements. If there are downstream conveyance restrictions or flooding problems, additional measures may be required on site to infiltrate and/or attenuate runoff. When designing grading and drainage on a site, applicants should avoid grading that redirects runoff from its historic path into a different drainage basin or onto a neighboring property.

In many cases drainage areas and flow paths are the same for the minor event (2- or 5-year depending on land use) and the major event (100-year). However, in urban areas with curb and gutter and storm drains, tributary areas and flow paths may be different between the minor and major events. The minor event will typically flow in curb and gutter or in storm drains, generally following the grade of the street. During the major event, however, the curb and/or crown of the street may be overtopped, sending major storm runoff in a different direction. This phenomenon also may occur at intersections, where the major event flow path deviates from the alignment of the storm drain.

When analyzing the major runoff event occurring in an area that has a storm sewer system sized for the minor storm, care must be used when determining the time of concentration. Normally, the design of storm drains assumes that the storm drains or gutters collect all of the runoff for the minor event. For the minor storm design, the time of concentration is, in part, dependent upon the flow time in the storm drain. However, during the major runoff event, the storm drains are likely to be at capacity and unable to accept all the runoff flowing to the inlets. This additional runoff then bypasses the inlets and continues overland, generally at a somewhat lower velocity than the runoff in the storm drains. This requires analysis of different times of concentration between underground flow and overland flow.

During the major storm event, "carryover" flow from an inlet that is at capacity to a downgradient inlet often occurs. If that inlet is also at capacity, the runoff will often continue on until capacity is available in the storm drain. The analysis of this aspect of the interaction between the storm drain system and the major storm runoff is complex. The most useful procedure for this analysis is routing of the major and minor storm runoff hydrographs through the overland and storm drain routes concurrently. This can be accomplished using tabular methods for the Rational Method or using a model such as SWMM.

UDFCD Excel Workbooks for Calculating Runoff

UDFCD has developed Excel workbooks including UD-Rational and UD-Detention to aid engineers in standard calculations for the Rational Method and for detention sizing. UD-Rational has tools to assist with calculating the time of concentration, runoff coefficients and peak runoff rates.

For detention facility sizing, UDFCD has developed UD-Detention. This workbook uses CUHP algorithms to calculate runoff and uses the Modified Puls reservoir routing method to evaluate performance of a detention facility based on tributary watershed parameters and variables associated with the basin/pond geometry and outlet configuration.

UD-Detention compares calculated release rates to predevelopment discharges for the 2-, 5-, 10-, 25-, 50-, and 100-year events. UD-Detention allows analysis of any retention pond or detention basin including extended detention, bioretention, sand filters, basins that may or may not be full spectrum, basins that only include one or two controlled zones, or basins having unusual outlet structures.

6.2.2 Rational Method

As noted above, the Rational Method is most applicable for inlet sizing and calculation of peak flow rates for design of inlets and storm drains for relatively small, homogeneous watersheds. Details of the Rational Method are presented in the Runoff Chapter of the UDFCD Manual. The assumptions and limitations presented in the UDFCD Manual should be reviewed to ensure that the use of the Rational Method is appropriate.

6.2.2.1 Time of Concentration

UDFCD provides a methodology for estimating the times of concentration for both urban and rural areas in the Runoff Chapter. This method must be used to estimate times of concentration for use with the Rational Method in the Village. The initial flow time must be used only for overland flow (sheet flow conditions). Once the flow becomes concentrated in a swale, ditch, gutter, or storm drain, the travel time equation in the Runoff Chapter must be used. The time of

concentration is found by adding the initial (overland) flow time and the travel time to the point interest for design.

The minimum time of concentration must be 5 minutes for urban areas and 10 minutes for rural areas. The maximum time of concentration for the first design point for urbanized areas must not exceed that discussed in the UDFCD Manual.

6.2.2.2 Rainfall Intensity

The intensity, I, is the average rainfall rate, in inches per hour, for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration. After the design rainfall frequency has been selected (i.e., 2-, 5- or 100-year occurrence), the intensity can be determined for the selected time of concentration using Table 5-1 in the Rainfall Chapter of this Manual.

6.2.2.3 Runoff Coefficient

The runoff coefficient, C, represents the integrated effects of infiltration, depression storage, and interception, all of which affect the time distribution and peak rate of runoff. Determination of the runoff coefficient requires judgment and understanding by the engineer. The coefficients presented in the Runoff Chapter of the UDFCD Manual must be used in the Village. These runoff coefficients are determined based on imperviousness, hydrologic soil group, and the frequency of the event.

Calculation of impervious area is an important step in determining the runoff coefficient. Surface area is either considered pervious or impervious. Pervious areas are those surface areas where water can readily infiltrate into the ground. Impervious areas are those surface areas where the infiltration of water into the ground is restricted. Examples of impervious areas are parking lots, sidewalks, roads, pool deck areas, and structures. As an area is developed (i.e., the land use changes from undeveloped to commercial, industrial, and/or residential use), the amount of impervious area typically increases. As the amount of impervious area increases, less water is able to infiltrate into the ground. This typically causes the rate and volume of runoff to increase and the time to the runoff peak to decrease.

Proposed development conditions must be used to estimate the percent imperviousness of drainage areas. Table 6-3 in the UDFCD Manual Runoff Chapter presents typical imperviousness values for a range of land uses and is appropriate for estimating imperviousness at the planning and early design stages for the purpose of a Conceptual and Preliminary Drainage Study. Once the applicant has prepared the site layout, a more accurate estimate of the impervious area for the project must be used. For a Final Drainage Study, impervious areas must be measured from the design drawings, typically using AutoCAD or GIS. The measured imperviousness can then be used to determine a runoff coefficient with the equations presented in Table 6-4, the tabular data in Table 6-5, or Figures 6-1 through 6-3 in the UDFCD Manual Runoff Chapter.

6.2.3 CUHP and SWMM

CUHP and SWMM can be used for the full range of drainage basin sizes encountered in the Village. These methods are needed when hydrograph routing is necessary to reflect timing of peak runoff from multiple drainage basins, for complex drainage systems, and/or for design of

detention facilities. CUHP is used to generate the hydrology (i.e., runoff hydrographs based on rainfall hyetographs), and SWMM is used for routing through the drainage network of storm drains, detention ponds and open channels.

6.2.3.1 CUHP Rainfall Input

Rainfall input for CUHP is derived from NOAA Atlas 14 1-hour point rainfall depths within the Village. Table 5-2 in the Rainfall Chapter provides the 1-hour point rainfall depths that should be used. CUHP automatically generates hyetographs using the methods described in the Rainfall Chapter of the UDFCD Manual based on specified 1-hour point rainfall depths.

6.2.3.2 CUHP Runoff

"Effective rainfall" is that portion of precipitation that runs off land into a stormwater collection system or drainageway closely following a precipitation event (i.e., runoff). The portions of precipitation that do not become runoff are called abstractions. Abstractions include interception by vegetation, infiltration, depression storage on pervious and impervious surfaces, and other types of retention storage. The abstractions for pervious areas tend to be substantially larger than those for impervious areas. Any reasonable estimate of runoff must be based on a reasonably accurate estimate of the impervious area and parameters for initial abstractions (interception and depression storage) and infiltration.

Depression storage is defined as precipitation that is collected and held in small surface depressions and does not become a part of general surface runoff. Most of this water eventually infiltrates or evaporates. CUHP requires values for pervious and impervious area depression storage as input in calculating runoff. The actual input for CUHP can be an area-weighted average for the basin. Table 6-6 in the Runoff Chapter of the UDFCD Manual provides depression storage parameters that should be used in CUHP.

Infiltration is the percolation of water into underlying soil. Soil type and soil moisture content are the important factors for determining infiltration rates. Fine-grained soils, clays and clay loams exhibit slower infiltration rates, whereas coarse-grained soils and sands exhibit faster infiltration rates. As soil moisture increases, the rate of infiltration decreases. If the soil has several layers or horizons, the least permeable layer will control the maximum infiltration rate. Other factors that affect infiltration rates include the type of vegetation, slope of land, age of lawn, soil compaction and antecedent soil moisture condition. When a rainfall event occurs on dry soil, the infiltration rate is higher than if it occurs on a wet soil, such as irrigated lawn grass. As rainfall continues during a storm event, infiltration rates decrease. This changing rate of infiltration is more important for small rainfall events that carry most of the stormwater pollutants than it is for larger rainfall events such as the 100-year storm.

UDFCD uses Horton's Equation for estimating infiltration in CUHP. Table 6-7 in the Runoff Chapter of the UDFCD Manual provides input parameters for CUHP. UDFCD Manual criteria for selecting parameters for infiltration, depression storage and other CUHP and SWMM inputs apply in the Village.

6.3 Water Quality Capture Volume for Stormwater Quality

The Village is required to treat runoff for stormwater quality purposes in accordance with its MS4 permit and the Cherry Creek Reservoir Control Regulation (Regulation 72). For facilities designed to treat stormwater quality, the WQCV must be captured and released over a period ranging from 12 to 40 hours depending on the type of water quality facility being used. As described in the UDFCD Manual, the WQCV corresponds to an 80th percentile runoff event and was developed by analyzing long-term precipitation data from the Denver metropolitan area and performing runoff and storage calculations for a range of drain times. This analysis showed that by providing a WQCV equivalent to the runoff from a 0.60-inch storm, 80% of runoff-producing storms would be fully treated over the long term by water quality facility and that larger events would receive at least partial treatment. See Chapter 15 Stormwater Quality for guidance and criteria for calculating the WQCV.

History of Water Quality Design Storm in the Village

Prior to 2019, the water quality design approach in this Manual was based on reducing phosphorus concentrations in stormwater runoff by 60% using BMPs. This requirement was driven by pre-2010 versions of the Cherry Creek Reservoir Control Regulation, which were based on a Total Maximum Annual Load (TMAL) for total phosphorus and included in-lake phosphorus concentration standards. As the scientific underpinnings of Regulation 72 evolved, both the TMAL and the phosphorus in-lake standard were removed from Regulation 72, as well as percent reduction-based requirements for phosphorus removal for stormwater runoff.

Both Regulation 72 and the Village's MS4 permit continue to recognize the importance of reducing phosphorus and other nutrients in stormwater runoff; however, the minimum design standard in these regulations is more closely aligned with treatment of the WQCV in accordance with Volume 3 of the UDFCD Manual, as opposed to percent concentration reduction calculations. Although this is a significant change in the regulatory basis for water quality treatment in the Village (i.e., WQCV-based approach versus percent removal), for properly designed, installed and maintained facilities, phosphorus reductions on the order of 60% are feasible.

7.0 Open Channels

7.1 Introduction

Open channels are important components of the urban drainage system, ranging in size from shallow surface drainage swales that convey runoff only during storm events to perennial streams such as Cottonwood Creek and Goldsmith Gulch. Open channels offer many advantages that are absent in piped systems such as ecological benefits, recreational uses, natural areas, infiltration capabilities, aesthetics and ease of maintenance, among others. The Village encourages the use of open channels for conveyance of stormwater runoff in applications from lot-level swales to the creeks and gulches that run through the Village. Two major categories of open channels are addressed in this Manual:

- **Major Drainageways**: Open channels with tributary drainage areas of greater than 130 acres are considered "major drainageways." UDFCD works with municipalities to plan, design, restore and maintain major drainageways. Major drainageways typically have mapped floodplains, either in the form of Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) and/or UDFCD Flood Hazard Area Delineations (FHADs). Any work on major drainageways in the Village must conform to criteria in the UDFCD Manual and must go through the FEMA letter of map change process if there are changes in base flood elevations or in the floodplain or floodway boundaries. All major drainageway projects in the Village must be designed and constructed to meet the criteria necessary for acceptance into the UDFCD Maintenance Eligibility Program.

- **Minor Drainageways**: Open channels with tributary drainage areas of less than 130 acres are "minor drainageways." These channels comprise the collection system that delivers runoff to the major drainageway. As areas urbanize, gutters often replace these small, usually ephemeral channels, and storm drains speed up the travel time of runoff and eliminate opportunities for infiltration during conveyance. Because the loss of these minor drainage channels has a cumulative effect of greater peak rates and volumes of stormwater runoff, a goal of the Village is to preserve or restore minor drainage channels in development and redevelopment projects to provide open channel conveyances with permeable, vegetated channel linings.

7.2 Major Drainageways

Major drainageways in the Village include Big Dry Creek, Little Dry Creek, Greenwood Gulch, Prentice Gulch, Goldsmith Gulch, and Cottonwood Creek. These drainageways are amenities to the community, incorporating parks, recreational trails, open space, natural areas and other features along these corridors. Chapter 8 Open Channels and Chapter 10 Stream Access and Recreational Channels of the UDFCD Manual provide extensive guidance on preserving natural channels, stream restoration, naturalized constructed channels, and swales. Because the Village is largely already developed and open space has been preserved along many major drainageways, large subdivision projects where a developer would be responsible for restoring or constructing a major drainageway channel to UDFCD criteria are not expected in the Village. However, any repairs, modifications, or new construction of major drainageways within the Village must be

performed in accordance with the criteria in the UDFCD Manual. The Village will review and approve analysis and design of any modifications to major drainageways in the Village, including, but not restricted to, erosion and grade control structures, channel realignment, outfalls, and crossings.

Most of the major drainageways within the Village are natural or naturalized channels. Cottonwood Creek within Cherry Creek State Park is a good example of a natural channel, and Goldsmith Gulch is a good example of a naturalized channel. The UDFCD Manual provides extensive guidance and criteria for preserving and restoring natural stream channels and designing and constructing naturalized channels that mimic the processes and aesthetics of natural channels. This chapter provides an overview of key criteria and topics that should be considered for major drainageway projects; however, many additional details and criteria are provided in the UDFCD Manual that are adopted herein by reference.

