DESIGN CRITERIA
AND
CONSTRUCTION SPECIFICATIONS

VOLUME II
STORM DRAINAGE

September 2024

DEPARTMENT OF PUBLIC WORKS

CITY OF GREELEY, COLORADO

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EXECUTED:

The City of Greeley

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Date: 9/30/2024

PREFACE

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PREFACE

I. USER'S GUIDE

The City of Greeley Storm Drainage Design Criteria (SDDC or Criteria) has been developed by the City's Stormwater Management Division, referred to herein as the Stormwater Division. It is intended to streamline the planning and design process of drainage facilities. Preparation of final design plans, addressing details of structural adequacy, public safety, hydraulic functionality, maintainability, and aesthetics, are the sole responsibility of the engineer. The SDDC is organized in the following sections.

Section 1 – General Provisions. Includes information on the principles of planning and design, subdivision grading requirements, stormwater master planning, public versus private facilities, variances, and the Mile High Flood District (MHFD).

Section 2 – Submittal Requirements & Permits. Discusses the City's general review process for development and requirements for each type of project and submittal. It also includes requirements for as-constructed record drawings and recorded agreements.

Section 3 – Rainfall. Provides rainfall depth, duration, intensity, and frequency data, the guidance on the development of rainfall distributions, and analytical methods used to develop the rainfall information needed to carry out the hydrological analysis needed to calculate runoff.

Section 4 – Runoff. Presents methods to calculate the peak rate of runoff, runoff volume, and the time distribution of flow, which is the basis for all planning and design of drainage facilities.

Section 5 – Open Channels. Includes discussion on the principles of open channel hydraulics, guidance on selecting and designing linings for bank stabilization, and open channel design criteria, including for swales and roadside ditches.

Section 6 – Roadway Conveyance. Presents design criteria utilizing streets as part of the drainage system. Criteria includes limits on the depth and spread of flow for different roadway classifications within the City.

Section 7 – Storm Drainage System. Presents design criteria for stormwater collection in a storm drain system including inlet capture and pipe capacity calculations.

Section 8 – Culverts & Bridges. Includes methods to analyze the conveyance of surface water in culverts and City design criteria for the design of culverts and bridges.

Section 9 – Hydraulic Structures. Includes design of various types of grade control structures for open channels and energy dissipators for points of concentrated inflow such as culvert and storm drain outlets.

Section 10 – Detention. Provides guidance and requirements for the analysis and design of stormwater storage facilities including required volume and appurtenant facilities such as forebays, micropools, and trickle channels.

Section 11 – Permanent Water Quality. Provides guidance and requirements for the selection, design, and construction of stormwater control measures. This section also includes information on which sites require the installation of stormwater control measures.

Section 12 – Construction Water Quality & Revegetation. Provides guidance and requirements for the development of the Stormwater Management Plan (SWMP) to be used during construction as required by the Colorado Discharge Permit System (CDPS) administered by the Colorado Department of Public Health and Environment (CDPHE). Information on required maintenance of the SWMP during construction is also provided, as are guidelines and requirements for revegetation.

Section 13 – Access, Easements, Operations, & Maintenance. Provides guidelines and requirements access, easements, and operations and maintenance of drainage and water quality facilities throughout the lifecycle of the project including during planning, design, construction, and post-construction.

A reference subsection is provided at the end of each section.

II. PURPOSE

The purpose of the SDDC is to establish technical criteria and provide guidance for engineers, planners, landscape architects, developers, contractors, and City reviewers for the analysis, design, construction, and maintenance of stormwater facilities to reduce flood risk and improve the quality of water discharged to the river system so that the health, safety, and welfare of people, property, and environment will be protected. Meeting the criteria in the SDDC will also result in compliance with the City's National Pollutant Discharge Elimination System (NPDES) Colorado Discharge Permit System (CDPS) Permit and the City's Municipal Separate Storm Sewer System (MS4) Permit.

No section of the SDDC is intended to be inclusive of all design situations or needs that may be encountered. Additional engineering judgment may be required for a facility to meet design intent, be constructable, and facilitate long-term operation and maintenance. The Public Works Director may determine if any proposed improvement is in the best interest of the City, regardless of whether it meets the criteria in the SDDC.

III. AUTHORITY

The City of Greeley Storm Drainage Design Criteria (SDDC or Criteria) shall apply to all land, construction activities, and facilities within the incorporated area of the City of Greeley, and to those areas outside the City of Greeley covered by intergovernmental agreements, including any public lands. The Stormwater Manager has the final authority to interpret the requirements of the SDDC. This authority has been delegated by the Public Works Director.

Additionally, planning and design of all stormwater drainage systems should adhere to Title 20, Chapter 4 of the City Code. Sec. 20-622 – Creation of Stormwater Management Program under Title 20 – Public Works and Utilities, Chapter 4 – Stormwater Management Program empowers the City to implement the provisions of this chapter. (Code 1994, § 14.15.030; Ord. No. 5, 1995, § 1(part), 1-17-1995; Ord. No. 91, 2001, § 1, 11-6-2001; Ord. No. 37, 2012, § 2, 10-2-2012; Ord. No. 31, 2019, exh. B, § 14.15.030, 7-2-2019). City Code changes regularly and the most recent version supersedes previous versions.

These Criteria, or individual sections of these Criteria, may be revised or amended as new technology is developed; new federal, regional, or state permits are required; or as otherwise needed. The most recent version of these Criteria shall be used.

IV. RELATED STANDARDS

Whenever a provision of these Criteria, and any other applicable provision in any law, ordinance, resolution, rule, or regulation of any kind, contains any restrictions covering any of the same subject matter, the most restrictive standard shall apply. Adherence to these Criteria does not remove the responsibility of the user to meet all other applicable regulations, or to investigate and obtain any other regulatory permits or approvals, from applicable local, regional, state, or federal agencies that may be required for a particular project. When there is a conflict among City, state-wide, or federal criteria, the more stringent criteria shall apply.

The design guidance and methodologies in these Criteria are generally consistent with the Urban Storm Drainage Criteria Manual (USDCM) published by the MHFD, but not exclusively so. The City design criteria herein supersede any criteria included in the USDCM. For some design criteria or methodologies, the SDDC refers the user to the USDCM. In rare cases, updates to the USDCM after the date of publication of these SDDC may result in conflicting design criteria or methodologies between versions of the USDCM. In these cases, contact the Stormwater Manager to confirm the criteria or methodology to be used. The USDCM also contains additional information on drainage law, recreational channels, bridges, and stream preservation and restoration that are not discussed herein but may be used as a reference if an applicable site requires this type of design guidance.

V. CONSTRUCTION SPECIFICATIONS

Construction specifications for stormwater facilities not covered by the City's Standard Stormwater Details shall be those in the most recent version of either the CDOT Standard Specifications for Road and Bridge Construction or the construction specifications published by the Mile High Flood District (MHFD). Standard details not in the City's Standard Stormwater Details shall be those in the CDOT Miscellaneous Standard Plans (M-Standards) or those published by the MHFD or as approved by the City of Greeley.

VI. COMMON ABBREVIATIONS & UNITS

This section presents common abbreviations and units of measurement.