Because of urbanization, both natural and naturalized channels in the Village experience hydromodification that manifests as increased streamflow volume, duration, and flow rates, especially at the more frequent end of the flow spectrum. To address hydromodification, measures for grade control and bank stability typically must be provided to guard against longitudinal and lateral instability caused by the erosion potential of the additional volume, duration and rates of stream flow under urbanized conditions.

Natural or naturalized channels are the preferred channel types for major drainageways in the Village. Other types of channel linings such as riprap and smooth linings (e.g., concrete) are discouraged in the Village due to high velocities and a lack of multifunctional benefits. In some cases, a riprap or concrete channel may be warranted due to high velocities resulting from steep slopes and/or space constraints, but these types of channels will be allowed only with the approval of the Village. Major drainage channels in the Village must be designed in accordance with UDFCD criteria in Chapters 8 Open Channels and Chapter 10 Stream Access and Recreational Channels of the UDFCD Manual.

7.3 Minor Drainageways

As watersheds develop, typically improvements are required to minor drainageways to convey developed condition flows. Even when on-site detention and water quality are provided to mitigate effects of development or redevelopment, the increase in runoff volume and duration on the low end of the flow spectrum where there were no flows under pre-development conditions can cause instability along minor drainageways. Historically, many minor drainageways have been replaced by storm drains or confined to a narrow right-of-way in a hard-lined channel cross section. These practices eliminate important functions of natural minor drainageways, including their abilities to slow down runoff and allow infiltration during transit. Given the natural benefits of vegetated natural channels, to the extent feasible, minor drainageways in the Village will be designed as vegetated open channels. Riprap-lined channels or conduits for minor drainageways are discouraged but may be allowed on a case-by-case basis when approved by the Village.

Because the upstream drainage basin conditions may change dramatically for minor drainageways as a result of development or redevelopment, resulting in higher flows and low sediment loads, it is likely that creating a naturalistic channel design may require regrading of unimproved channels.

This will generally require the removal and reestablishment of natural vegetation, rather than its preservation. To the extent feasible, the naturalized channel design criteria in the UDFCD Manual should also be followed for minor drainageways. To assure that a vegetated minor drainageway will not experience excessive erosion, the criteria in Table 7-1 must be achieved at a minimum.

Constructed naturalized channels must be analyzed for two conditions: 1) higher velocity conditions, when projects are newly completed and vegetation may not have matured, and 2) for greater flood depth potential and capacity limitations, when vegetation has fully matured and creates the greatest resistance to flow.

Table 7-1. Hydraulic Design Criteria for Naturalized Vegetated Channels for Minor Drainageways

Design Parameter	Erosive Soils or Poor Vegetation	Erosion Resistant Soils and Vegetation
Maximum 5-year Velocity (ft/sec)	3.5 ft/sec	5.0 ft/sec
Maximum 100-year Velocity (ft/sec)	5.0 ft/sec	7.0 ft/sec
Froude No., 5-year	0.5	0.7
Froude No., 100-year	0.6	0.8
Maximum Tractive Force, 100-year	0.60 lb/sf	1.0 lb/sf

Grass-lined channels are an option for minor drainageways, especially where the tributary area is relatively small and minimal baseflows are expected. Sod-forming native grasses suited to wetter conditions are recommended for grass-lined channels. If irrigated bluegrass sod is proposed, a small baseflow channel must be provided and vegetated with the wetter, sod-forming native grasses. Hard-lined baseflow channels are not desired in grass-lined channels. Grade control structures or rock stabilization in the bottom of the channel may be necessary if velocities or Froude numbers exceed the values in Table 7-1.

7.4 Vegetated Swales

The functions and benefits of natural streams can be extended further upstream in the watershed by conveying runoff on the surface in vegetated channels or swales rather than in underground storm drains. Besides the aesthetic and habitat value of surface channels, stormwater quality can be enhanced by promoting beneficial interaction between water, soil, and vegetation. Conveyance in storm drains produces no such interaction or water quality enhancement.

Chapter 8 Open Channels of the UDFCD Manual provides guidance and criteria for the design of swales that drain areas from less than one acre up to about 10 impervious acres (e.g., 20 acres at 50% imperviousness). The UDFCD Manual includes a series of design charts to guide the designer in determining stable conditions in vegetated swales of varying cross sections based on design flow rate and slope. The UDFCD Manual charts show flow rates as high as 100 cfs (stable at relatively flat slopes) and slopes as steep as 10 percent (stable at relatively low flows). Charts are provided for varying swale bottom widths and side slopes, and chart outputs include the

recommended swale depth and armoring requirements, if any. If riprap armoring is needed, soil riprap must be used to create a vegetated appearance.

The single most important factor governing the stability of vegetated swales is the quality of vegetation. Extensive guidance on revegetation of drainageways can be found in Chapter 13 Revegetation of the UDFCD Manual. Guidance includes proper site preparation including soil testing, topsoil, amendments, recommendations for addressing soil compaction, and recommended seed mixes. Turf-forming grasses that include a variety of species work best. It is imperative that the construction drawings and specifications address seedbed preparation; installation of seed, blankets, and plugs; temporary irrigation; weed control; and follow-up reseeding and maintenance.

Good temporary erosion controls are critical during establishment of vegetation. In addition to seeding, it is recommended that grass plugs of the dominant species in the seed mix be planted to provide some immediate vegetative cover and improve overall establishment. Place drier species on the side slopes. Placing sod is also an option for grass swales.

7.5 Hydraulic Analysis

Evaluating channel and floodplain hydraulics is a key component of any stream project. Hydraulic modeling provides insight into flow properties including water surface elevation, depth, velocity, shear stress, and Froude Number. Understanding these flow properties is necessary to assess risks associated with structure flooding and channel erosion and can help guide the design of stream capacity and stabilization improvements. Methods for preliminary channel analysis and modeling are described in this section.

7.5.1 Preliminary Channel Analysis

There may be times when a preliminary or “quick” analysis is needed, rather than using hydraulic modeling software, to evaluate channel properties in uniform, steady, open-flow conditions. For these cases, Manning’s Equation may be used. The designer should realize that uniform flow is more often a theoretical abstraction than an actuality; namely, true uniform flow is difficult to find. Channels are sometimes designed on the assumption that they will carry uniform flow at normal depth, but because of ignored conditions that create backwater, the flow actually has depths that can be considerably different. Uniform flow computation provides only an approximation of the hydraulic conditions that will actually occur.

7.5.2 HEC-RAS Modeling

The most commonly used tool for open channel hydraulic modeling is the Hydrologic Engineering Center’s River Analysis System (HEC-RAS) from the U.S. Army Corps of Engineers (USACE). HEC-RAS is non-proprietary software that can be downloaded and used free of charge from the USACE website.

HEC-RAS models must use model parameters described in the Open Channels chapter of the UDFCD Manual or in the software program documentation for parameters not explicitly identified in the UDFCD Manual. See the HEC-RAS Hydraulic Reference Manual for guidance

on modeling techniques, parameter selection and other topics (USACE, Version 5.0, February 2016 or later, accessible from USACE's website).

Justification must be provided for values used that are not consistent with the UDFCD Manual and/or the HEC-RAS Hydraulic Reference Manual. Typical input parameters include flow rate, channel cross-section geometry, roughness coefficients, main channel bank stations, etc. HEC-RAS has the capability to model bridges, culverts, weirs and spillways as well as address unsteady flow computations. In most cases, a subcritical HEC-RAS model run is appropriate for natural and naturalized channels. See Chapter 8 Open Channels of the UDFCD Manual for guidance and criteria related to cross-section layout and/orientation, cross-section geometry, roughness coefficients for channels and overbanks, design storms, and output variables.

7.6 Rock and Boulders

In conditions where conveyance of high velocity/high energy flows is required, soil riprap, void-filled riprap, or boulders must be used. For small installations and where vegetation is not anticipated, riprap over bedding material may also be used. Types of channel armoring include:

- **Soil Riprap:** Soil riprap refers to riprap that has all void spaces filled with topsoil with the intention of supporting vegetative growth. Soil riprap is intended for use in applications where vegetative cover can be established and where the shear stress imposed by frequently occurring flows is less than the resistive strength of the vegetation and soil. The riprap layer is designed to remain stable and provide protection during extreme events.

- **Void-filled Riprap:** Void-filled riprap is designed to emulate natural rock riffle material found in steep gradient streams. It contains a well-graded mix of cobble, gravel, sand, and soil that fills all voids and acts as an internal filter; therefore, a separate bedding layer between subgrade and rock is not required. In applications where it is difficult to establish vegetation, void-filled riprap is better able to resist the direct, prolonged impingement of water on the riprap installation compared to soil riprap. However, void-filled riprap is more difficult to properly mix and install compared to soil riprap. UDFCD recommends review of the technical paper titled *Demonstration Project Illustrating Void-Filled Riprap Applications in Stream Restoration* (Wulliman and Johns [2011], accessible on UDFCD's website). This paper provides background on the derivation of void-filled riprap and its applications in stream restoration.

- **Boulders:** Boulders may be placed and grouted or placed without grout. When not grouted, boulders require careful design to provide a firm foundation and stable configuration as well as properly graded backfill material sized to prevent migration of fine subgrade material through voids in the boulders. All stacked boulders require consideration of stability and any stacked boulder configuration over four feet in height requires structural analysis to confirm proper design and a building permit.

- **Ordinary Riprap:** Riprap is generally the least preferred protection material. See Section 8.0 of the UDFCD Manual Open Channels chapter for information on selecting the appropriate type of riprap for the application and for riprap sizing procedures.

Material and installation specifications for riprap and boulders can be found in UDFCD's Construction Specifications, available on UDFCD's website.

8.0 Streets

8.1 Introduction

Streets are primarily designed to function as transportation corridors. Conveyance of stormwater drainage is a secondary function and must be designed with the safety of the transportation route in mind. Street drainage design also must protect the pavement and subgrade from deterioration due to stormwater runoff.

Streets serve important functions in both the minor and major events. In the minor event, curb and gutter along the streets conveys runoff to inlets that lead to storm drains. In some cases, roadside swales may be used instead of curb and gutter. The spread of runoff in the street is controlled by inlet sizing and spacing, and inlets must be provided to meet the criteria for allowable spread and depth in this chapter. As part of the major drainage system, streets function as overflow corridors conveying runoff exceeding the capacity of the storm drain system. Greater inundation of streets is allowed for the major event; however, allowable depths are limited to allow for the safe passage of emergency vehicles.

Hydraulic analysis of street conveyance capacity and design of street drainage infrastructure requires determination of the spread and depth of the minor and major events based on the street cross section, inlet sizing, slope, inlet spacing, storm drain sizing and other factors. Table 8-1 establishes criteria for maximum spread and/or depth for minor and major events. Often, it is necessary to iteratively evaluate placement and sizing of inlets with spread and depth calculations to find a combination of inlet sizing and spacing that does not exceed the allowable spread and/or depth criteria.

8.2 Street Classifications and Allowable Drainage Encroachments

The integration of planning concepts, theoretical design, and long-term maintenance of streets as drainage corridors is consistent with the criteria presented in the Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual. Table 8-1 provides criteria for local, collector, and arterial streets in the Village. The allowable drainage encroachment (spread) into the driving lanes becomes more restrictive with increasing transportation capacity, as described in Table 8-1 for both the minor and major storm events. For residential areas, the minor event is defined as the 2-year storm; for non-residential areas, the minor event is a 5-year storm. The major event is defined as the 100-year (1% Annual Exceedance Probability) event throughout the Village.

Table 8-1. Street Depth and Spread Criteria for Minor and Major Storm Events

Street Classification	Minor Storm Runoff[1] Design Recurrence Interval: 2-yr or 5-yr		Major Storm Runoff Design Recurrence Interval: 100-yr	
	Maximum Allowable Street Encroachment	Maximum Depth of Cross Street Flow	Maximum Allowable Depth	Maximum Depth of Cross Street Flow
Local	No overtopping of curb or backside of roadside ditch. Flow may spread to crown of street.	6-inch depth in cross pan.	The same criteria apply to all street classifications for the major event. Residential dwelling, public, commercial, and industrial buildings should be no less than 12 inches above the 100-yr flood at the ground line, unless buildings are floodproofed. The depth of water at the gutter flowline must not exceed 12 inches. Drainage easements must be provided for all areas flooded by the major storm runoff.	18-inch depth at gutter flowline.
Collector	No over topping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	Where cross pans are allowed, flow depth must not exceed 6 inches.		18-inch depth at gutter flowline.
Arterial	No overtopping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	No cross flow allowed.		12-inch depth or less over crown.[2]

[1] The 2-year design storm applies to residential areas. The 5-year design storm applies to commercial, business, and industrial areas.

[2] Cross-street flow is only allowed when the flow in a drainageway exceeds capacity of a road culvert and subsequently overtops the crown of the streets.

8.3 Design Criteria

The hydraulic analysis and design of streets for drainage conveyance must be in accordance with the criteria presented in Chapter 7 Streets, Inlets, and Storm Drains of the UDFCD Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following sections. Unless otherwise specified in this chapter, the criteria and procedures in Chapter 7 Streets, Inlets, and Storm Drains of the UDFCD Manual apply. The criteria in this chapter are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements of individual projects.

The Village requires grading of property along the edge of streets to minimize flooding of areas beyond the street right-of-way. The initial 15 feet behind a curb must slope towards the street at a minimum 2% grade (0.3 feet of vertical fall over 15 feet). For streets with roadside ditches, the ground 15 feet from the edge of the pavement must be 0.75 feet higher than the elevation of the edge of the pavement.

8.3.1 Curb and Gutter

All curb and gutter designs must be in accordance with the Village's Public Infrastructure Design and Construction Standards. Use of other curb and gutter designs requires prior approval by the Village.

8.3.2 Roadside Swales

The Village encourages the use of grass-lined roadside ditches or swales for stormwater conveyance. Roadside swales must be designed in accordance with the criteria in Chapter 7 of this Manual. Roadside swales in residential areas must be designed to convey the 2-year peak design discharge, and roadside swales in non-residential areas must be designed to convey the 5-year peak design discharge.

In addition to the criteria in this chapter and Chapter 7 of this Manual, the swale section in Chapter 8 Open Channels of the UDFCD Manual provides detailed criteria and sizing methods for roadside swales with vegetated and rock linings. The UDFCD criteria include swale cross-sectional geometry with a flat bottom and mild side slopes to maximize infiltration, hydraulic, and water quality benefits of shallow flow through vegetation. In space-constrained areas, the Village may allow a variance for steeper side slopes and/or a "V" shaped swale if the applicant can demonstrate that the channel will remain stable over time.

Maintenance of Roadside Swales

Roadside swales must be designed to minimize long-term maintenance requirements by including design features that minimize deterioration from velocity-induced scour, sediment deposition at low velocity, and ponding of runoff.

Typically, maintenance of public infrastructure within the right-of-way will be performed by the Village. Maintenance of landscaping within the right-of-way is the responsibility of the adjacent property owner.

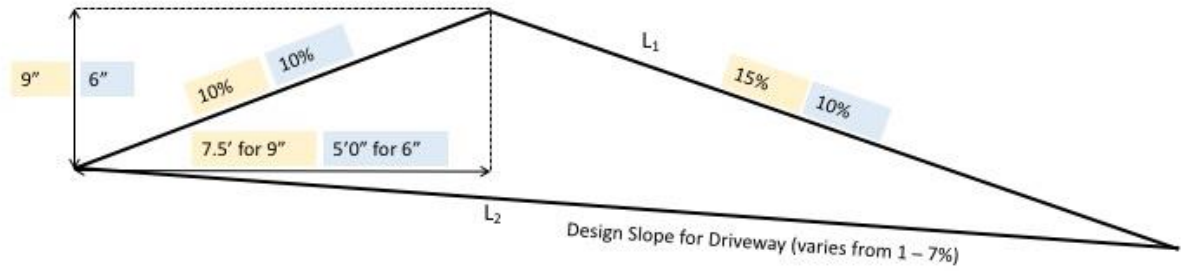
Maintenance within private street rights-of-way and in drainage easements on private property must be performed by the owner of the property unless otherwise specified.

8.3.3 Driveway Culverts

Driveway culverts in residential areas must be sized to pass the 2-year design discharge without overtopping of the driveway. Driveway culverts in non-residential area must be sized to pass the 5-year design discharge without overtopping of the driveway. The minimum culvert size for residential driveways is 12-inch-diameter circular pipe, or the equivalent arch pipe, with flared end sections or headwalls. For non-residential driveway culverts, the minimum diameter is 18 inches. Maintenance of driveway culverts is the responsibility of the owner of the property. In many residential areas, the driveway culvert is located within the public right of way. However, if the culvert is installed to provide access to a private lot, and otherwise would not be necessary, maintenance of the culvert is the responsibility of the adjacent property owner.

When access to a property (i.e., driveway) slopes down from the adjacent street, the Village requires that a high point be provided so that runoff from the street does not flow down driveways in frequently occurring events. The height of the high point can be 6 or 9 inches, and should be selected by the design engineer based on anticipated depths of runoff in the street. The 6-inch high point should be used for streets with curb and gutter, and the 9-inch high point is required when roadside swales or ditches are used. The design engineer should design the driveway highpoint so that major event flows are contained in the street and do not flood down the driveway. Figure 8-1 illustrates typical geometry, and Table 8-2 provides dimensions.

Figure 8-1. Typical Geometry for High Point in Driveway



Note: Yellow-shaded values correspond to 9-inch highpoint. Blue-shaded values correspond to a 6-inch highpoint.

Table 8-2. Dimensions for Driveway High Point Corresponding to Figure 8-1

Overall Driveway Grade	Length L_1 & L_2 (ft)	6-inch Highpoint	9-inch Highpoint
1%	L_1	6.2 ft	6.0 ft
	L_2	11.1 ft	13.4 ft
2%	L_1	7.5 ft	7.0 ft
	L_2	12.5 ft	14.4 ft
3%	L_1	9.3 ft	8.2 ft
	L_2	14.3 ft	15.6 ft
4%	L_1	11.7 ft	9.7 ft
	L_2	16.7 ft	17.1 ft
5%	L_1	15.1 ft	11.4 ft
	L_2	20.0 ft	18.8 ft
6%	L_1	20.1 ft	13.5 ft
	L_2	25.0 ft	20.9 ft
7%	L_1	28.5 ft	16.1 ft
	L_2	33.4 ft	23.5 ft

8.3.4 Drainage Easements

Drainage easements must be provided for any areas inundated by the major storm runoff. These easements must be shown on all drawings and plats. It is the responsibility of the design engineer to clearly identify drainage easements for the 100-year event on drawings and plats.

8.4 Design Procedures

An effective street design integrates both transportation and drainage functions. The philosophy of the Village is that street drainage design criteria should complement the transportation design criteria. The Village will review street design projects from the dual perspective of transportation and drainage.

Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual provides equations that can be applied for street hydraulics; however, most users will opt for a spreadsheet or other software to calculate street flow. Selection of Manning's roughness coefficients and other input parameters must be in accordance with the UDFCD Manual. UD-Inlet is a design workbook developed by UDFCD for street capacity and inlet sizing calculations (accessible on UDFCD's website).

Engineers are encouraged to use this workbook for design calculations and submittals to the Village for consistency of methodology and ease of review.

8.4.1 Minor Storm

The theoretical allowable street capacity for minor storm events must be determined using a version of Manning's Equation that has been derived for triangular gutter flow. Equations for triangular gutter and street sections are presented in Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual. To simplify calculations, the use of the UD-Inlet spreadsheet or similar software that can calculate uniform flow for a street cross section is recommended. The theoretical gutter capacity must be modified using reduction factors in Figure 7-4 of Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual to account for obstructions to gutter flow.

8.4.2 Major Storm

The theoretical allowable street capacity for major storm events is determined by applying Manning's Equation to a composite cross section consisting of the street, sidewalk, landscaped areas, and adjacent structural features that may confine the flow. For these calculations, a street cross section including the area behind the curb is needed to determine how far the major flow spreads beyond the street onto adjacent property. A composite roughness coefficient must be calculated by weighting the roughness coefficient for each segment of the cross section.

As with the minor storm, the calculated theoretical gutter capacity for the major storm must be modified using reduction factors in Figure 7-4 of Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual to account for obstructions to gutter flow. The UD-Inlet software program automatically applies these reduction factors.

9.0 Storm Drain Inlets

9.1 Introduction

Storm drain inlets are structural openings in a curbside or a swale that collect surface runoff for conveyance in a storm drain system. Inlets are critical components of the drainage system because well-designed inlets will minimize ponding and flooding of streets and other areas. Inlet design must be conservative, not only to ensure performance as a critical component of the drainage system, but also to adequately address the uncertainty of hydraulic flow characteristics in an urban environment with parked cars with wheels in the gutter, trash, debris, etc. The Village requires that all inlets be labeled to warn against dumping anything into the inlet because of sensitive downstream areas.

9.2 Standard Inlet Classifications

Storm drain inlets are classified by type of opening and grade-dependent hydraulic inlet conditions. The Village allows the use of curb inlets (non-grated), grated curb inlets, and combination inlets. Hydraulic inlet conditions are classified as inlets located on a continuous grade with bypass flow or inlets located in a sump condition that function under ponding head.

Standard inlets permitted for use in the Village are provided in Table 9-1 as a function of street classification as defined in Chapter 8 of this Manual. Other inlet types or configurations of inlet grates may be used with prior approval of the Village.

Table 9-1. Storm Drain Inlet Design

Inlet Type	Grade Permitted	Use Permitted
Curb Opening Inlet Type R	Collector and Arterial streets with standard 6-inch vertical curb and gutter	Continuous or Sump
Grated Inlet Type C	Local streets only, with a roadside ditch	Sump only
Grated Inlet Type 16	Local streets only, with a valley gutter	Continuous or Sump
Combination Inlet Type 16	All street types with standard 6-inch vertical curb and gutter	Continuous or Sump

The standard details for the inlets listed in Table 9-1 are provided in the Colorado Department of Transportation (CDOT) Standard Drawings. Selection of grate types should consider pedestrian and bicycle safety.

9.3 Design Procedures

The hydraulic analysis and design of storm drain inlets must be in accordance with the criteria presented in Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following sections.

The UDFCD Manual provides detailed documentation of calculations for inlet sizing. UDFCD has also developed the UD-Inlet workbook to automate many of these calculations. UD-Inlet can be downloaded from UDFCD's website.

9.3.1 Continuous Grade Condition

Inlet capacity on a continuous grade depends on many factors including gutter slope and flow depth, street cross slope, height and length of curb opening, and the amount of depression at the inlet. Inlets on a continuous grade are subject to bypass or carryover flow that must be included in the design of the inlet as well as the downstream storm drain. Inlets must be sized and spaced to satisfy the street encroachment and depth criteria in Chapter 8 of this Manual.

9.3.2 Sump Condition

Inlet capacity in a sump depends on many factors including gutter slope and flow depth, street cross slope, height and length of curb opening, and the depth of ponding at the inlet. Under submerged conditions, the inlet begins to act as an orifice rather than a weir. For inlets under sump conditions, the design procedure typically requires estimating the number of inlets needed to convey the design flow without exceeding depth or spread criteria in Chapter 8 of this Manual.

9.3.3 Inlet Spacing

The optimal spacing of storm inlets depends on several factors, including allowable spread to meet traffic requirements, contributing land use, street slope, and distance to the nearest outfall system. The interception rate of inlets in a continuous grade condition varies from less than 50% to as much as 100% of the allowable street capacity. Therefore, the optimal inlet spacing cannot be achieved in all instances, and the applicant should carefully analyze the spacing requirements.

The suggested sizing and spacing of the inlets based upon an interception rate of 70% to 80% is typically more economical than a spacing based upon a 100% interception rate. Using the suggested spacing, only the most downstream inlet in a development would be designed to intercept 100% of the flow. Inlet spacing design should consider the improvements in overall inlet system efficiency that can be achieved if inlets are located in the sumps created by street intersections.

Design of inlets also should consider nuisance flows, snowmelt and sediment accumulation in gutters and cross-pans. Nuisance flows are dry weather flows that typically originate from over irrigation or other urban or suburban water uses (car washing, outdoor water use, etc.). Nuisance flows can lead to growth of algae in gutters and cross pans during warm weather and can cause icing problems in winter months. Placement of inlets in areas with poor solar exposure should be avoided due to icing problems in winter months. Additional guidance on locating inlets is provided in the UDFCD Manual.

9.3.4 Clogging

Inlets are subject to clogging by trash and debris carried in runoff. Selection of a clogging factor reflects the condition of debris and trash on the street. During a storm event, street inlets are usually loaded with debris by the first-flush runoff volume. As a common practice for street drainage, 50% clogging is considered for the design of a single grate inlet and 10% clogging is

considered for a single curb-opening inlet. Often, it takes multiple units to collect the stormwater on the street. Since the amount of debris is largely associated with the first-flush volume in a storm event, the clogging factor applied to a multiple-unit street inlet should be decreased with respect to the length of the inlet. Linearly applying a single-unit clogging factor to a multiple-unit inlet will lead to an excessive increase in inlet length. For example, if a 50% clogging factor is applied to a six-unit inlet, the inlet would be presumed to function as a three-unit inlet. In reality, the upgradient units of the inlet would be more susceptible to clogging (perhaps at the 50% level) than the downgradient portions. In fact, continuously applying a 50% reduction to the discharge on the street will always leave 50% of the residual flow on the street. This means that the inlet will never reach a 100% capture and leads to unnecessarily long inlets. UDFCD has developed equations that account for this effect. Clogging reduction factors should be calculated following the procedures in Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual or using UD-Inlet.

10.0 Storm Drain Systems

10.1 Introduction

A storm drain system consists of inlets, pipes, manholes, junctions, cleanouts, outlets, and other appurtenant structures that collect and convey minor storm runoff. Storm drain systems must be conservatively designed to function with a level of reliability that maximizes safety and minimizes the inconveniences of inadequate control of frequent storm events.

10.2 Classifications

Storm drain systems are hydraulically classified by the type of flow in the pipe – gravity or pressurized flow. Storm drains are typically designed for gravity flow for the minor storm event. Under gravity flow conditions, flow in a storm drain acts like open channel flow with a free water surface. For events larger than the minor storm, a storm drain may operate under pressurized flow conditions, which occur when the pipe is full and the inlet of the pipe is submerged.

10.3 Design Criteria

The hydraulic analysis and design of storm drain systems must be in accordance with the criteria presented in Chapter 7 Streets, Inlets and Storm Drains of the UDFCD Manual. Detailed design criteria and procedures specific for the Village are highlighted in the following sections. These criteria and guidelines are intended to serve as minimum standards and not intended to replace site-specific analysis and design requirements of individual projects.