A. Abbreviations

1. ASCE – American Society of Civil Engineers
2. ASTM – American Society for Testing and Materials
3. BFE – Base flood elevation
4. BMP – Best management practice; in the SDDC, a product or practice used during construction to prevent or reduce erosion, spills, and the discharge of pollutants to State waters, often removed at the completion of construction.
5. CDOT – Colorado Department of Transportation

6. CDPHE – Colorado Department of Public Health and Environment
7. CM – Control Measure; in the SDDC, a permanent facility or mechanism used to provide water quality treatment in perpetuity that is maintained over time.
8. CMP – Corrugated metal pipe
9. CRS – Colorado Revised Statute(s)
10. CUHP – Colorado Urban Hydrograph Procedure
11. CWCB – Colorado Water Conservation Board
12. DCIA – Directly connected impervious area
13. DFIRM – Digital Flood Insurance Rate Map
14. EGL – Energy grade line
15. EPA – U.S. Environmental Protection Agency
16. EURV – Excess Urban Runoff Volume
17. FAA – Federal Aviation Administration
18. FEMA – Federal Emergency Management Agency
19. FDP – Floodplain Development Permit
20. FHAD – Flood Hazard Area Delineation
21. FHWA – Federal Highway Administration
22. FIRM – Flood Insurance Rate Map
23. FIS – Flood Insurance Study
24. GSB – Grouted stepped or sloping boulder drop structure
25. HDPE – High Density Polyethylene
26. HEC – Hydrologic Engineering Center
27. HGL – Hydraulic grade line
28. HMS – Hydrologic Modeling System
29. HW – Headwater
30. H:V – Horizontal to vertical ratio of a slope

31. LID – Low impact development
32. MDCIA – Minimized directly connected impervious area
33. NASSCO – National Association of Sewer Service Companies
34. NAVD – North American Vertical Datum
35. NGVD – National Geodetic Vertical Datum
36. NFIP – National Flood Insurance Program
37. NOAA – National Oceanic and Atmospheric Administration
38. NPDES – National Pollutant Discharge Elimination System
39. NRCS – Natural Resources Conservation Service
40. PP – Polypropylene Pipe
41. RCP – Reinforced concrete pipe
42. SCM – Stormwater Control Measure
43. SCS – Soil Conservation Service
44. SDDC – City of Greeley Storm Drainage Design Criteria
45. SEO – Colorado State Engineer's Office
46. SFHA – Special Flood Hazard Area
47. SUE – Subsurface Utility Engineering
48. SWMM – EPA Stormwater Management Model
49. USACE – U.S. Army Corps of Engineers
50. USDCM – Urban Storm Drainage Criteria Manual (published by the MHFD)
51. USGS – U.S. Geological Survey
52. WOTUS – Waters of the United States
53. WQCV – Water quality capture volume

B. Common Units of Measurement

1. ‘ – foot or feet
2. “ – inch or inches

3. AF – acre foot
4. cfs – cubic feet per second
5. cfs/ft – cubic feet per second per foot
6. CY – cubic yard
7. fps – feet per second
8. ft – feet or foot
9. ft^2 – square feet
10. ft/ft – foot per foot
11. ft/sec – feet per second
12. ft/sec^2 – feet per second squared
13. hr – hour
14. in – inch
15. in/hr – inches per hour
16. lbs – pounds
17. lbs/cy – pounds per cubic yard
18. lbs/ft^2 – pounds per square foot
19. lbs/ft^3 – pounds per cubic foot
20. lbs PLS/acre – pounds pure live seed per acre
21. min – minute
22. psi – pounds per square inch
23. psf – pounds per square foot

VII. COMMON DEFINITIONS & TERMS

This section presents abbreviations and definitions for standard terms.

A. ACRE FOOT – a measurement of water volume. An acre foot equals the amount of water necessary to cover an acre at a depth of one foot (43,560 cubic feet).

B. 100-YEAR STORM & 5-YEAR STORM – these terms refer to the statistical recurrence interval of different types of storms. A recurrence interval is a statistically determined average

length of time within which a given rainfall intensity and duration will be equaled or exceeded only once. For example, the 100-year storm refers to the intensity and duration of rainfall which, on average, will be equaled or exceeded once during a 100-year period. The larger the recurrence interval, the higher the intensity. The 100-year storm will have a higher intensity and total volume than the 5-year storm.

C. 100-YEAR FLOW/FLOOD – a peak discharge that can be expected to be equaled or exceeded once every hundred years. This event has a 1% chance of occurring during any given year. Discharge rates for the South Platte River and the Cache la Poudre and their major tributaries are provided in the FEMA Flood Insurance Study.

D. BASE FLOOD ELEVATION – the expected water surface during the 100-year flood.

E. BASIN – an area of land, so defined by a physical boundary that when rain falls upon this area all the resulting stormwater runoff will drain by gravity toward a common watercourse (natural stream, reach, river, or manmade channel, ditch, gutter, etc.) and ultimately exits the area at the specific point (known as the outfall). Major basins shall be as defined by the City's Comprehensive Drainage Master Plan.

F. CITY – the City of Greeley or an individual employed by the City of Greeley who is authorized to make certain decisions on behalf of the City.

G. CHIEF ENGINEER – a term used in situations where a decision or action may be required by the Chief Engineer, or his authorized representative employed by the City of Greeley. The Chief Engineer or his authorized representative shall have the authority on behalf of the City to determine that design and construction meet or exceed the minimum requirements set forth in these Criteria.

H. CONTOUR INTERVAL – a contour is a line drawn on a map through points of equal elevation. A contour interval is the difference between contour lines.

I. CONTROL MEASURE – a term used in the SDDC uniquely for a permanent facility or mechanism used to provide water quality treatment in perpetuity that is maintained over time. Note that regulatory language in other documents may use the term control measure or temporary control measure to refer to products and practices used during construction.

J. CROSS-STREET FLOW – flow across the traffic lanes of a street from external sources, as distinguished from sheet flow of water falling on pavement surface.

K. CULVERT – a covered channel or pipe that takes a watercourse under a road, through the downstream dike of a detention facility or simply below ground.

L. DETENTION FACILITY – a basin or structure designed for the storage of stormwater runoff for controlled release during or immediately following a storm. A typical facility consists of a detention pond with an embankment on the downstream side, and a pipe or concrete box outlet. The size of the pond is based on a specific design storm and the amount of water that can be discharged through the outlet. Design features may be incorporated into detention facilities to allow them to function as sediment ponds.

M. DEVELOPER – the owner, corporation, association, partnership, or individual who has entered into an agreement with the City and has entered into an agreement with the Contractor to perform the construction work.

N. DRAINAGEWAY – a route or course along which water moves or may move to drain an area. A "natural" drainageway refers to the route or course in an area prior to the construction of any urban improvements.

O. DRAINAGE EASEMENT – a right granted by a property owner allowing the use of private land for management, conveyance, or storage of stormwater that is surface water. A stormwater easement is similar but used for stormwater conveyed or stored underground in a pipe or other enclosed facility.

P. DRAINAGE FACILITY – structures or landforms that store, treat, or convey stormwater including ponds and their associated elements (embankments, inlets, forebays, trickle channels, micropools, outlet structures, spillways, access, etc.), open channels and ditches, rundowns, swales, storm drains, cross pans, inlets, culverts and wingwalls, check and drop structures, stilling basins, and siphons, among others. Also known as a stormwater facility.

Q. FLOODPLAIN – any land area susceptible to being inundated by floodwaters from any source during a storm with a given return period. For example, the 100-year floodplain is the area that is expected to be inundated during a storm that has a 1% chance of being equaled or exceeded in any given year.

R. FLOODPLAIN FRINGE – the lands outside the floodway but at or below the base flood elevation.

S. FLOODWAY – the channel of a river or other watercourse and the adjacent land areas that must be reserved to convey the base flood without cumulatively increasing the water surface elevation more than a designated height.

T. FREEBOARD – the elevation difference between the normal maximum level of water surface and the top of the confining structure, which is provided so debris may more readily pass through the structure without creating blockage and waves and other movements of the water will not overtop such confining structures.

U. GEOTECHNICAL ENGINEER – the partnership, corporation, or individual who is registered as a Professional Engineer or Professional Geologist, according to Colorado Statutes, and who is hired by the Developer/Owner to prepare the Geotechnical Report, Soils Report, and/or Final Pavement Design Report for the project.

V. GRADE – the inclination or slope of a channel, canal, conduit, etc., or other natural ground surface, usually expressed in terms of the percentage or number of units of vertical rise (or fall) per unit of horizontal distance.

W. HISTORIC RUNOFF – the rate of stormwater runoff that occurred before any development, including pavement, buildings, drives, or parking areas whether concrete, asphalt, or aggregate. This is also known as predevelopment runoff. The imperviousness used to calculate historic runoff shall be 2%.