10.3.1 Design Storm Frequency

A storm drain system is required when the allowable street capacity is exceeded by runoff from the design storm. The design storm recurrence interval is given in Table 8-1 (Streets Chapter) as a function of street classification. In some cases, it may be necessary to design storm drain systems for capacity that exceeds the design storm requirements in Table 8-1. For example, at sump inlets with no alternative drainage outlet for the major storm, the storm drain may need to be sized for the 100-year event. The design of storm-drain systems must include hydraulic analysis of both the minor and the major storm events.

10.3.2 Construction Materials

Pipe materials acceptable for use in storm drain construction include the following:

1. Reinforced concrete pipe (RCP), in accordance with the criteria specified in ASTM C-76, C-506, C-507, with Class II pipe being the minimum acceptable standard;

2. Corrugated polyvinyl chloride (PVC) pipe, in accordance with the criteria specified in ASTM F-794, ASTM F-949 or ASTM F-679, as applicable; and

3. Corrugated dual wall high-density polyethylene pipe (HDPE), in accordance with the criteria specified in ASTM F-2306.

In areas of high abrasion potential and under roadways, the Village requires use of RCP. Approval from the Village is required to use of other storm drain materials in these situations.

10.3.3 Vertical and Horizontal Alignment

Manholes are required at all locations of hydraulic discontinuity, including junctions and changes in pipe size or alignment. The maximum spacing between manholes must be no more than 400 feet, in accordance with UDFCD criteria.

The storm drain grade must be sufficient to provide minimum cover required for HS-20 loading conditions as specified in the American Association of State Highway and Transportation Officials (AASHTO) "Standard Specifications for Highway Bridges." The minimum cover must not be less than 30 inches at any point along the pipe unless approved by the Village.

Storm drain alignment between manholes must be straight, except when approved in writing by the Village. Storm drains may be constructed with curvilinear alignment using pulled-joints, pipe bends, or radius pipe. The maximum allowable joint pull is ¾ inch. The radius requirements for pipe bends must be in accordance with the manufacturer's specifications and must consider pressurized flow conditions, as applicable.

10.3.4 Pipe Diameter

The minimum allowable pipe size for storm drains is dependent upon maintenance considerations. The length of the storm drain also affects maintenance. The minimum allowable pipe diameter for all public infrastructure is 18 inches. Private storm drains serving a single lot or business may be as small as 12-inch diameter; however, a minimum pipe diameter of 18 inches applies for any drainage system serving two or more lots.

10.3.5 Storm Drain Outlets

Selection of an outfall location is an important and sometimes critical design issue. Isolated sites or other project constraints may require design and construction of an intermediate surface water drainage system to convey site runoff to an acceptable outfall, or existing outfalls may require substantial improvements to convey the increased flows from the developed site. Erosion control requirements for outfalls may vary from rock-lined protection to stilling basins, depending on the magnitude of the discharge, the extent of the existing surrounding development, and the relationship of site hydraulics relative to receiving water hydraulics.

All storm-drain outlets that discharge into open channels must be constructed with a headwall and wingwalls or a flared end section. Alternative design methods can be approved by the Village for outfalls in lieu of a headwall and/or wingwalls. Outfall erosion protection must be provided at the outlet in accordance with the criteria presented in Chapter 12.

10.3.6 Hydraulic Design Criteria

The hydraulic analysis must include calculation of the hydraulic and energy grade lines to ensure that the storm drain system is capable of conveying the design discharge without surcharge for the minor storm. The hydraulic grade lines must be at least 6 inches below the top of any storm drain

structures or the ground surface during the major storm. The energy grade line for the design discharge must be at or below final grade during the major (100-year) storm.

Total hydraulic losses, including friction losses and losses due to expansions, contractions, bends, and junctions, must be computed in accordance with the criteria presented in the UDFCD Manual or manufacturer's criteria. Use of other hydraulic loss criteria requires approval from the Village.

10.4 Design Procedures

Design of many storm drain systems can be adequately addressed by manual application of the computational procedures described in the UDFCD Manual. The Village, however, recognizes the efficiency of using computerized applications, including spreadsheets and other technical software, to design larger and more complicated systems.

Storm drain systems can be sized using the Rational Method as presented in the Streets, Inlets and Storm Drains Chapter in the UDFCD Manual. The Colorado Urban Hydrograph Procedure (CUHP) with the U.S. Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) or UDFCD's UD-Sewer workbook (2009 or later) may also be used for basins larger than 10 acres. Proprietary software that would require the Village to pay a license fee to review is not allowed.

10.4.1 Gravity Flow Design

The design of gravity flow storm drain systems must be in accordance with the criteria presented in the UDFCD Manual. Storm drains with gravity flow conditions are hydraulically equivalent to open channels and are analyzed using Manning's equation for uniform open channel flow.

The computation of hydraulic properties for conduits under partial flow conditions is arithmetically complex. Hydraulic reference manuals and pipe manufacturers have, therefore, simplified the computations into nomographs that allow users to graphically determine partially full storm drain hydraulics. The full flow capacity of the storm drain is computed using Manning's equation, and partial flow values are estimated from the nomographs based on dimensionless ratios.

10.4.2 Pressurized Flow Design

The design of a pressurized storm drain system must be in accordance with the criteria presented in the UDFCD Manual. When dealing with pressurized flow, designers should give special attention to the hydraulic grade line and energy grade line to limit velocities in pipes and avoid having the energy grade line exceed the ground elevation under pressurized conditions. Joints, bends and outfall protection/energy dissipation measures also need to be carefully evaluated due to the increased hydraulic forces of pressurized flow.

11.0 Culverts

11.1 Introduction

A culvert is defined as a conduit for conveyance of surface water drainage beneath a driveway, street, highway, railroad, canal, or other embankment. The hydraulic analysis of culvert flow is complicated by a variety of discharge-dependent flow conditions that can occur. Over the range of operating conditions, culvert conveyance capacity may be a function of both inlet and discharge (outlet) flow conditions.

11.2 Culvert Classifications

Hydraulic classification of culverts is based on the types of hydraulic control (inlet or outlet) that exist at the design discharge. Culverts functioning under inlet control are limited in conveyance capacity by entrance losses. Culverts functioning under outlet control are limited in capacity by the material properties, geometry of the conduit, and/or downstream flow conditions (tailwater). Culverts designed for inlet control require analysis of the entrance head loss at the inlet to the culvert. A well-designed inlet can dramatically improve the hydraulic performance of the culvert. Culverts designed for outlet control require analysis of the hydraulic properties of the conduit, such as slope, roughness, shape, and diameter. Tailwater conditions at the point of discharge of the culvert must also be considered and may decrease the capacity of the culvert. Culverts may operate under inlet control at one design discharge and under outlet control at another depending on site-specific characteristics and assumptions.

11.3 Design Criteria

The hydraulic analysis and design of culverts must be in accordance with the criteria presented in Chapter 11 Culverts and Bridges of the UDFCD Manual. Design criteria and procedures specific for the Village are highlighted in the following sections.

Additional design procedures for concrete culverts are described in the American Concrete Pipe Association's *Concrete Pipe Design Manual*. Additional design procedures for corrugated metal conduits are described in the American Iron and Steel Institute's *Handbook of Steel Drainage and Highway Construction Products*.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements for individual projects.

11.3.1 Construction Material and Pipe Size

Materials acceptable for culverts include reinforced concrete pipe (RCP), corrugated metal pipe (CMP), and high-density polyethylene pipe (HDPE). Culverts beneath roadways must be RCP or reinforced concrete box culverts. CMP may be used for residential driveways, and CMP and HDPE pipes are allowable for landscape areas. The use of CMP on public projects requires a soil analysis to ensure that the corrosivity of the soil will not shorten the design life of the culvert. The Village will consider use of other culvert materials on a case-by-case basis. The minimum sizes for culverts are provided in Table 11-1.

Table 11-1. Minimum Culvert Sizes

Shape of Culvert	Minimum Equivalent Pipe Diameter (in)		Minimum Cross-Sectional Area (sq. ft.)	
	Streets	Driveways	Streets	Driveways
Circular	24	12	3.1	0.79
Arch	24	12	2.8	0.70
Elliptical	24	12	3.3	0.82

11.3.2 Inlet and Outlet Configuration

All culverts other than private driveway culverts must be designed with headwalls and wingwalls or flared end sections at the inlet and outlet. Culverts for unpaved roads must extend far enough out from the road so that road maintenance activities do not affect the entrance or exit of the culvert. Erosion protection must be provided at the outlet in accordance with the criteria presented in Chapter 12 Hydraulic Structures and the Greenwood Village Construction Site Management Manual. All culverts must be designed and installed to resist damage from errant vehicular traffic. For gravel roads, culverts must have collared end sections so that periodic road regrading activities will not damage the end sections of the culvert.

11.3.3 Hydraulic Design Criteria

11.3.3.1 Friction Losses

Culvert capacity and velocity must be computed using the Manning's roughness coefficient (n) in accordance with the manufacturer's criteria or published values in the UDFCD Manual.

11.3.3.2 Velocity

Culverts are designed for both a minimum and a maximum allowable velocity. A minimum cleansing velocity of 3 feet per second (fps) is required for the minor storm. The maximum allowable velocity for culverts should be determined based on the culvert material, outlet protection, and downstream permissible velocities.

11.3.3.3 Headwater Criteria

The maximum headwater for the major storm peak discharge is no more than 1.5 times the culvert diameter or rise dimension.

11.3.4 Structural Criteria

All culverts for public roads must be structurally designed to withstand a minimum H-20 or HS-20 loading condition depending on projected traffic characteristics in accordance with AASHTO's *Standard Specifications for Highway Bridges* or in accordance with the pipe manufacturer's recommendations. The design engineer is responsible for identifying and designing for the appropriate traffic loading conditions.

11.3.5 Trash Racks

The use of trash racks at culverts may reduce long-term maintenance requirements of the conduit and improves public safety. Field experience has demonstrated, however, that trash racks routinely become blocked with sediment and debris, requiring regular maintenance to ensure adequate conveyance capacity of the conduit during storm events. Use of trash racks must be evaluated with respect to project-specific constraints with due consideration of surroundings and public safety. Small diameter culverts and/or those with long underground reaches often warrant trash racks to avoid blockage, reduce maintenance and keep out the public.

All trash racks must be designed and installed to be resistant to damage from errant traffic. Breakaway designs are acceptable to the Village and will be reviewed on a case-by-case basis consistent with generally accepted culvert and trash rack manufacturer's recommendations. When a trash rack is used, it must be sized in accordance with criteria in the UDFCD Manual.

11.4 Design Procedures

Culverts in the Village that convey drainage beneath roadways must be designed to pass the 100-year peak discharge without road overtopping. In cases where the maximum headwater to depth ratio of 1.5 or other criteria cannot be satisfied or if it is infeasible to size the culvert to convey the 100-year event without road overtopping, some overtopping may be allowed up to the limits defined for street inundation in Table 8-1 in Chapter 8 Streets, with the prior written approval of the Village. Private driveways crossing roadside swales or ditches must be designed to prevent overtopping during the minor storm.

Allowable methods for culvert sizing include calculations performed in accordance with the guidance in the UDFCD Manual, calculations using UD-Culvert or analysis using the Federal Highway Administration's HY-8 computer program.

12.0 Hydraulic Structures

12.1 Introduction

Hydraulic structures are used in stormwater systems to ensure the long-term integrity of drainage facilities and to protect the environment by controlling the energy, direction and velocity of channelized flow. In the absence of adequate controls, the energy and hydraulic forces of flowing water can lead to significant erosion and scour, which can damage infrastructure through repetitive stresses or episodic events.

In addition to long-term maintenance considerations, hydraulic structures should be designed and constructed with consideration to safety and aesthetics and fit in with surroundings to the extent practicable. The safety and appearance of structures including bridges, headwalls, and wingwalls are important considerations for acceptance of design. Requirements include:

- Safety must be considered in all designs, using handrails and edge treatments where applicable in areas where there is pedestrian or recreational access and/or uses.

- Structure geometry, materials, texture, pattern, color of surfaces should be selected to blend with the adjacent landscape and provide an attractive appearance. Use dry-stack flagstone, sandstone, rock veneer or concrete forms for structures. Keystone brick or precast concrete block are prohibited.

- Anti-graffiti coating must be used.

Maintenance issues and access must be considered in the structure design and appropriate measures be included to facilitate proper maintenance (access road, if necessary, etc.). In some cases, additional right of way or easement width may be required to facilitate the construction, operation or maintenance of the structure. Design plans must include the proposed easement and/or right-of-way limits.

The analysis and design of hydraulic structures must be in accordance with the criteria in Chapter 9 Hydraulic Structures of the UDFCD Manual. Detailed design criteria and design procedures specific to the Village are highlighted in the following sections.

For bridges and culverts for public roads, the engineer must design improvements so that they qualify for UDFCD's Maintenance Eligibility Program. As a policy, the Village requires crossings, major drainageway improvements, culvert outfalls, and others to be designed for UDFCD Maintenance Eligibility when feasible. This requires coordination with UDFCD early in the project.

Design spreadsheets and other software for analysis and design of hydraulic structures must be applied in accordance with the criteria in the UDFCD Manual.

12.2 Types of Hydraulic Structures

12.2.1 Conduit Outlet Structures

Turbulence induced by high-energy transitions from conduit flow to open channel flow is a common source of scour in stormwater systems. Energy dissipation measures are required at conduit outlets. The type of outlet energy dissipation can range from ordinary riprap to energy dissipation structures such as U.S. Bureau of Reclamation (USBR) impact stilling basins, depending on the magnitude and velocity of the flow.