X. INLET – 1) an opening into a storm drain system for the entrance of surface storm runoff; 2) a structure at the upstream end of a conduit; or 3) the upstream connection between the surface of the ground and a storm drain for the admission of surface or storm water.

Y. MASTER DRAINAGE PLAN – a local or regional plan for the major drainage system to manage the 100-year runoff that, when implemented, will reduce loss of life and major damage to the community and its infrastructure during large flood events. Master drainage plans covering the entire City should be developed and maintained in an up-to-date fashion.

Z. MHFD – Mile High Flood District, formerly the Urban Drainage and Flood Control District (UDFCD).

AA. MINOR STORM & MAJOR STORM – these terms refer to the recurrence intervals of storms used to design stormwater infrastructure. The minor storm (also called the initial storm) is the 5-year storm. The major storm is the 100-year storm, and the uncontrolled runoff from this storm could cause major property damage or even loss of life.

BB. OPEN CHANNEL – an open channel or open drainageway is a watercourse which carries stormwater runoff within the drainage basin to the outfall of the basin. It has defined bed and banks that confine the runoff, but it has no top and is not enclosed like a culvert or storm drain.

CC. OUTLOT – a tract of land platted in a subdivision or development for a specific purpose which shall be shown on the plat. Specific purposes may include, but are not limited to, stormwater facilities, parks, open space, or land areas reserved for other public facilities.

DD. OWNER – the developer, corporation, association, partnership, or individual who has entered into an agreement with the City and has entered into an agreement with the Contractor to perform the work.

EE. PLANS – detailed working drawings including plan, profile, and detail sheets of proposed construction or grading that are approved or accepted by the City.

FF. PROFESSIONAL ENGINEER – an individual who has been licensed and has active status as determined by the Colorado Department of Regulatory Agencies, State Board of Registration for Professional Engineers.

GG. REAL ESTATE MANAGEMENT – the City department responsible for the management of the City's real estate assets and interests. This includes the acquisition, inventory, assessment, and disposition of City real estate and oil and gas interests in support of the City's goals and work plans. This department is also responsible for property acquisitions and conveyance, eminent domain, property negotiations, CDOT/ Federal Compliance, and easement acquisitions and agreements for City-owned property as well as for property not owned by the City.

HH. SPECIAL FLOOD HAZARD AREA – an area having special flood, mudflow or flood-related erosion hazards as shown on a FEMA FIRM. The SFHA is the area where the NFIP's floodplain management regulations must be enforced and the area where the mandatory

purchase of flood insurance applies. The SFHA is typically subject to 1% chance or greater of flooding in any given year.

II. STABLE CHANNEL – a streambed, drainageway, or ditch in which sediment transport conditions are in balance, neither leaving significant deposits of sediments nor experiencing significant erosion.

JJ. STORMWATER CONTROL MEASURE – a permanent facility or practice that treats the water quality of stormwater runoff from a site in perpetuity once construction is complete.

KK. STORMWATER EASEMENT – a right granted by a property owner allowing the use of private land for management, conveyance, or storage of stormwater that is underground in a pipe or other enclosed facility. A drainage easement is similar but used for stormwater on the surface of the land.

LL. STORMWATER FACILITY – structures or landforms that store, treat, or convey stormwater including ponds and their associated elements (embankments, inlets, forebays, trickle channels, micropools, outlet structures, spillways, access, etc.), open channels and ditches, rundowns, swales, storm drains, cross pans, inlets, culverts and wingwalls, check and drop structures, stilling basins, and siphons, among others. Also known as a storm drainage facility or drainage facility.

MM. STORMWATER MANAGER – the City employee that manages the Stormwater Division within the Department of Public Works.

NN. STORMWATER RUNOFF – the water from precipitation running off from the surface of a basin during and immediately following a period of rain.

OO. STORM DRAIN SYSTEM – a system of inlets, manholes, and conduits that conveys runoff to drainageways and natural channels.

PP. STREET FLOW – the total flow of runoff in a street, usually the sum of the gutter flows on each side of the street.

QQ. SUBSTANTIAL COMPLETION –when the City's representative certifies that construction is sufficiently completed that the Owner can occupy or utilize the work or designated portion thereof for the use for which it is intended.

RR. SUBSURFACE UTILITY ENGINEERING – the investigation into subsurface utilities mandated by Colorado Senate Bill 18-167 that amended Title 9, Article1.5 of the Colorado Revised Statutes to improve safety by modifying requirements associated with locating underground utilities prior to construction.

SS. SURCHARGED – when the hydraulic grade line within a storm drain system rises above the elevation of an inlet or manhole.

TT. USER –any person or company that uses the SDDC.

UU. WATERS OF THE UNITED STATES – a threshold term in the Clean Water Act that establishes the scope of federal jurisdiction for programs including Water Quality Standards, TMDLs, and sections 311, 402, and 404.

VV. WETLAND – an area that is inundated or saturated by surface or ground water 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.

SECTION 1
GENERAL PROVISIONS

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SECTION 1
GENERAL PROVISIONS

1.01 PRINCIPLES FOR STORM DRAINAGE PLANNING & DESIGN

Drainage is a subsystem of all development. The planning and design of stormwater facilities meeting these Criteria shall be included for all residential, commercial, or industrial development, or any other proposed construction, that is submitted to the City for approval. The City will evaluate the design of the development, including site grading and stormwater infrastructure, based on the planning guidance and requirements in this section.

A. Planning and design of stormwater systems should not be based on the premise that problems can be transferred from one location to another. Colorado drainage law recognizes the inequity of transferring the burden of managing stormwater from one property to another. No property may initiate such a transfer through any grading or construction activities without mitigating the transfer as discussed in Part C below. Liability questions also arise when runoff is transferred from one major basin to another; these are called trans-basin diversions and shall be avoided. Major basins are defined in the City's Comprehensive Drainage Master Plan. Developments should locate new drainage outfalls at or near their historic location.

B. Developments should also maintain historic peak discharge rates and historic stormwater quality of stormwater runoff. Implementing low impact development principles, such as green infrastructure and minimizing directly connected impervious areas, along with the use of permanent stormwater control measures and detention facilities will help meet these standards. Where possible, stormwater facilities shall be designed to provide recreational, environmental, and ecological benefit to the community in addition to hydraulic conveyance. The USDCM is an excellent resource for guidance on these principles.

C. If development cannot be designed to avoid all impacts to properties and water rights, the Developer is responsible for mitigating these impacts in advance of construction. These responsibilities may include but are not limited to obtaining easements from downstream properties to accept any changes in frequency or quantity of stormwater runoff and augmenting losses of water rights. The Stormwater Manager has the authority to determine if a proposed development will result in impacts and if any impacts are adequately mitigated.

D. Areas upstream of a development site must be evaluated to determine peak runoff flow rates and volumes anticipated to discharge into the development site. Developments must accommodate these peak runoff flow rates and volumes generated outside the development. Runoff generated offsite must be safely conveyed through or around the development without creating adverse impacts to any properties or to water quality.

E. Detention and stormwater quality requirements must be accommodated early in the development site design process. Section 11 provides detailed planning guidance for detention facilities and stormwater control measures.

1.02 SUBDIVISION GRADING REQUIREMENTS

A. **Lot Designations.** Each lot within a subdivision must be designated as an "A" lot or a "B" lot, depending on how it is graded to drain. There is a mandatory minimum slope of 2% for

all subdivision lot grading, regardless of the lot type or location within the lot. Lot types are defined as follows:

1. **"**A" lots are graded to drain completely and continuously from back to front. They provide continuous positive drainage from the back property line to the frontage back of walk, top of ditch, or top of curb, with a typical grade difference of 12" to 18" from back to front. "A" lots may receive runoff from a portion of an adjacent lot, but they do not discharge runoff to other lots. If they are designed to receive runoff from other lot, they must be graded to accommodate this runoff.
2. "B" lots may be graded so that some portion of the lot drains to the back of the lot. This portion may not exceed half the lot, and runoff from the residential structure and associated patios and walks must be directed to the front. At least half the lot must be graded to provide continuous positive drainage from the back property line to the frontage back of walk, top of ditch or top of curb. "B" lots may discharge some runoff to an adjacent "A" lot.