Conduit outlet protection design must be in accordance with the criteria in Chapter 9 Hydraulic Structures of the UDFCD Manual. A riprap apron must be provided at all outlets for conduits that discharge with velocity greater than 5.0 fps in erosive soils and greater than 7.0 fps in non-erosive soils. Conduit outfalls must have headwalls, wingwalls and/or flared end sections in accordance with UDFCD criteria. Concrete collars must be used for outfalls for separation of the conduit outfall from the embankment or roadway above. This is especially important for outfalls beneath gravel roads or embankments where roadway maintenance activities have the potential to affect the ends of the culvert. Concrete or other lined energy dissipation structures must be provided for conduit discharges with a Froude Number exceeding 2.5 in accordance with Chapter 9 Hydraulic Structures of the UDFCD Manual. When conditions warrant an impact stilling basin for flow control, the Village requires the use of UDFCD's modified USBR Type VI basins. Other types of designs may be allowed based on site-specific conditions and analysis with the approval from the Village.

12.2.2 Hydraulic Drop Structures

Reducing the longitudinal channel slope using hydraulic drop structures is a common method of controlling velocity and dissipating energy in a controlled manner. Design of hydraulic drop structures must be in accordance with the criteria presented in Chapter 9 Hydraulic Structures of the UDFCD Manual.

Due to durability and aesthetics, boulder and/or sculpted concrete designs are preferred for drop structures. Other types of drop structures may be considered on a case-by-case basis with approval of the Village. Vertical drops are not allowed. Typical designs for boulder drop structures are provided in Chapter 9 Hydraulic Structures of the UDFCD Manual. These designs are more adaptable to the parks, recreation, and trail usage of the major drainageways in the Village. When feasible, drop structures should be designed without the use of grout. This typically requires using larger boulders and in some cases a series of smaller drops rather than a single larger drop structure.

12.2.3 Bridges

Bridge hydraulic design must be in accordance with the criteria presented in Chapter 11 Culverts and Bridges of the UDFCD Manual and applicable master plans.

Bridge hydraulic capacity must be designed in accordance with the following criteria:

1. Flow through the bridge constriction must be modeled using backwater analysis to establish the water surface profile.

2. The Village prohibits supercritical flow through bridge openings. Analysis must be conducted assuming sub-critical flow conditions, and at least one foot of freeboard must be provided between the low cord of the bridge and the 100-year water surface elevation or the energy grade line, whichever is greater.

3. Maximum allowable velocities must be consistent with the constraints of the abutment lining material and the potential for scour.

4. Bridges and large culverts often provide opportunities for trail crossings. The engineer must consult with the Village to determine if a crossing has been identified as a potential separated grade crossing. Final design requirements for trail width, lighting, safety, vertical clearance, connection to the roadway grade and consideration of the low-flow condition and flooding should be in accordance with Village design guidelines and criteria in Chapter 10 Stream Access and Recreational Channels of the UDFCD Manual.

12.2.4 Transitions, Bends, and Confluences

The design of hydraulic structures for erosion protection for transitions, bends, and confluences must be in accordance with the criteria presented in Chapter 8 Open Channels of the UDFCD Manual.

12.2.5 Crossings and Discharges into Irrigation Ditches

The Village is divided by the Highline Canal, which crosses Greenwood Gulch, Prentice Gulch, and Little Dry Creek within the Village boundaries. The Highline Canal is owned and operated by the Denver Board of Water Commissioners (Denver Water Board). Documentation of approval by the Denver Water Board is required for any discharges into the Highline Canal. By a separate document, the applicant must indemnify the Village for any claims against the Village as a result of activities of the applicant adjacent to the Highline Canal.

Highline Canal Working Group

In 2010, Arapahoe County led an effort to establish the Highline Canal Working Group. The group consists of representatives from more than 20 municipalities and entities that serve the 66 miles of terrain along the 125-year-old Highline Canal. The Group is a collaborative effort to secure funding for projects. That will help ensure and protect the unique recreation experience along the Highline Trail. As a part of their work, the Highline Canal Working Group is evaluating opportunities to have the canal, which is no longer used for conveyance of significant ditch water, provide water quality benefits to public and private properties that drain to the canal. The Village is a part of this working group, which ultimately will lead to a master plan that considers drainage and water quality for areas that drain to the canal.

13.0 Flood Attenuation (Detention)

13.1 Introduction

Drainage systems must be designed to control flood discharges to protect people, property and the environment. Flood discharges from development or redevelopment in the Village must be regulated to levels that will not cause or worsen drainage and flooding problems. Flood attenuation is required for all development and redevelopment activities that create 500 square feet or more of new impervious area. When a site develops or redevelops, stormwater runoff must be controlled so that peak discharge rates to downstream properties do not cause adverse effects. This is most commonly achieved through temporarily storing and releasing runoff at controlled rates in stormwater detention facilities, which provide flood attenuation. The Village requires attenuation of the peak stormwater discharges using Full Spectrum Detention (FSD) and/or runoff reduction methods in accordance with the criteria and procedures in the UDFCD Manual. The Village strongly encourages the development of multipurpose, attractive detention facilities that are safe, maintainable and viewed as community assets rather than liabilities.

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 excess urban runoff volume (EURV) and releasing it over approximately 72 hours. The EURV is essentially the increase in runoff volume from undeveloped to urbanized conditions. The EURV includes the water quality capture volume (WQCV), which corresponds to the 80th percentile storm runoff event. FSD is intended to help protect streams from the effects of runoff from urbanization.

Development and redevelopment projects must minimize directly connected impervious areas to the maximum extent practicable. Eliminating unnecessary impervious areas and routing runoff from impervious surfaces to vegetated or landscaped pervious receiving areas helps reduce the volume, rate and frequency of runoff, as well as the size of detention and water quality facilities. The Quantifying Runoff Reduction Fact Sheet T-0 in Volume 3 of the UDFCD Manual provides information on runoff reduction techniques. A corresponding spreadsheet for performing runoff reduction calculations can be downloaded from UDFCD's website.

Three approaches to flood attenuation are available for development and redevelopment projects in the Village:

1. **Runoff Reduction:** For relatively small development and redevelopment projects (residential addition, deck, etc.) with good (or amended) soils and sufficient pervious area, flood attenuation may be accomplished by implementing runoff reduction measures that infiltrate excess runoff, as described in the Quantifying Runoff Reduction Fact Sheet T-0 in the UDFCD Manual.

2. **Onsite Detention:** Onsite detention facilities serve one lot, generally residential, commercial or industrial sites draining areas 20 to 30 acres or less.

3. **Regional/Subregional Detention:** Subregional detention facilities serve multiple landowners or lots and have a total watershed area of less than 130 acres. Most detention facilities located within residential communities are subregional, serving multiple individually owned lots. Subregional detention facilities are located off-line from the receiving stream. Regional detention facilities serve an area of 130 acres or more and are usually publicly owned and maintained. Regional detention facilities are allowed when recommended in UDFCD-sponsored master plans or if the Village has determined that onsite detention is impractical or not in the best interest of the public health, safety, and welfare.

In general, onsite or subregional detention will be required, as there are relatively few existing or planned regional detention facilities within the Village.

13.2 Flood Attenuation Requirements

Flood attenuation requirements in the Village vary based on the size of the development of redevelopment project as summarized in Table 1-1 of Chapter 1 and described as follows:

1. Flood attenuation is required for all development and redevelopment activities with impervious area increases of 500 square feet or more. Flood attenuation practices must be designed in accordance with the criteria in this Manual and the UDFCD Manual.

2. For development and redevelopment sites that add 500 square feet or more of imperviousness or disturb one or more acres of land, flood attenuation requirements can be met through use of full-spectrum detention flood attenuation facilities and/or UDFCD Manual runoff reduction practices. Runoff reduction practices avoid the direct connection of impervious areas to the storm drain and instead, guide runoff from pavement and roofs to vegetated areas such as grass buffers and grass swales in a manner that maintains sheet flow conditions. Runoff is reduced by infiltration, depression storage, and evapotranspiration. Runoff reduction methods are generally only applicable as a stand-alone practice on small sites. Required release rates vary for redevelopment and development sites and must meet these criteria:

    a. For redevelopment of existing development, release rates must be equal to discharge rates based on 1998 impervious area.

    b. For new development, release rates must achieve 90% of the historic discharge rate for the undeveloped area.

3. Flood attenuation requirements must be met prior to discharge of stormwater to a major drainageway, wetland, or across the property line of the applicant. If on-site detention or runoff reduction are impractical or if it is in the best interest of health, safety, and welfare, the applicant may apply for a waiver.

13.2.1 Underground Storage

Underground storage facilities are discouraged by the Village and will only be approved when no other option is feasible. In such cases, a carefully designed access and maintenance program is required and must be provided to the Village.

13.3 Design Criteria

Analysis and design of storage facilities for flood attenuation must be in accordance with the criteria and procedures presented in the Storage Chapter of the UDFCD Manual. When runoff reduction practices are implemented, criteria and procedures in Volume 3 of the UDFCD Manual must be followed. Volume 3 provides guidance on a variety of methods for quantifying runoff reduction, including a simplified procedure for small sites in Fact Sheet T-0. Additional criteria and design procedures specific to the Village are described in the following sections.

Software packages for analysis and design must be applied in accordance with the criteria presented in the UDFCD Manual. The UD-Detention workbook is recommended for preliminary design of FSD facilities and may be used for final sizing and design of onsite and subregional detention facilities. Regional facilities (as well as smaller facilities that do not fit the assumptions of the UD-Detention workbook) must use the Colorado Urban Hydrograph Procedure (CUHP) and the EPA Stormwater Management Model (SWMM) for detention facility sizing and design.

13.3.1 General Criteria

All detention facilities must be designed in accordance with the following criteria:

1. Detention facilities must be designed to provide FSD in accordance with the criteria and design procedures in the UDFCD Manual. Runoff reduction practices may be able to achieve flood attenuation requirements for small sites or can be used in conjunction with FSD facilities.

2. Onsite detention must be provided to control runoff unless regional or subregional facilities have adequate capacity to accommodate flood attenuation requirements for the site.

3. Offsite runoff from upstream drainage areas must be diverted around any proposed detention facility, or the detention facility must be designed to control the offsite runoff in addition to onsite runoff.

4. Detention facilities must be designed to reduce the peak discharge rate for developed site conditions in accordance with Section 13.2. Developed site conditions must include all anticipated future development that may drain to the detention facility.

5. Detention facilities must incorporate design features to minimize, maintain and enhance the physical aesthetics of the site. Design features may include proposed grading that mimics or improves the existing site profile and use of construction materials that visually integrate with the ambient environmental textures and patterns.

6. Properties served by an existing regional detention facility may only use the existing facility if the following conditions are met:

    a. Drainage-related characteristics of the property being developed are consistent with the design assumptions used in the regional facility's design. The applicant must demonstrate that the regional facility has capacity to serve the project and that the proposed imperviousness on the project site does not exceed the assumed imperviousness for the site in the design of the regional facility.

    b. If design assumptions for a property have changed from assumptions used to design the regional facility, then calculations must be provided that show that the drainage system between the property and the regional facility is adequate to convey the peak runoff from the property without adversely affecting other properties between the subject property and the regional facility.

13.3.2 State Regulatory Criteria

Any detention pond embankment used for storing water that meets the criteria of a regulatory dam based on surface area, volume, and/or height specified in CRS 37-87-105, as amended, must be designed and constructed in accordance with state dam safety criteria and require plan approval by the State Engineer's Office. The Village discourages creating regulatory dams for purposes of stormwater detention unless part of a regional, master-planned facility.

The applicant must comply with stormwater detention and infiltration facility notification and reporting requirements in accordance with CRS §37-92-602(8). This statute provides water rights related legal protection for regional and individual site stormwater detention and infiltration facilities in Colorado. See Section 1.7 of Chapter 1 for reporting requirements.

13.3.3 Detention Facility Volume

Storage volumes for detention facilities including the water quality capture volume (WQCV), the excess urban runoff volume (EURV) and 100-year flood attenuation volume are illustrated in figures in the Storage Chapter of the UDFCD Manual. FSD treats the WQCV as a volume that is "nested" within the EURV. The basic approach to FSD is to release the EURV over a period of approximately 72 hours. With a properly designed outlet structure, the required drain time for the WQCV (from 12 to 40 hours, depending on the type of water quality facility) can also be achieved.

13.3.4 Grading Requirements

Flood attenuation and stormwater quality facilities with embankments 5 feet or less in height must have a maximum embankment slope of 4:1 H:V (horizontal: vertical). Even milder slopes are preferred for ease of maintenance, aesthetics and reduced erosion potential. Embankments between 5 feet and 10 feet in height must have a maximum embankment slope of 3:1 H:V. Embankments greater than 10 feet in height must be designed with slopes adequate to maintain structural stability and in accordance with dam safety requirements of the State Engineer's Office. Geometry and slopes of the bottoms of detention ponds, trickle channels, forebays, micropools and other design elements must be in accordance with the UDFCD Manual.

13.3.5 Freeboard

The elevation of the top of the embankment should be a minimum of 1 foot above the water surface elevation when the emergency spillway is conveying the maximum design or emergency flow. This same level or more freeboard should be provided between the maximum design water surface elevation in the detention pond and first floor elevations of any adjacent structures. For small detention facilities where it is not feasible to construct 1 foot of freeboard, freeboard of 0.5 feet may be allowed when approved by the Village.

13.3.6 Outlet Configuration

All outlet control structures for detention facilities must conform to the details in the Storage Chapter of the UDFCD Manual. Other outlet configurations that satisfy release rate requirements may be considered on a case-by-case basis and must be approved by the Village.