B. **Lot Layout Priorities.** Subdivisions shall be laid out to minimize excessive drainage being conveyed along rear lot lines by prioritizing subdivision layout as follows:

1. The ideal scenario is to design "A" lots to back to other "A" lots.
2. The next best scenario is to design "A" lots to back to "B" lots.
3. The least desirable scenario is to design "B" lots to back to other "B" lots; this scenario may not be allowed. In the event a "B" lot is allowed to back to another "B" lot, a 2' wide by 3" deep concrete pan may be required along the rear property line.

C. **Drainage Swales.** Developers, builders, and property owners are responsible for providing site grading to manage onsite runoff. Swales may be required to convey onsite surface runoff around the residential structure or to the lot frontage. A residential swale is typically 6" to 12" deep and at least 6' wide. Drainage swales may not be blocked with fences. A space must be left under the fence for water to pass.

Drainage may also be conveyed along the base of a retaining wall. Drainage may not be conveyed across the back of more than one lot before being conveyed to the frontage. An easement may be required for some drainage swales. See Section 13 for information on easements.

D. **Offsite Drainage.** Drainage swales within residential subdivision lots shall not be designated to convey runoff that originates outside the development. Offsite runoff must be conveyed in a more formal drainage facility. An easement, an outlot, or a City right-of-way must be used to convey these flows. See Section 13 for information on easements.

E. **Window Wells.** The tops of all window wells shall be 6" above surrounding grade or at the top of the foundation wall, whichever is higher, and site grading shall be sloped to drain away from all window wells. Each window well shall have a sump of 8" to 12" below the bottom of the window to store water. Window wells shall be sealed along all edges with outdoor silicon caulking.

1.03 STORMWATER MASTER PLANNING

All development plans must include master and localized drainage planning to accommodate the increased runoff that comes with urbanization. Channels, detention ponds, storm drains, and other stormwater infrastructure provide both conveyance and storage. If adequate space is not provided during planning and development to accommodate the stormwater infrastructure required to handle the increased runoff, stormwater will encroach on adjacent properties during large storms. This may cause damage to residences, businesses, and other infrastructure and impede or disturb the flow of traffic.

The City has developed and adopted several regional basin-wide master plans that define major drainageway infrastructure improvements that will be required, establish requirements for new development, and provide criteria and requirements for unit runoff rates and levels of flood protection. These can be found via an internet search for "City of Greeley Drainage Basin Master Plans." If the SDDC conflicts with a master plan, the Stormwater Manager will determine which criteria will govern. The City also requires that all new development and redevelopment include the design and construction of the master-planned improvements within the development. In cases where a master plan is outdated, as determined by the Stormwater Manager, the development may be required to construct improvements that vary from those in the master plan based on updated hydrology or levels of urbanization that were not anticipated by the master plan.

1.04 MILE HIGH FLOOD DISTRICT

The design criteria and methodologies in the SDDC are generally consistent with the Urban Storm Drainage Criteria Manual (USDCM) published by the Mile High Flood District (MHFD), but not exclusively so. The Preface of these Criteria includes additional information on how related standards interact with the SDDC.

1.05 IRRIGATION FACILITIES

Irrigation ditches and reservoirs within the City have historically intercepted storm runoff from rural and agricultural basins. As these basins urbanize, storm runoff increases in rate, total volume, and frequency, and the water quality of the runoff is negatively impacted.

Irrigation facilities shall not be considered part of any drainage system, and irrigation water, including irrigation tailwater, shall be kept separate from stormwater. Irrigation ditches are designed with flat slopes and limited carrying capacity. Additionally, some ditches are abandoned after urbanization. However, irrigation facilities must be preserved to maintain service to any users. An easement must be provided for the ditch, including access for operations and maintenance as specified by the associated ditch company. Any modifications to irrigation facilities must be approved by the associated ditch company.

1.06 FLOODPLAIN DEVELOPMENT

The National Flood Insurance Program (NFIP) is managed by the Federal Emergency Management Agency (FEMA). The City of Greeley joined the National Flood Insurance Program (NFIP) in 1979 and adopted the FEMA Flood Insurance Study (FIS) for Weld County. As a member of the NFIP, the City is charged by FEMA with adopting all new flood studies and administering all applicable federal, state, and municipal regulations regarding FEMA floodplains and floodways. The City has no mapped floodplains that are not FEMA-regulated. Mapping and

information on FEMA-regulated floodplains is available at the FEMA Map Service Center website at (https://msc.fema.gov) or via an internet search for FEMA map service center.

There are eight streams within the City of Greeley jurisdiction that must meet FEMA regulations: the Cache la Poudre River, the South Platte River, Sheep Draw, Coal Bank Creek, John Law Ditch, Eaton Draw, Sand Creek, and Ashcroft Draw.

All construction within the regulatory floodplain requires a Floodplain Development Permit in accordance with Title 24, Chapter 10, Section 24-1001 of the Municipal Code. This includes remodels and expansion of existing structures; storage of fill, machinery, or temporary structures for longer than 180 days; dry utilities including but not limited to electric, gas, telephone, cable, fiber optic; and wet utilities including but not limited to storm, sanitary, potable water, and non-potable water lines. If a project is proposed in one of the City's floodplains, the City Floodplain Administrator should be contacted as early in the development process as possible to verify submittal requirements and restrictions.

The City permits construction of insurable structures, including residences, within the regulatory floodplain fringe without a certification of a "no rise" condition or hydraulic model. To be granted a Floodplain Development Permit, the project must meet all NFIP requirements, and all finished floor elevations must be at least one foot above the Base Flood Elevation. An elevation certificate must also be completed, and the project must meet all City zoning requirements. Applying for and receiving a FEMA LOMR-F may reduce flood insurance rates for insurable structures in the floodplain fringe.

For any construction within the regulatory floodway, a certification of a "no rise" condition or a Conditional Letter of Map Revision (CLOMR) from FEMA is required. Any facility that stores or handles solid waste will not be permitted within a regulatory floodplain. The City's website (www.greeleygov.com/floodplain) includes additional information.

1.07 VARIANCES

All applications for the design of any stormwater facility varying from these Criteria, except those that do not require any type of permit, shall obtain written approval of the variance from the Stormwater Manager on the City's Variance Request Form prior to final approval of the plans. Approval of a variance request is not guaranteed and maximizing development density is not an acceptable rationale for approval. At a minimum, the applicant must show that no hazards will be created on the subject property, neighboring properties, or right-of-way. The following additional items, among others, will be considered when evaluating variance requests:

1. Site-specific constraints
2. Effect on safety
3. Right-of-way constraints
4. Public benefit
5. Availability of other alternatives
6. Maintenance costs
7. Need for mitigation measures

The City's Variance Request Form is available on the City's Construction Standards webpage. Variance requests shall be submitted as early in the project as practicable to minimize delays in the development review process and shall include plans, text, and supporting documentation as necessary to support the information provided in the form.

The variance request must be prepared by or under the direct supervision of a Colorado-licensed professional engineer and be stamped and signed certifying that the variance will not result in any hazard to the public or increase the likelihood of damage to any public or private properties. A variance request review fee must be paid at the time the variance request is submitted.

Upon receipt of a written request for a variance from a particular provision of these Criteria, the Stormwater Manager will issue a determination on whether the variance should be granted or denied given the specific circumstances for which it was requested. The applicant will receive a copy of the determination. Determinations made in interpreting and enforcing these Criteria involve the considered application of professional engineering judgment and skill in the context of each situation.

Variance requests may be submitted at any stage of a project for review and approval. An approved variance must be re-reviewed and re-approved if substantive changes to design alter the conditions for which the original variance was approved. All approved variances shall be discussed in the Drainage Report, and the approved Variance Request Form(s) shall be included as an appendix to the Drainage Report.

SECTION 2
SUBMITTAL REQUIREMENTS & PERMITS

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Checklists

SECTION 2
SUBMITTAL REQUIREMENTS & PERMITS

2.01 GENERAL

Submittal requirements in this section are the minimum for any new or improved infrastructure or land grading that collects, conveys, stores, protects, or treats stormwater and are not meant to be all-inclusive. Other requirements may be needed for a complete design. The Design Engineer shall consider how each facility will operate, be constructed, and be maintained. All reports, plans, and maps shall be prepared or supervised, signed, and stamped by a Professional Engineer licensed in the State of Colorado with adequate experience in hydrology and hydraulics to complete the design. This section also includes an abbreviated discussion of permits that are frequently required and a discussion of when subsurface utility engineering (SUE) must be completed.

2.02 APPLICABILITY

Projects that include proposed public or private storm sewers; storm inlets; roads of any classification; curb and gutter; roadside ditches; natural, improved, or open channels; culverts; bridges; stormwater quality treatment facilities; stormwater detention facilities; or site disturbances of 1 acre or more must meet the submittal requirements in this section.

2.03 REVIEW PROCESS

The City's Stormwater Division reviews documents submitted to Engineering Development Review for projects that include stormwater facilities or land grading. The review process can be found in the Greeley Development Code Application Manual, available on the City's website, or by contacting the Community Development Department. The naming convention for the design phases in this section, Conceptual, Preliminary, and Final, represent a typical project design progression, but they are not necessarily those used by Engineering Development Review or referenced in the Development Code Application Manual. This section discusses the typical timing of drainage submittals as they relate to the overall review process.

Delay in approval may be avoided when the contents of each submittal meet those in the checklists provided at the end of this section. Delay in approval may also be avoided by contacting Engineering Development Review to schedule a pre-application meeting prior to the first submittal to discuss the project scope, conceptual design, site constraints, review process, conformance with local master drainage plans, and specific Stormwater Division requirements. If a Design Engineer, Developer, or Owner has questions or concerns about the stormwater or permanent water quality facilities that will be required by the City, it can be requested that a representative from the Stormwater Division attend the pre-application meeting with Engineering Development Review. Note that this is not a necessary step but may be appropriate depending on the complexity of the site drainage and water quality requirements.

Depending on the location of the development, the Stormwater Division may request that certain stormwater facilities be upsized to accommodate increased runoff from future, upstream development. The Stormwater Division will reimburse the developer for the materials cost increase associated with the requested upsizing in these cases through a development agreement. The City will not reimburse the developer for the cost of installation. The Stormwater Division will discuss contributed capital requirements with each development.

2.04 FORMATTING

Formatting requirements vary by the document type.

A. Reports. Digital submittals of reports shall be provided in searchable PDF format. The body of the report shall print to scale on 8½" x 11" paper. Required drawings, exhibits, plats, tables, figures, maps, and reference materials shall print to scale on 8½" x 11" or 11" x 17" paper and be included in the report, either within the text or as appendices, as appropriate. Font size must be no smaller than 8-point; a minimum 10-point font is preferred.

   A Drainage Report is a stand-alone document. When references are made or assumptions are based on previously submitted studies or reports, the report must include the appropriate excerpts, pages, tables, and maps containing the referenced information. All reports, including charts, tables, nomographs, calculations, or any other material must be legible, include reference information if applicable, and be clearly and cleanly produced.

B. Maps, Plans, and Construction Drawings. Basin Maps, Grading Plans, and Construction Drawings shall be submitted in PDF format at a full size of 22" x 34" so that they may be printed to half-scale on 11" x 17" paper. Information presented in the appendices shall contain sufficient detail to allow replication of the results presented in the report. A CAD text height of at least 0.08 must be used; a minimum of 0.10 is preferred.

C. Hydrologic and Hydraulic Models. Hydrologic and hydraulic model files shall be included with the digital submittal in a separate folder for each type of model. All report pages, including appendices, shall be numbered so each page is easily referenced. Incomplete submittals may require resubmittal, delaying the review process.

2.05 DRAINAGE REPORTS

Projects that impact existing drainage conditions must submit a Drainage Report which includes a Basin Map. All projects that alter sites for which there is an approved Drainage Report or Memo must submit a Drainage Report Addendum, discussed later in this section. Projects at sites that do not have an approved Drainage Report and that result in no impact to existing drainage conditions may request a variance to submit a Drainage Memo in lieu of a Drainage Report. Approval of this variance is not guaranteed. If use of a Drainage Memo is approved, the Stormwater Division reserves the right to require a Drainage Report after review of the Drainage Memo. A Drainage Memo does not require a separate Basin Map but must provide discussion and calculations that show that no impact to existing drainage conditions will result from the project. A Drainage Memo must include the basin map from the most recent applicable master plan, with the project site delineated, if no site specific Basin Map is provided. Additional contents may be required. Drainage Reports and Memos are valid for construction for three years after approval.

2.06 CERTIFICATION STATEMENT

Preliminary and Final Drainage Reports shall include the following certification statement stamped and signed by a professional engineer registered in Colorado, with the appropriate level of review selected (Preliminary or Final).

"I hereby attest that this report for the [Preliminary, Final] drainage design of [Name of Development or Project] was prepared by me, or under my direct supervision, in accordance with the provisions of the City of Greeley Storm Drainage Design Criteria for the responsible parties thereof. I understand that the City of Greeley does not and shall not assume liability for drainage facilities designed by others.

_____

Registered Professional Engineer (Affix Seal with Signature & Date)

State of Colorado No._____

2.07 CONCEPTUAL SUBMITTAL

A Conceptual Drainage Report, including a Basin Map and Grading Plan, is required for commercial and multifamily residential properties that will be subdivided or phased to ensure that drainage, detention, and water quality are handled safely and efficiently throughout the entire original parcel. Conceptual submittals typically include an evaluation of the characteristics of the site and help determine the feasibility of the proposed development. They also provide a basis for discussion between the Design Engineer, Owner, or Developer and the Stormwater Division during the pre-application meeting with Engineering Development Review. A Conceptual submittal will help establish likely stormwater or permanent water quality facilities required by the City for projects that may have complex drainage or water quality needs.

The Drainage Report, Grading Plan, and Basin Map Checklists included at the end of this section list the required contents of the Conceptual Drainage Report, Grading Plan, and Basin Map that shall be provided in the pre-application meeting submittals to Engineering Development Review if a Conceptual submittal review is requested or required.

2.08 PRELIMINARY SUBMITTAL

The Preliminary submittal includes the Preliminary Drainage Report and Basin Map, Grading Plan, Construction Drawings, and Stormwater Management Plan (SWMP). All documents shall be submitted to Engineering Development Review in searchable PDF format. The Preliminary submittal must address all onsite and offsite implications of development as they relate to drainage. Any onsite drainage problems that existed prior to development must also be addressed. Checklists for the Drainage Report, Basin Map, Grading Plan, and Construction Drawings are at the end of this section and list the minimum required contents of the documents required for each submittal phase. Incomplete Preliminary submittals will be returned to minimize comments from the City. Revised Preliminary submittals may be resubmitted once all items in the checklists are included in the submittal.

A. Drainage Report. The Preliminary Drainage Report refines the concepts and design in the Conceptual Drainage Report and addresses any comments provided during the pre-application meeting, if applicable.

B. Basin Map. The Preliminary Basin Map refines the concepts and design in the Conceptual Basin Map and addresses any comments provided during the pre-application meeting, if applicable. Basin boundaries must be clearly designated, and basins must be labeled. A table of peak minor and major storm flow rates must be provided for each basin and at design points where basins combine.

C. Grading Plan. The Preliminary Grading Plan refines the concepts and design in the Conceptual Grading Plan and addresses any comments provided during the pre-application meeting, if applicable.

D. Construction Drawings. The Preliminary submittal must include a full set of Preliminary Construction Drawings.

E. SWMP. The Preliminary submittal must include a Preliminary Stormwater Management Plan (SWMP). The SWMP has two parts, an Erosion and Sediment Control Plan (ESCP) and a SWMP Report. The requirements for these are in Section 12. The SWMP Report will meet the formatting requirements in this section and the ESCP will meet the general formatting requirements in the Construction Drawings checklist.