13.3.7 Emergency Overflow Spillway

Emergency overflow spillways must be provided for all detention facilities to protect the embankment from catastrophic failure in the event of a storm that exceeds the design storage capacity or due to obstruction of the primary outlet works. At a minimum, the emergency overflow spillway must be designed for the fully developed, 100-year peak inflow rate to the detention facility.

13.3.8 Vegetation Requirements

All detention facilities must be vegetated in accordance with a landscaping plan approved by the Village. The type of grass used in vegetating a newly constructed detention facility is a function of the frequency and duration of inundation of the area, soil types, and the other potential uses (park, open space, etc.) of the area. UDFCD recommends using native grasses to reduce the frequency and cost of maintenance and help maintain infiltration rates, although irrigated turf may be used in some urban and park settings in the Village. See the Revegetation Chapter of the UDFCD Manual for detailed information on establishing vegetation, including soil testing and amendments, seed mixes, and plantings.

13.3.9 Considerations for Detention in Parking Lots

For some sites, detention may be integrated within parking areas. In general, this is not a desirable approach from a water quality perspective since parking lots typically are sources of urban runoff pollutants, and runoff detained within a parking area has little or no opportunity to infiltrate. Therefore, detention in parking lots is discouraged.

On some highly impervious sites or redevelopment sites, there may not be adequate pervious area for construction of an FSD facility. In these cases, parking lot detention may be allowed if the following minimum criteria are met:

- 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.

- The maximum allowable ponding depth for the 100-year design storm is no more than 12 inches.

- Inlets are designed with pipes having a minimum diameter of 18 inches. Weir outlets are designed with a minimum width of 3 inches.

- 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.

- 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 used to detain runoff
and is subject to periodic flooding
to a depth of (design depth).

Sign materials, geometry, and location are subject to approval by the Village.

13.4 Maintenance Requirements

Flood attenuation facilities must be maintained in effective operating condition. Facilities should be designed to facilitate maintenance access and ease of maintenance. Facilities that are eligible for maintenance by UDFCD must be designed and constructed to meet the requirements of UDFCD's Maintenance Eligibility Program. Design and construction must be approved by the UDFCD.

14.0 Wetland Criteria

14.1 Introduction

Wetlands provide a variety of benefits to the Village, including facilitating stormwater and floodplain management, providing recreational opportunities and promoting aesthetic enhancement. The Village requires projects to demonstrate compliance with Clean Water Act Section 404 (Section 404), as administered by the U.S. Army Corps of Engineers (USACE). Additionally, the Village encourages water quality, stream restoration and drainage management projects that will protect and enhance wetland resources within the Village.

14.2 Federal Regulations

Section 404 of the federal Clean Water Act applies to many drainageway and development projects. Under Section 404, discharges of fill or dredged material into Waters of the United Sates typically require obtaining authorization from the USACE. This authorization may be in the form of a General Permit or an Individual Permit. Regardless of the authorization form, federal and state conditions and requirements apply, including the need to minimize adverse environmental effects, maintain compliance with State of Colorado Section 401 Water Quality Certifications, and minimize erosion from the project.

For projects in drainageways, the Village requires submittal of one of the following:

1. A statement by the permittee affirming that permitting under Section 404 regulations is not required for the project. This statement must be supported by technical and/or regulatory documents or analyses, such as a wetland delineation, a letter of understanding from the USACE, or a letter prepared by a qualified professional.

2. Correspondence to/from the USACE that documents a project's compliance with Section 404 program requirements. This correspondence may include, as examples, wetland delineations and/or pre-construction notifications sent from the permittee to the USACE in addition to letters confirming project authorization under a General Permit from the USACE to the permittee.

14.3 Drainageway Maintenance to Minimize Future Section 404 Regulation

When drainageway infrastructure is not maintained, sediment deposits in channels and ponds can develop wetland characteristics. Under certain conditions, these wetland areas can be subsequently determined to be Waters of the United States by the USACE. In these situations, enlargement or modification of the drainageway can require Section 404 authorization and in some cases, mitigation of impacts to wetlands. To promote flexibility with drainageway management, the Village encourages regular drainageway maintenance to prevent the inadvertent creation of wetlands that could potentially be regulated under Section 404.

14.4 Wetland Maintenance

Wetlands that are part of the managed drainageway network generally require periodic maintenance. Many drainageway maintenance activities do not require USACE Section 404 authorization. For example, vegetation thinning and clearing that does not result in soil disturbance (e.g., trunks are cut 1-inch or more above the ground surface) typically does not require authorization. Removal of accumulated sediment is also typically exempt from Section 404 regulation. The Village requires that maintenance projects conform with USACE general permits or that the applicant coordinates with the USACE and complies with Section 404 requirements.

15.0 Stormwater Quality Management

15.1 Introduction

To minimize adverse impacts to waterbodies from new development and redevelopment, the Village requires proper design, implementation and maintenance of stormwater quality best management practices (BMPs) that help to reduce runoff peaks and volumes and reduce pollutant loading to waterbodies. This chapter summarizes applicable water quality and stormwater regulatory requirements and provides guidance and design criteria for overall site design approaches that minimize directly connected impervious area and for individual BMPs that can be utilized in the Village.

Terminology

Colorado's stormwater permits use the term "control measures" to refer to any best management practice (BMP) or other method used to prevent or reduce the discharge of pollutants to Waters of the State. Control measures include, but are not limited to, BMPs, green infrastructure (GI), green stormwater infrastructure (GSI) and low impact development (LID).

15.2 Water Quality Permits and Regulations

Since original publication of the Village's Manual, significant changes in federal and state stormwater and water quality regulations have occurred. Because stormwater quality and water quality regulations continue to evolve, users are encouraged to check for the most current version of the regulations on the Colorado Department of Public Health and Environment website. The Village's criteria for stormwater quality must comply with the Colorado Discharge Permit System Municipal Separate Storm Sewer System (MS4) for the Cherry Creek Reservoir Basin and Cherry Creek Reservoir Control Regulation 72. Additionally, CDPS MS4 permit requirements may be affected by Total Maximum Daily Load (TMDL) requirements as described in Table 1-2 in Chapter 1.

15.2.1 Colorado Discharge Permit System Municipal Separate Storm Sewer System (MS4) Permit

Regulation 61 Colorado Discharge Permit System (5 CCR 1002-61) defines regulatory requirements for stormwater discharge permitting in Colorado. Under Regulation 61, the Water Quality Control Division of CDPHE is required to issue stormwater quality control discharge permits to MS4s meeting certain urban population requirements. The Village is regulated under the "Phase 2" stormwater program for smaller municipalities under Cherry Creek Reservoir Basin MS4 General Permit (COR080000). The permit includes requirements for all land areas in the Village and specifies additional requirements for land areas subject to the Cherry Creek Basin Control Regulation. The most current version of the MS4 permit, supporting fact sheets and modifications can be accessed through CDPHE's water quality permits webpage. The requirements of the permit (COR080000) are hereby incorporated into this Manual by reference. Many of the requirements are focused on the Village as a local government and can generally be described as requiring implementation of "minimum control measures" to minimize stormwater quality impacts:

1. Public Education and Outreach
2. Illicit Discharge Detection and Elimination

3. Construction Site Stormwater Management
4. Post-Construction Stormwater Management in New Development and Redevelopment
5. Pollution Prevention/Good Housekeeping for Municipal Operations

The Village is required to implement pollutant restrictions, prohibitions, and pollutant reduction requirements to comply with the MS4 permit and demonstrate compliance with permit requirements through detailed tracking and reporting to the Division in accordance with the permit and the Village's stormwater program.

This chapter focuses on Post-Construction Stormwater Management, whereas Chapter 16 focuses on the Village's Construction Site Stormwater Management Requirements. This control measure is implemented by properly designed, constructed and maintained BMPs. The Village hereby incorporates by reference the most current version of Volume 3 Best Management Practices of the UDFCD Manual.

15.2.2 Watershed Protection Control Regulation for Cherry Creek Reservoir (Regulation 72)

The Cherry Creek Reservoir Control Regulation 72 (5 CCR 1002-72) was originally adopted in 1985 and has undergone many changes since that time. For a history of this control regulation, see the Statements of Basis and Purpose for the triennial reviews of the regulation provided in Regulation 72. Changes to Regulation 72 have also affected stormwater management requirements in the basin, particularly as they relate to phosphorus control requirements. The regulation identifies activities necessary to reduce the inflow total phosphorus concentrations to Cherry Creek Reservoir throughout the watershed. Such activities include, but are not limited to, construction of nonpoint source projects (pollutant reduction facilities or PRFs) and regulated stormwater projects (BMPs) to reduce phosphorous concentrations to the maximum extent practicable. The construction of any PRFs and BMPs must be consistent with the requirements defined in Regulation 72, which are also integrated into the Cherry Creek Reservoir Basin MS4 General Permit (COR080000). Thresholds and specific requirements for BMP treatment in the Cherry Creek Basin are summarized in Chapter 1 of this Manual, as well as described in checklists accessible on the Village's website.

Post-construction stormwater management requirements include ensuring that a combination of structural and/or nonstructural controls are in place that would prevent or minimize water quality impacts to the MS4 from new development and redevelopment projects. Post-construction stormwater-related submittal requirements must include not only a post-construction BMP Plan prior to the commencement of land disturbances, but also a long-term inspection and maintenance plan. Design, operation and maintenance criteria needed to support these requirements are provided in this chapter. Phosphorus control for stormwater in the Cherry Creek Basin is BMP-based with a maximum extent practicable (MEP) performance standard, rather than relying on a numeric effluent limit or percent removal target. Additionally, performance is oriented to nutrient removal, which is broader than phosphorus.

15.2.3 Impaired Waters and Total Maximum Daily Loads (TMDLs) (Regulation 93)

On a biennial basis, Colorado is required to review whether waterbodies with assigned water quality standards are attaining their designated uses. This process culminates in Regulation 93,

also known as the "303(d) List." Although this list serves as a tool to identify waterbodies in need of additional monitoring and evaluation, one of its primary uses is to identify waterbodies that will be targeted for development of a TMDL to control pollutant loading to the waterbody so that designated uses are attained. If the pollutant can be associated with stormwater sources, TMDLs often result in additional MS4 permit requirements to meet wasteload allocations assigned under the TMDL. Examples of such requirements could include additional monitoring, public outreach, source controls or structural BMP implementation, but specific requirements vary depending on the nature of the TMDL. Regulation 93 should be reviewed for current impairments (if any) present within the Village and where feasible, BMPs that effectively target pollutants causing impairments should be selected.

15.3 Stormwater BMP Design

The Village adopts the design criteria in Volume 3 of the UDFCD Manual as the basis for design for all BMPs installed in the Village. This includes the stormwater quality design approach utilizing UDFCD's four-step process, design of volume-based stormwater quality facilities using the UDFCD's water quality capture volume (WQCV) and UDFCD's runoff reduction method, where site constraints allow the stormwater quality requirements to be met through runoff reduction. Where flood attenuation facilities are designed to treat the Excess Urban Runoff Volume (EURV), the WQCV is incorporated into the design.

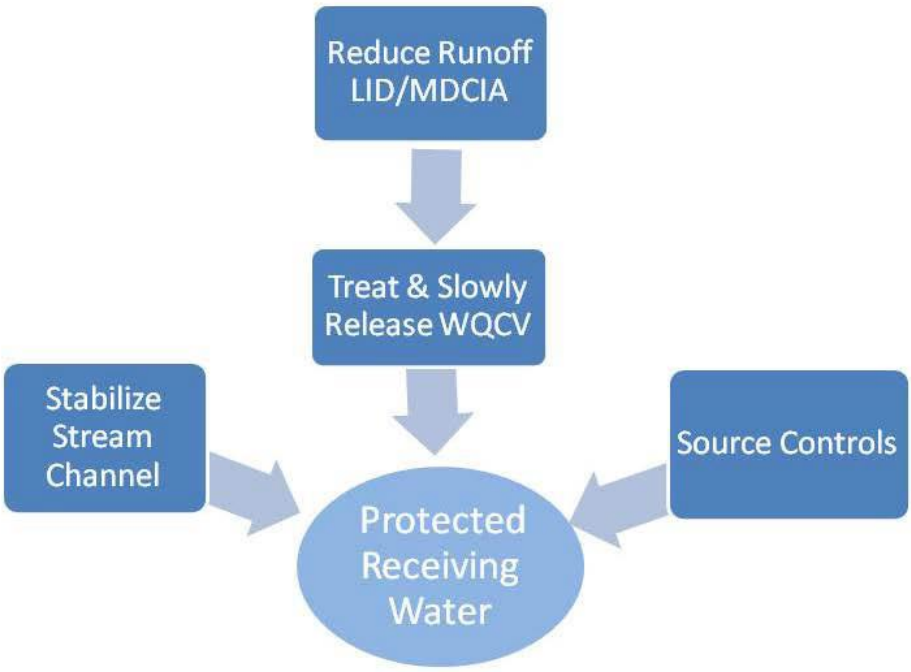
Table 1-1 of Chapter 1 of this Manual describes conditions triggering implementation of stormwater quality requirements and allowable options for use in developments in the Village, with additional conditions applicable for land areas subject to the Cherry Creek Reservoir Control Regulation.

15.3.1 Overview of Four-Step Process

Stormwater quality management approaches in the Village are based on the "Four-Step Process" described in Volume 3 of the UDFCD Manual (Figure 15-1). Additionally, the Village encourages integration of water quality and flood control in full spectrum detention facilities, as described in Chapter 13 Flood Attenuation.