2.09 FINAL SUBMITTAL

The Final submittal includes the Final Drainage Report and Basin Map, Grading Plan, Construction Drawings, and Stormwater Management Plan (SWMP) as well as a draft final Operation and Maintenance (O&M) Plan and Operation and Maintenance Covenant (OMC) if the site has any permanent water quality or detention facilities. All documents shall be submitted to Engineering Development Review in searchable PDF format. Any changes to the drainage concept presented in the Preliminary submittal must be supported with the same level of information required in the Preliminary submittal. Checklists for the Drainage Report, Basin Map, Grading Plan, and Construction Drawings are at the end of this section and list the minimum required contents of the documents required for each submittal phase.

All Final submittals shall include electronic versions of the files used to create the final PDF submittal. These may include CAD files and hydrologic and hydraulic modeling files such as CUHP, SWMM, and spreadsheets used for inlet or detention pond design.

A. Drainage Report. The Final Drainage Report refines the concepts and design in the Preliminary Drainage Report. The Final Drainage Report must address the City's comments on previous submittals. Concept-level changes shall be presented in a separate section of the Final Drainage Report. The Stormwater Manager may request a revised Preliminary Drainage Report if changes are significant. All Final Drainage Reports shall include electronic versions of any hydrologic or hydraulic modeling or design files included in the report.

B. Basin Map. The Final Basin Map refines the concepts and design in the Preliminary Basin Map and addresses any comments provided on the Preliminary Basin Map. A CAD file of the Final Basin Map along with any associated external references shall be provided.

C. Grading Plan. The Final Grading Plan refines the concepts and design in the Preliminary Grading Plan and addresses any comments provided on the Preliminary Grading Plan. A CAD file of the Final Grading Plan along with any associated external references shall be provided.

D. Construction Drawings. The Final Construction Drawings must address any comments provided on the Preliminary Construction Drawings. CAD files of the Final Construction Drawings along with any associated external references shall be provided.

E. SWMP. The Final Stormwater Management Plan (SWMP) must address any comments provided on the Preliminary SWMP. The SWMP has two parts, an Erosion and Sediment Control Plan (ESCP) and a SWMP Report. The requirements for these are in Section 12. The SWMP Report will meet the formatting requirements in this section and the ESCP will meet the general formatting requirements in the Construction Drawings checklist. CAD files of the Final ESCP along with any associated external references shall be provided.

F. O&M Plan. The Final submittal must include a draft final Operations & Maintenance (O&M) Plan if the project includes any permanent water quality or detention facilities. The requirements for these are in Section 13. The O&M Plan will need to be updated with as-constructed information once the project is constructed. CAD files of the Final O&M Plan along with any associated external references shall be provided.

2.10 DRAINAGE REPORT ADDENDUM

A Drainage Report Addendum is required when site development proposes modifications or deviations from what was presented in the approved Drainage Report and Basin Map, a change to site drainage is proposed, or additional inflow to a water quality or detention facility is proposed. These conditions can include increases to offsite drainage entering the site. The Drainage Report Addendum shall include a cover letter indicating which sections of the approved Drainage Report or Memo have proposed revisions and the rationale for each. The Drainage Report Addendum shall also include all revised supporting text, calculations, and figures to support the proposed changes to the approved Drainage Report. Additional information may be requested.

2.11 VARIANCES

A Variance Request Form shall be submitted for the design of any stormwater facility that varies from these Criteria prior to final approval of the plans. Variance requests shall be submitted as early in the project as practicable to minimize delays in the development review process and shall include plans, text, and supporting documentation as necessary to support the information provided in the form. More details on the variance approval process are in Section 1.

2.12 PERMITS

There are multiple permits that may be required for a project that are not discussed in this section. The Design Engineer or Developer is responsible for determining which permits are required for each project. Two of the most common City permits are the Right-of-Way/Easement Construction Permit (ROW Permit) for construction in the City right-of-way or easement and a Land Grading Permit, both available via the City's eTRAKiT portal. A common State permit is the General Permit for Stormwater Discharges Associated with Construction Activities (Permit COR400000), issued by the Colorado Discharge Permit System (CDPS) program. This permit is often referred to as the Construction Stormwater Permit. A common federal permit is the Clean Water Act Section 404 Permit, issued by the U.S. Army Corps of Engineers. This permit is often referred to as the 404 Permit.

The Stormwater Division may be asked to review City permit applications for projects that include stormwater or water quality facilities. The Stormwater Division will review and approve applications for Floodplain Development Permits and Land Grading Permits. The State reviews Construction Stormwater Permit applications. The U.S. Army Corps of Engineers reviews 404 Permit applications.

A. Land Grading Permit. A Land Grading Permit is required for any disturbance of 1 acre or more. The Land Grading Permit application is available on the City's eTRAKiT portal.

B. Construction Stormwater Permit. The COR400000 application is available on the internet via a search for COR400000 Stormwater Discharge.

C. Floodplain Development Permit. A Floodplain Development Permit (FDP) is required if any part of the disturbed site is within 100' of a FEMA-designated floodplain. An encroachment analysis is required when any construction is proposed in a FEMA floodway. FEMA floodplain and floodway limits can be found at the FEMA Flood Map Service Center. The Floodplain Development Permit application is available via the City's eTRAKiT portal or by contacting the Stormwater Division.

D. 404 Permit. A 404 Permit is required before any dredged or fill material can be discharged into waters of the United States, including wetlands, for development, water resource projects, infrastructure development, and mining projects. If surface water is present on a development site, a wetland delineation is required to establish the existing conditions on the site as a condition of the permit.

E. Public Space Permit. A Public Space Permit is required when any proposed utility will cross City-owned infrastructure including but not limited to water, sewer, and stormwater utilities.

F. Building Permit. A building permit available via the City's eTRAKiT portal is required per Municipal Code R105.2 for retaining walls that are over 4' high and fences over 7' high.

2.13 VERIFICATION SURVEY DRAWING REQUIREMENTS

A. Prior to paving, concrete flatwork, or trickle channel construction, the Design Engineer shall provide the City with a survey of the installed storm drainage, detention, and water quality facilities. The purpose of this survey is to verify that the improvements were installed or graded per design and within allowable construction tolerances. Once the City has accepted the verification survey, the City shall give the Contractor written notice to proceed with additional construction. Verification Survey Drawings are not As-Constructed Record Drawings. See section 2.14 for As-Constructed Record Drawing requirements.

B. The Verification Survey Drawings shall be prepared for easy modification and transition to final As-Constructed Record Drawings.

C. The Verification Survey Drawings shall be modified from the original construction plan and profile sheets showing the design information as well as the surveyed information. The original design information shall be lined-through when the as-constructed condition differs from the approved construction plans. The surveyed information shall be in the same area as the design information and shall be either clouded or made with a heavier line weight than the design information for clear differentiation.

D. Verifications Survey Drawings shall be prepared by a Professional Engineer. Surveyed elevations for the Verification Survey shall be obtained by a Colorado Registered Land Surveyor. The surveyor shall obtain horizontal locations, elevations, and information for the following to the same precision and at and using the same datum as the design drawings.

1. Storm inlets, pipes, manholes, and junction boxes – Horizontal locations, elevations, inverts, diameters, and dimensions of the manholes, inlets, junction boxes, and pipes including rims, sumps, and inverts relative to the original construction drawing callout.

2. Channels, swales, ditches – Channel plan location and invert elevations at the same locations called out on the construction drawings and bottom widths and top of slope location and elevation at three evenly-spaced locations along the length of the channel, swale, or ditch.

3. Detention and water quality pond grading – Plan view and elevations along the top and toe of slope of all embankments so that the pond volume may be confirmed. The surveyor shall provide closed polyline contours around the pond from the location of the outlet structure to the top of the embankment so that the volume of the pond may be certified.

4. Detention and water quality outlets – Plan view and section dimensions and elevations of the structure and the elevation of every orifice or weir called out in the construction drawings, including of the orifices on the orifice plate.