As described in Volume 3 of the UDFCD Manual, effective stormwater management 1) integrates pollutant source controls, 2) reduces runoff volumes through minimized directly connected impervious area (MDCIA), 3) treats the WQCV, and 4) incorporates stream stabilization. This chapter focuses on runoff reduction through MDCIA and treatment of the WQCV (which may be treated as part of the EURV).

Figure 15-1. UDFCD's Four Step Process for Stormwater Quality Management



Development and redevelopment projects must minimize directly connected impervious areas to the maximum extent practicable. Eliminating unnecessary impervious areas and routing runoff from impervious surfaces to vegetated or landscaped pervious receiving areas helps reduce the volume, rate and frequency of runoff, as well as the size of detention and water quality facilities. In order for runoff reduction practices to be implemented on a site, opportunities must be considered early in the land development planning process. On some small sites, it may be possible to meet stormwater quality management requirements through only the use of runoff reduction practices. On larger sites, the size of WQCV facilities may be reduced through implementation of runoff reduction practices. The Village adopts UDFCD's method for quantifying volume reduction described in Volume 3, Treatment BMP Fact Sheet T-0. A spreadsheet for performing runoff reduction calculations can be downloaded from UDFCD's website.

15.3.2 Scale of Application

In addition to minimizing directly connected imperviousness to the maximum extent practicable, three approaches to stormwater quality management are available for development and redevelopment projects in the Village:

1. **Runoff Reduction**: For relatively small development and redevelopment projects (residential addition, deck, etc.) with good (or amended) soils and sufficient pervious area, stormwater quality requirements may be accomplished by implementing runoff reduction measures that infiltrate excess runoff, as described in the Quantifying Runoff Reduction Fact Sheet in Volume 3 of the UDFCD Manual.

2. **Onsite treatment of WQCV/EURV**: Onsite stormwater quality facilities serve one lot, generally residential, commercial or industrial sites draining areas 20 to 30 acres or less.

3. **Regional/subregional detention WQCV/EURV:** Subregional detention facilities serve multiple landowners or lots and have a total watershed area of less than 130 acres. Most detention facilities located within residential communities are subregional, serving multiple individually owned lots. Subregional detention facilities are located off-line from the receiving stream. Regional detention facilities serve an area of 130 acres or more and are usually publicly owned and maintained. Regional detention facilities are allowed when recommended in UDFCD-sponsored master plans or if the Village has determined that onsite detention is impractical or not in the best interest of the health, safety, and welfare of the Village.

In general, onsite or subregional detention will be required, as there are relatively few existing or planned regional detention facilities within the Village.

The contributing drainage area is an important consideration both on the site level and at the regional level. On the site level, there is a practical minimum size for certain BMPs, largely related to the ability to drain the WQCV over the required drain time. For example, it is technically possible to size the WQCV for an extended detention basin for a half-acre site; however, designing a functional outlet to release the WQCV over a 40-hour drain time is not practicable due to the very small orifices that would be required. For this size watershed, bioretention would be more appropriate. At the other end of the spectrum, there must be a limit on the maximum drainage area for a regional facility to assure adequate treatment of rainfall events that may produce runoff from only a portion of the area draining to the BMP. If the overall drainage area is too large, events that produce runoff from only a portion of the contributing area will pass through the BMP outlet (sized for the full drainage area) without adequate residence time in the BMP. As a practical limit, the maximum drainage area contributing to a regional water quality facility should be no larger than one square mile.

15.3.3 Base Design Standards in MS4 Permit

The base design standards for stormwater control measures (i.e., BMPs) in the Village allow several options, as described in the Village's MS4 permit. Additional and/or more restrictive requirements may apply in the Cherry Creek Reservoir Basin as described in Regulation 72. The base design standards include these options:

1. **WQCV Standard**: The control measure(s) is designed to provide treatment and/or infiltration of the WQCV and:

    a. 100% of the applicable development site is captured, except the applicant may exclude up to 20%, not to exceed 1 acre, of the applicable development site area when the applicant has determined that it is not practicable to capture runoff from portions of the site that will not drain towards control measures. In addition, the applicant must also determine that the implementation of a separate control measure for that portion of the site is not practicable (e.g., driveway access that drains directly to street).

b. Evaluation of the minimum drain time must be based on the pollutant removal mechanism and functionality of the control measure implemented. Consideration of drain time must include maintaining vegetation necessary for operation of the control measure (e.g., wetland vegetation).

2. **Pollutant Removal Standard**: The control measure(s) is designed to treat at a minimum the 80th%ile storm event. The control measure(s) must be designed to treat stormwater runoff in a manner expected to reduce the event mean concentration of total suspended solids (TSS) to a median value of 30 mg/L or less. Under this standard, 100% of the applicable development site must be captured, except the applicant may exclude up to 20% not to exceed 1 acre of the applicable development site area when the applicant has determined that it is not practicable to capture runoff from portions of the site that will not drain towards control measures. In addition, the applicant must also determine that the implementation of a separate control measure for that portion of the site is not practicable (e.g., driveway access that drains directly to street).

3. **Runoff Reduction Standard**: The control measure(s) is designed to infiltrate into the ground where site geology permits, evaporate, or evapotranspire a quantity of water equal to 60% of what the calculated WQCV would be if all impervious area for the applicable development site discharged without infiltration. This base design standard can be met through practices such as green infrastructure. "Green infrastructure" generally refers to control measures that use vegetation, soils, and natural processes or mimic natural processes to manage stormwater. Green infrastructure can be used in place of or in addition to low impact development principles.

4. **Applicable Development Site Draining to a Regional WQCV Control Measure**: The regional WQCV control measure must be designed to accept the drainage from the applicable development site. Stormwater from the site must not discharge to a water of the state before being discharged to the regional WQCV control measure. The regional WQCV control measure must meet the requirements described in the Village's MS4 permit.

5. **Applicable Development Site Draining to a Regional WQCV Facility**: The regional WQCV facility is designed to accept drainage from the applicable development site. Stormwater from the site may discharge to a water of the state before being discharged to the regional WQCV facility. Before discharging to a water of the state, at least 20% of imperviousness of the applicable development site must drain through a receiving pervious area control measure comprising a footprint of at least 10% of the disconnected tributary impervious area. The control measure must be designed in accordance with Volume 3 of the UDFCD Manual. In addition, the stream channel between the discharge point of the applicable development site and the regional WQCV facility must be stabilized. The regional WQCV facility must meet requirements specified in the Village's MS4 permit.

6. **Constrained Redevelopment Sites Standard**: The constrained redevelopment sites standard applies to redevelopment sites (sites that are already substantially developed with 35% or more of existing imperviousness) meeting the following criteria: (a) the applicable

redevelopment site is for a site that has greater than 75% impervious area, and (b) it is not practicable to meet any of the design standards in (A), (B), or (C) above. The applicant's determination must include an evaluation of the applicable redevelopment site's ability to install a control measure without reducing surface area covered with the structures. In these cases, the control measure(s) must be designed to meet one of the following:

a. Provide treatment of the WQCV for the area captured. The captured area must be 50% or more of the impervious area of the applicable redevelopment site. Evaluation of the minimum drain time must be based on the pollutant removal mechanism and functionality of the control measure implemented,

b. The control measure(s) is designed to provide for treatment of the 80th%ile storm event. The control measure(s) must be designed to treat stormwater runoff in a manner expected to reduce the event mean concentration of TSS to a median value of 30 mg/L or less. A minimum of 50% of the applicable development area including 50% or more of the impervious area of the applicable development area must drain to the control measure(s). This standard does not require that 100% of the applicable redevelopment site area be directed to control measure(s) as long as the overall removal goal is met or exceeded (e.g., providing increased removal for a smaller area), or

c. Infiltrate, evaporate, or evapotranspire, through practices such as green infrastructure, a quantity of water equal to 30% of what the calculated WQCV would be if all impervious area for the applicable redevelopment site discharged without infiltration.

15.3.4 BMP Design Criteria

Design of conveyance-based BMPs (e.g., grass buffers, swales) is based on design flow rates specified in Volume 3 of the UDFCD Manual. Storage-based BMPs (e.g., extended detention basins, bioretention, sand filters) are based on storing and slowly releasing the WQCV unless Full Spectrum Detention designs are implemented providing treatment of the EURV, as described in Chapter 13 Storage. The WQCV is calculated using methods in Volume 3 of the UDFCD Manual. UDFCD's UD-BMP workbook can be used as a design aid for BMP selection and sizing, as well as to quantify runoff reduction achieved through disconnection of impervious area. The Village requires treatment of the full WQCV unless the required treatment volume is reduced through implementation of volume reduction methods. Reductions in WQCV treatment volumes must be quantified following using the Runoff Reduction Method (Fact Sheet T-0) described in UDFCD Volume 3.

Volume 3 of the UDFCD Manual provides design criteria for BMP types appropriate for use in the Village. The Village adopts UDFCD's design criteria for BMPs listed in Table 15-1. Additionally, the Village may approve use of other BMP types with demonstrated performance on a case-by-case basis. Chapter 2 BMP Selection in Volume 3 of the UDFCD Manual provides BMP selection guidance considering factors such as watershed size, soils, depths to groundwater and bedrock, baseflows, watershed conditions and targeted pollutants.

Table 15-1. BMP Types Allowed in the Village

BMP Type[1]	Comment
Grass Buffers and Grass Swales	Can be used to disconnect impervious area and provide volume reduction. These are usually part of a treatment train with other practices that provide the WQCV and can be designed to infiltrate the WQCV on smaller sites. Can provide pretreatment for underground BMPs.
Bioretention	Can be designed for WQCV or EURV. Well suited for smaller sites, infill and redevelopment.
Green Roof	Primarily provides volume reduction.
Extended Detention Basin	Can be designed for WQCV or EURV. Not recommended for drainage areas with less than 2 impervious acres and not allowed for sites with less than 1 impervious acre.
Sand Filter	Can be designed for WQCV or EURV. Suitable for drainage areas less than 1 acre. The Village prefers aboveground (surface-accessible) sand filters. A variance is required for sand filters in underground vaults.
Retention Pond (Wet Pond)	Can be designed for WQCV or EURV. Water rights and space constraints may limit application in the Village. Only allowed for drainage areas greater than 1 acre.
Constructed Wetland Pond	Can be designed for WQCV or EURV. Water rights and space constraints may limit application in the Village. Only allowed for drainage areas greater than 1 acre.
Constructed Wetland Channel	Does not provide WQCV. Water rights and base flow required. Only allowed for drainage areas greater than 1 acre.
Permeable Pavement	Can be designed for WQCV and flood attenuation. Suitable for parking areas, alleys and low-use areas without potential for groundwater contamination. Enables use of BMP surface area for other purposes.
Underground BMPs (Proprietary Practices)	The Village prefers above-ground treatment approaches. May be used for pretreatment or approved on a case-by-case basis when no above-ground alternatives are feasible.

[1]For sites located within the Cherry Creek Basin, specific treatment train configurations may be required to use certain BMPs in this table, as described in Regulation 72.

15.4 Maintenance Requirements

BMPs must be maintained in effective operating condition. BMPs should be designed to facilitate maintenance access and ease of maintenance. UDFCD designs in Volume 3 include features such as forebays to facilitate maintenance.

All facilities eligible for maintenance by UDFCD must be designed and constructed to meet the requirements of UDFCD's Maintenance Eligibility Program and be approved by UDFCD.

15.5 Stormwater Facility Reporting Requirements Related to Water Rights

Certain stormwater control measures require water rights-related reporting under CRS §37-92-602(8) (also known as Senate Bill 15-212). Requirements for reporting are provided in Chapter 1 of this Manual.

16.0 Construction Site Stormwater Management

16.1 Introduction

The Village manages and implements a program to reduce or prevent the discharge of pollutants from construction activities to the storm drain system, receiving waters and wetlands. The Village's program complies with its Colorado Discharge Permit System Municipal Separate Storm Sewer (CDPS MS4) permit requirements, the statewide CDPS General Permit for Stormwater Discharges Associated with Construction Activity (COR-040000), and the Cherry Creek Reservoir Control Regulation (Regulation 72) for sites located in the Cherry Creek Reservoir Basin. The Village adopts Chapter 7 Construction BMPs of Volume 3 of the UDFCD Manual as the basis for design, implementation and maintenance of erosion and sediment control practices in the Village.

Duty to Comply with Permits and Regulations

The Village's construction site stormwater management criteria incorporate by reference detailed requirements described in the Village's CDPS MS4 Permit, the statewide CDPS General Permit for Stormwater Discharges Associated with Construction Activity (COR-040000) and the Cherry Creek Reservoir Regulation 72. It is the applicant's responsibility to obtain the most current versions of these documents and comply with these regulatory requirements, which are updated periodically by the Colorado Department of Public Health and Environment (CDPHE). For convenience, the Village provides weblinks to these documents on its website, along with checklists that can be used to prepare stormwater management plans for construction sites in the Village.

16.2 Construction Site Stormwater Management Requirements

Table 16-1 summarizes construction site stormwater management requirements for development and redevelopment sites in the Village. The Village requires implementation of control measures to minimize the discharge of pollutants from all potential pollutant sources at construction sites. Control measures must be installed prior to commencement of construction activities. Control measures must be selected, designed, installed and maintained in accordance with good engineering, hydrologic and pollution control practices. Control measures implemented at the site must be designed to prevent pollution or degradation of State waters.

Stormwater management plans (SWMPs) must include a combination of erosion controls, materials management, sediment controls, and site management practices appropriate for the construction site. A written plan is required for applicable construction activities with one or more acre of disturbance.[1] This plan must locate and identify all structural and non-structural control measures for the applicable construction activities. The site plan must contain installation and implementation specifications or a reference to the document with installation and

[1] "Applicable construction activities" include construction activities that result in a land disturbance of greater than or equal to one acre or that is less than one acre, but is part of a larger common plan of development or sale that would disturb one acre or more. See Village's MS4 permit for additional definitions and requirements.

implementation specifications for all structural control measures. A narrative description of non-structural control measures must be included in the site plan.

Appropriate control measures must be implemented prior to the start of construction activity, must control potential pollutants during each phase of construction, and must be continued through final stabilization. Additionally, temporary stabilization activities are required in accordance with the CDPS General Stormwater Construction Permit (COR-040000) and Regulation 72 for areas within the Cherry Creek Reservoir basin. Appropriate structural control measures must be maintained in operational condition.

Table 16-1. Construction Site Stormwater Management Requirements

Construction Activity	Basis of Requirement	Requirements
Outside Cherry Creek Reservoir Basin		
< 1 acre of disturbance	City policy	Vehicle tracking controls, silt fence and/or erosion control logs may be required based on site conditions. See Village's checklist for Construction Site Control Plan requirements.
> 1 acre of disturbance for applicable construction activities	Village's CDPS MS4 Permit (COR-80000) CDPS General Permit for Stormwater Discharges Associated with Construction Activity (COR-040000)	Obtain and comply with CDPS Construction General Permit Prepare and maintain written SWMP. Implement and maintain construction-phase BMPs for stormwater management. See Village's checklist for requirements.
Inside Cherry Creek Reservoir Basin		
< 1 acre of disturbance for individual residential lots	Regulation 72	Control sediment from leaving the site with a sediment entrapment BMP and vehicle tracking control. See Village's checklist for requirements for sites in the Cherry Creek Reservoir Basin.
< 1 acre of disturbance for non-residential lots	Regulation 72	See Village's checklist for requirements for sites in the Cherry Creek Reservoir Basin.
> 1 acre of disturbance for applicable construction activities	Village's CDPS MS4 Permit (COR-80000) CDPS General Permit for Stormwater Discharges Associated with Construction Activity (COR-040000) Regulation 72	Obtain and comply with CDPS Construction General Permit. Prepare and maintain written SWMP. Implement and maintain construction-phase BMPs for stormwater management. See Village's checklist for requirements.

16.3 Construction Site Stormwater Management Plan Requirements

For construction sites with greater than or equal to one acre of disturbance, a SWMP must be prepared and submitted to the Village for review and approval. The Village follows the SWMP requirements identified in the statewide CDPS Construction General Permit for Stormwater Discharges Associated with Construction Activity (COR-040000) and the Village's CDPS MS4 Permit (COR-080000). Checklists for the construction sites types described in Table 16-1 are provided on the Village's website to assist with the development of these plans.

A SWMP must be prepared in accordance with good engineering, hydrologic and pollution control practices and implemented from commencement of construction activity until final stabilization is complete. A copy of the SWMP must be retained onsite or be onsite when construction activities are occurring at the site, unless the owner/operator specifies another location and obtains approval from the Village.

The SWMP, at a minimum, must include the following elements:

1. **Qualified Stormwater Manager.** The SWMP must list individual(s) by title and name who are designated as the site's qualified stormwater manager(s) responsible for implementing the SWMP in its entirety. This role may be filled by more than one individual.

2. **Spill Prevention and Response Plan.** The SWMP must have a spill prevention and response plan. The plan may incorporate by reference any part of a Spill Prevention Control and Countermeasure (SPCC) plan under section 311 of the federal Clean Water Act or a Spill Prevention Plan required by a separate CDPS permit. The relevant sections of any referenced plans must be available as part of the SWMP consistent with Part I.C.4.

3. **Materials Handling.** The SWMP must describe and locate all control measures implemented at the site to minimize impacts from handling significant materials that could contribute pollutants to runoff. These handling procedures can include control measures for pollutants and activities such as exposed storage of building materials, paints and solvents, landscape materials, fertilizers or chemicals, sanitary waste material, trash and equipment maintenance or fueling procedures.

4. **Potential Sources of Pollution.** The SWMP must list all potential sources of pollution that may reasonably be expected to affect the quality of stormwater discharges associated with construction activity from the site. At a minimum, the SWMP must specifically address the following pollutant sources:

    a. disturbed and stored soils;
    b. vehicle tracking;
    c. management of contaminated soils;
    d. loading and unloading operations;
    e. outdoor storage activities (e.g., erodible building materials, fertilizers, chemicals, bulk storage of materials including those 55 gallons or greater which require secondary containment);
    f. vehicle and equipment maintenance and fueling;

g. significant dust or particulate generating processes (e.g., saw cutting material, including dust);
h. routine maintenance activities involving fertilizers, pesticides, herbicides, detergents, fuels, solvents, oils, etc.;
i. on-site waste management practices (waste piles, liquid wastes, dumpsters);
j. concrete truck/equipment washing, including washing of the concrete truck chute and associated fixtures and equipment;
k. dedicated asphalt and concrete batch plants and masonry mixing stations;
l. non-industrial waste sources such as worker trash and portable toilets; and
m. other non-stormwater discharges including construction dewatering not covered under the Construction Dewatering Discharges general permit and wash water that may contribute pollutants to the MS4.

5. **Implementation of Control Measures.** The SWMP must include design specifications that contain information on the implementation of the control measure in accordance with good engineering hydrologic and pollution control practices. These include applicable drawings, dimensions, installation information, materials, implementation processes, control measure-specific inspection expectations, and maintenance requirements.

   The SWMP must include a documented use agreement between the permittee and the owner or operator of any control measures located outside of the permitted area that are utilized by the permittee's construction site for compliance with this permit, but not under the direct control of the permittee. The permittee is responsible for ensuring that all control measures located outside of their permitted area that are being utilized by the permittee's construction site, are properly maintained and in compliance with all terms and conditions of the permit. The SWMP must include all information required of and relevant to any such control measures located outside the permitted area, including location, installation specifications, design specifications and maintenance requirements.

6. **Site Description.** The SWMP must include a site description in accordance with the Village's checklist, which includes, at a minimum, the following:

   a. the nature of the construction activity at the site;
   b. the proposed schedule for the sequence for major construction activities and the planned implementation of control measures for each phase (e.g., clearing, grading, utilities, vertical, etc.);
   c. estimates of the total acreage of the site, and the acreage expected to be disturbed by clearing, excavation, grading, or any other construction activities;
   d. a summary of any existing data used in the development of the construction site plans or SWMP that describe the soil or existing potential for soil erosion;
   e. a description of the percent of existing vegetative ground cover relative to the entire site and the method for determining the percentage;
   f. a description of any allowable non-stormwater discharges at the site, including those being discharged under CDPHE's low-risk discharge guidance policy;
   g. a description of areas receiving discharges from the site, including a description of the immediate source receiving the discharge. If the stormwater discharge is to a MS4, the

name of the entity owning that system, the location of the storm sewer discharge, and the ultimate receiving water(s); and

h. a description of all stream crossings located within the construction site boundary.

7. **Site Map**. The SWMP must include a site map in accordance with the Village's checklist, which includes, at a minimum, the following:

   a. construction site boundaries;
   b. flow arrows that depict stormwater flow directions on-site and runoff direction;
   c. all areas of ground disturbance including areas of borrow and fill;
   d. areas used for storage of soil;
   e. locations of all waste accumulation areas, including areas for liquid, concrete, masonry, and asphalt;
   f. locations of dedicated asphalt and concrete batch plants and masonry mixing stations;
   g. locations of all structural control measures;
   h. locations of all non-structural control measures;
   i. locations of springs, streams, wetlands and other state waters, including areas that require pre-existing vegetation be maintained within 50 feet of a receiving water, where determined feasible in accordance with the CDPS Construction General Permit; and
   j. locations of all stream crossings located within the construction site boundary.

8. **Final Stabilization and Long-Term Stormwater Management**. The SWMP must describe the practices used to achieve final stabilization of all disturbed areas at the site and any planned practices to control pollutants in stormwater discharges that will occur after construction operations are completed. These include, but are not limited to, detention/retention ponds, rain gardens, stormwater vaults, etc. (Temporary stabilization must also be addressed in the SWMP.)

9. **Inspection Reports**. The SWMP must include documented inspection reports in accordance with the CDPS Construction General Permit.

The Village's checklists provide additional information on performance standards, including specific requirements for practices such as temporary stabilization.

16.4 Construction Site Stormwater Control Measure Design Standards

The Village adopts UDFCD's criteria for construction BMPs, including practices listed in Table 16-2, including revisions to UDFCD's criteria that may be completed periodically. Selection of individual practices is based on site-specific conditions. The Village may allow additional practices at its discretion. For multi-jurisdictional projects (e.g., CDOT, SEMSWA), alternative criteria and/or practices may be substituted, as approved by the Village.

Table 16-2. UDFCD Manual Construction Site Stormwater Control Practices

Erosion Controls

EC-1 Surface Roughening (SR)
EC-2 Temporary and Permanent Seeding (TS/PS)
EC-3 Soil Binders (SB)
EC-4 Mulching (MU)
EC-5 Compost Blanket and Filter Berm (CB)
EC-6 Rolled Erosion Control Products (RECP)
EC-7 Temporary Slope Drains (TSD)
EC-8 Temporary Outlet Protection (TOP)
EC-9 Rough Cut Street Control (RCS)
EC-10 Earth Dikes and Drainage Swales (ED/DS)
EC-11 Terracing (TER)
EC-12 Check Dams (CD) (multiple types)
EC-13 Streambank Stabilization (SS)
EC-14 Wind Erosion/Dust Control (DC)

Sediment Controls

SC-1 Silt Fence (SF)
SC-2 Sediment Control Log (SCL)
SC-3 Straw Bale Barrier (SBB)
SC-4 Brush Barrier (BB)
SC-5 Rock Sock (RS)
SC-6 Inlet Protection (IP)
SC-7 Sediment Basin (SB)
SC-8 Sediment Trap (ST)
SC-9 Vegetative Buffers (VB)
SC-10 Chemical Treatment (CT)

Site Management and Other Specific Practices

SM-1 Construction Phasing/Sequencing (CP)
SM-2 Protection of Existing Vegetation (PV)
SM-3 Construction Fence (CF)
SM-4 Vehicle Tracking Control (VTC)
SM-5 Stabilized Construction Roadway (SCR)
SM-6 Stabilized Staging Area (SSA)
SM-7 Street Sweeping and Vacuuming (SS)
SM-8 Temporary Diversion Methods (TDM)
SM-9 Dewatering Operations (DW)
SM-10 Temporary Stream Crossing (TSC)
SM-11 Temporary Batch Plant (TBP)
SM-12 Paving and Grinding Operations (PGO)

Materials Management

MM-1 Concrete Washout Area (CWA)
MM-2 Stockpile Management (SP)
MM-3 Good Housekeeping Practices (GH)

16.5 Maintenance of Construction Site Stormwater Control Measures and Final Stabilization Requirements

Construction site erosion and sediment controls must be maintained until final stabilization of the site has been reached. Final stabilization is reached when all ground surface disturbing activities at the construction site are complete; and, for all areas of ground surface disturbing activities, either a uniform vegetative cover with an individual plant density of at least 70 percent of pre-disturbance levels is established, or equivalent permanent alternative stabilization methods are implemented.

Temporary erosion and sediment controls such as silt fence must be removed from the site and properly disposed of following final stabilization.

16.6 Inspections, Corrective Measures and Enforcement

Owners and/or operators must perform inspections in accordance with the applicable regulations and permits to assess the adequacy of control measures at the site and the need for changes to those control measures to ensure continued effective performance. The CDPS Construction General Permit outlines specific requirements for the person responsible for conducting inspection, inspection frequency, scope of inspection and inspection reports.

When inspections identify inadequate control measures and/or other changes needed for stormwater management at the construction site, owners/operators must implement and document corrective actions necessary to return the measure to effective operating condition and properly manage stormwater at the site. If applicable, the permittee must remove and properly dispose of any unauthorized release or discharge (e.g., discharge of non-stormwater, spill, or leak). The permittee must also clean up any contaminated surfaces to minimize discharges of the material in subsequent storm events.

In addition to inspections by the owner/operator, the Village will conduct inspections in accordance with the requirements of the Village's CDPS MS4 permit and conduct enforcement activities in accordance with the Village's Municipal Code.

Regardless of the size of the project or permit requirements, the Village may require remedial actions to address nuisance conditions caused by construction activity, as authorized by the Village's Municipal Code.

16.7 Submittals and Revisions

Submittal requirements vary based on the area disturbed by construction activities and location relative to the Cherry Creek Reservoir Basin, as described in Table 16-1. The Village's website provides checklists for submittal requirements for various types of construction activities.

For sites requiring a written SWMP, submittals must be in accordance with the applicable regulations and permits and must be reviewed and approved by the Village. After submittal to the Village, SWMPs must continue to be maintained and updated throughout the construction process to reflect actual site conditions and be available on the construction site for inspection and review by the Village. Minor and major revisions to the SWMP have differing requirements for approval, as follows:

1. Minor modifications involve substitutions of BMP types and/or include alternate details to BMPs that are equivalent in performance or more suitable to the specific site conditions. Minor modifications can be made to the SWMP without Village approval, but these changes must be documented in the SWMP.

2. Major modifications consist of changes in hydrology to the approved plan, requiring re-approval by the Village. Major modifications must be submitted to the Village for approval prior to implementation.

17.0 REFERENCES

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Wulliman, Jim and Derek Johns, *Demonstration Projects Illustrating Void-Filled Riprap Applications in Stream Restoration*, prepared for Urban Drainage and Flood Control District, April 2011.