5. Any other surveyed information as required by the City.

E. Construction tolerances shall be as indicated in this subsection for each type of drainage facility. If the location of any facility falls outside the acceptable tolerances but will not prevent the facility from functioning as intended, all approved reports, drawings, and calculations must be updated and resubmitted to the City for review and approval.

1. Storm drain pipes & culverts – 0.30’ horizontal and 0.08’ vertical for inverts provided no storm drain pipe is at a flatter slope than 0.30% and no culvert is at a flatter slope than 0.20%.

2. Manholes, inlets, and junction boxes – 0.30’ horizontal and 0.08’ vertical for rims.

3. Channel bottom width and centerline – 0.50’ horizontal and 0.30’ vertical for inverts provided the channel is not at an adverse slope at any location.

4. Detention and water quality outlets – 0.50’ horizontal for weir lengths and 0.08’ vertical for all orifices and weirs provided that the required WQCV, EURV, and 100-year volume is achieved.

5. Detention and water quality pond grading – as-constructed WQCV, EURV, and 100-year storage volumes shall be within 10% of the design value calculated based on the as-constructed elevations of relevant pipes, weirs, rims, and inverts. Note that the elevation at which the WQCV is realized in a pond may vary significantly from the design value provided 1) the WQCV cannot leave the facility without being detained and 2) the volume realized at the EURV overflow elevation is within 10% of the EURV design value.

F. Survey measurement accuracy shall be:

1. Horizontal locations: ± 0.10’
2. Elevations: ± 0.01’

2.14 AS-CONSTRUCTED RECORD DRAWINGS

A. The Contractor and Design Engineer shall be responsible for recording As-Constructed information on a set of Record Drawings kept at the construction site. A representative of the Developer shall monitor construction to assure that changes in construction (as approved in writing) and other pertinent details, such as horizontal location of swales, channels, ponds, inlets, manholes, junction boxes, etc., elevations of pipes, swales, channels, and structures, and all pipe and structure dimensions and depths, etc. are kept current on the As-Constructed Record Drawings.

B. Where the construction is phased with more than 30 days between phases, As-Constructed Record Drawings shall be submitted to the City after each completed phase. The Construction Drawings and Grading Plan for all future phases shall also reflect the "As-Constructed" conditions of the previous phases.

C. At a minimum, the As-Constructed Record Drawings set shall include the following sheets from the original accepted Construction Drawings:

1. Cover Sheet
2. Plan, profile, grading, section, and detail sheets of all storm drain inlets, manholes, junction boxes, pipes, outlet structures, detention and water quality facilities and their appurtenant structures, channels, swales, ditches, curb and gutter, and culverts. Open basin detention and water quality facilities must include a detailed topographical survey with closed polyline contours for basin volume confirmation.
3. City of Greeley Standard Drawings that were used in the construction of the storm drainage and water quality facilities.

D. At a minimum, the As-Constructed Record Drawings set shall also include the following sheets from the original accepted Grading Plan:

1. Cover Sheet
2. Plan view sheets showing high points, low points, and grade breaks along lot lines and within lots as well as lot corner elevations.

E. The As-Constructed Record Drawings shall show the original design information as well as the As-Constructed information. The original design information shall be lined-through. The As-Constructed information shall be in the same areas as the design information and shall be either clouded and/or made with a heavier line weight as the design information for clear differentiation. The month and year of the construction shall also be noted.

F. A Colorado Registered Land Surveyor shall certify the As-Constructed horizontal locations and surveyed elevations of all items listed in section 2.13 in addition to:

1. Final manhole, junction box, inlet, and outlet structure rim elevations and inverts.
2. Construction tolerances shall be evaluated based on original design and City design criteria.
3. Measurement tolerances shall be:
   a. Horizontal locations: ± 0.10'
   b. Elevations: ± 0.01'

If the location of any facility falls outside the acceptable tolerances but will not prevent the facility from functioning as intended, all approved reports, drawings, and calculations must be updated and resubmitted to the City for review and approval.

G. If a detention or water quality pond has been constructed, the O&M Plan and the MHFD-Detention spreadsheet must be updated with the information provided in the As-Constructed Record Drawings. The pond must be added to the state portal for Stormwater Detention and Infiltration Facility Notification found at (https://maperture.digitaldataservices.com/gvh/?viewer=cswdif) in accordance with Colorado Revised Statutes Title 37. Water & Irrigation § 37-92-602. Additional information is in Section 10

H. The project responsible Design Engineer and Land Surveyor shall observe construction as required to be able to certify the conditions and information recorded on the As-Constructed Record Drawings is true and correct.

I. The General Contractor for the project shall sign each drawing sheet of the As-Constructed Record Drawings set with the following statement:

I, _____, hereby state that this project was constructed to City of Greeley accepted Construction Drawings and standards, as designed by the project Design Engineer, and as field staked by the project Land Surveyor. All deviations to the approved Construction Drawings, standards, design, or survey were noted on field drawings and these were provided to the project Design Engineer for acceptance and inclusion in the As-Constructed Record Drawings.

_____

Construction Company

_____

Address

_____

Authorized Representative

_____

Title Date

J. A Professional Land Surveyor shall perform or directly supervise all field survey data collection to verify the As-Constructed conditions and shall stamp and seal each drawing sheet in the As-Constructed Record Drawing set with the following statement:

I, _____, hereby state that this project was field staked for construction per City of Greeley accepted Construction Drawings and standards and in accordance with the project design. I certify that the field survey information obtained for the As-Constructed Record Drawings was obtained in accordance with City current standards and is accurately represented on these As-Constructed Record Drawings.

_____

Registered Professional Land Surveyor (Affix Seal)

K. A Professional Engineer shall review all the As-Constructed information for compliance with the original approved design and standards and shall stamp and seal each drawing sheet in the As-Constructed Record plan set with the following statement:

> I, _____, hereby state that I have reviewed the As-Constructed information provided by the project Contractor and project Land Surveyor. I certify that according to the information provided the As-Constructed Record Drawings are in compliance with the City of Greeley accepted Construction Drawings and standards and will function as designed.
>
> _____
> Registered Professional Engineer (Affix Seal)

L. As-Constructed Record Drawings, signed and sealed, shall be submitted to and accepted by the City prior to issuance of Substantial Completion. The submittal shall follow the City's Digital Data Submission Standards and include one electronic PDF version and one file package containing GIS spatial data compatible with ESRI ArcGIS using the coordinate system referenced in the most recent City of Greeley Control Points Datasheet. CAD files of the as-constructed grading for all open basin detention and water quality facilities, shown as closed polylines at whole number elevation increments, shall be submitted as well. The two (2) year warranty period for the installed storm drainage facilities will begin after the Certificate of Substantial Completion has been issued by the City. The request for the Substantial Completion Certificate may be initiated by the City or requested by the Developer, but in all cases is the sole responsibility of the Developer.

M. The City will compare the certified As-Constructed Record Drawing information with the approved Construction Drawings, previously submitted Verification Survey, and information the City may be aware of during the construction process. Any corrections, additions, or omissions to the As-Constructed Record Drawings shall be provided to the Design Engineer who prepared the As-Constructed Record Drawings for changes.

N. The Certificate of Substantial Completion will not be granted until the As-Constructed Record Drawings for the storm drainage facilities are accepted by the City. (Ordinance 44, 2002)

2.15 VIDEO INSPECTIONS

All stormwater mains and laterals shall be televised. Work to complete the video inspection shall not be paid for by the City. Recordings must be submitted to the City for review and acceptance prior to issuance of the Certificate of Substantial Completion. All stormwater mains and laterals shall also be televised 3 months prior to the end of the warranty period or as deemed necessary by the City within the construction and warranty period. The warranty for the storm drainage system will remain in effect until the Stormwater Division has reviewed and approved the video recordings or the listed end of the warranty period, whichever is longer. Additional requirements are below.

A. Video Requirements

1. Recordings shall be completed by personnel trained and certified by NASSCO.

2. Recording shall be made using a color camera, self-propelled or other. Light may be used to show detail of problem areas and joints.
3. Camera shall have a swivel head capable of looking into each lateral connection.
4. Camera speed shall not exceed 3 feet per second.
5. Areas of concern witnessed by the operator require the camera to stop and swivel as necessary to record a detailed video of the area from all perspectives.
6. Recordings must include location logs (e.g., manhole 2 to manhole 3, etc.), with the time, date, street name (if applicable), and linear footage displayed.
7. Recordings must include an evaluation of each manholes.
8. Recordings must be narrated.

B. Completed videos must be provided in MP4 file format. Other file formats may be accepted with the approval of the Stormwater Division. If video files are too large to be submitted by email, contact the Stormwater Division to determine a mutually acceptable way to securely transmit the video files.

2.16 DETENTION CERTIFICATION

See Section 10 for requirements for detention certification and final acceptance.

2.17 SUBSURFACE UTILITY ENGINEERING (SUE)

Colorado Senate Bill 18-167 amended Title 9, Article 1.5 of the Colorado Revised Statutes to improve safety by modifying the requirements associated with the location of underground utilities prior to construction and implementing an enforcement program associated with the new requirements. The requirements must be met if a project meets all four of the following criteria.

1. Project involves a construction contract with a public entity, construction in the public ROW, infrastructure that will be dedicated to the City, or other work as determined by the City.
2. Project primarily involves horizontal construction and does not primarily involve the construction of buildings.
3. Anticipated excavation footprint exceeds two feet in depth and is at least a contiguous 1,000 square feet (excluding fencing and signing projects) or involves utility boring.
4. Project requires the design services of a licensed professional engineer.

If all the above criteria are met, subsurface utility engineering documentation shall be provided that includes:

1. Notification to 811 that there is an upcoming SUE required project.
2. Depiction of utilities on stamped plans in such a way that they meet or exceed ASCE 38 or provide documented reasons from a licensed professional engineer why they do not meet or exceed Quality Level B.
3. Meeting or exceeding Quality Level A for underground facilities at the point of a potential conflict with a gravity fed system including sanitary and stormwater facilities.

Quality-level requirements for subsurface utility engineering vary by project phase and are as follows:

1. Project Planning – Quality Level D
2. Preliminary Design – Quality Level B
3. Final Design – Quality Level A

Definitions of the Quality Levels are as follows:

1. Quality Level D is the most basic level of investigation and includes verbal recollections and review of existing records such as as-constructed drawings, utility system drawings, permit logs, field sketches, site visit logbooks, old surveys, one-call marks, and prior SUE investigations by others.
2. Quality Level C includes surveying those utilities that are visible above ground and use of surface features that indicate subsurface alignment such as valve covers, fire hydrants, pull boxes, manholes, and telephone pedestals. These should be reconciled to ASCE Quality Level D records.
3. Quality Level B includes the use of geophysical methods to determine the existence and horizontal position of all subsurface utilities. Quality Level B can be assigned to a utility segment or subsurface feature whose existence and position are based upon geophysical methods combined with professional judgment and whose location is tied to the project survey datum. Quality Level B is sometimes referred to as designating.
4. Quality Level A requires precise mapping via exposure of the utility. It provides type, size, condition, and material of the utility. Quality Level A includes using nondestructive excavating equipment at critical points to determine the precise horizontal and vertical position, type, size, condition, material, and any other characteristics of underground utilities. The utility should be vertically and horizontally tied to the project datum. Quality Level A is sometimes called locating.

DRAINAGE REPORT CHECKLIST

This is the checklist of items to include in Drainage Reports submitted to the City for review. Any items not applicable to a project shall be specified within the text of the report. All applicable checklists shall be included with each submittal. The table below may not contain all the information necessary for a project, and the Stormwater Division may require additional information. Design guidance and criteria to be used to complete the Drainage Report are in Volume II, Storm Drainage, of the City's Design Criteria and Construction Specifications.

Submittal: Conceptual Preliminary Final (circle one)

Concept	Prelim	Final	Included	N/A	Drainage Report Items	Office use
Cover Sheet						
X	X	X			Name of project, site address, & date	
X	X	X			Submittal level: Conceptual, Preliminary, Final	
X	X	X			Owner name & company name, primary contact name, title, phone number, email	
X	X	X			Developer & primary contact name, company, title, phone number, email	
X	X	X			Engineer & primary contact name, company, title, phone number, email	
Certification Page						
	X	X			Certification statement stamped, signed, & dated by a Colorado Professional Engineer	
Table of Contents						
	X	X			Table of contents (TOC) of checklist sections. Include separate TOCs for figures & tables	
Section I. Background Information						
X	X	X			Project location – include parcel number(s) and/or address(s); include bounding streets	
X	X	X			Include a vicinity map within the text showing the site boundary, nearby roads, & nearest arterial intersection	
X	X	X			Discuss ex land use; also include soil type(s), floodplains, and existing drainage infrastructure	
X	X	X			Discuss project purpose & need	
Section II. Proposed Construction						
X	X	X			Discuss proposed land use & provide a detailed description of all proposed construction including all drainage facilities & how stormwater drainage, detention, & water quality will be handled	
X	X	X			Approximate area of construction disturbance	
	X	X			Discuss proposed drainage easements, including intent of each & to whom each will be dedicated; Note that these are shown on the Basin Map and the plat.	
	X	X			Discuss construction phasing & access	
	X				Include anticipated development timeline	
	X	X			Include assumptions regarding adjacent development, drainage, detention, & water quality	

Concept	Prelim	Final	Included	N/A	Drainage Report Items	Office use
Section III. Hydrology						
	X	X			Discuss major basin characteristics & land use	
	X	X			List & discuss local & master drainageway planning documents & floodplain studies	
	X	X			Identify rainfall, design storm(s), & hydrologic methods used for hydrologic calculations, including any computer programs	
	X	X			Define historic & ex subbasins & discuss their outfall locations & peak discharges. Discuss development history, if applicable, or note historic & ex conditions are equal. Note these are shown on the Basin Map.	
X	X	X			Define proposed subbasins & discuss their outfall locations & peak discharges; discuss impacts to ex drainage facilities including the ex outfall system capacity to the Major Drainageway. Note outfalls are shown on the Basin Map.	
X	X	X			Estimate ex, proposed, & future flows from offsite areas, discuss management, & note these are shown on the Basin Map.	
X	X	X			Include a hydrology summary table of drainage subbasin area; imperviousness; C values; & historic, ex (if not equal to historic), & proposed peak flows	
X	X	X			Include FEMA flow rates, vertical datum, & bounding XS BFEs if near a FEMA floodplain	
X	X	X			Discuss irrigation facilities within 100 ft of property that will influence or be influenced by local drainage	
Section IV. Drainage Facility Design						
X	X	X			Discuss requirements or implications from local, adjacent, & master drainageway planning documents	
X	X	X			Discuss how site constraints (streets, utilities, structures, etc.) affect the drainage design	
	X	X			Discuss the continued use or abandonment of any ex facilities	
	X	X			Discuss design criteria, calculation methods, & results for sizing & locating stormwater conveyance facilities such as inlets, pipes, culverts, channels, ditches, swales, curb & gutter, etc. & note that HGLs are shown in the appendix.	
	X	X			Provide conveyance system details including ex & proposed lengths & sizes of pipe, culverts, ditches, & curb & gutter as well as the number of inlets, manholes, & any other stormwater infrastructure. Discuss sump inlet overflow paths. Include a table of peak flows during major & minor events. Discuss tables, charts, & exhibits used to explain the design & note if they are in the appendix. Note that the	

Concept	Prelim	Final	Included	N/A	Drainage Report Items	Office use
					conveyance facilities are shown in the Basin Map & Construction Drawings.	
X	X	X			Discuss the detention & water quality concept including how the site maximizes infiltration; include design criteria, calculation methods, & sizing results including peak volumes & inflow/outflow rates during design events. Include a detailed design narrative; Discuss geotechnical findings & note the geotechnical report is in the appendix; Note that supporting details, figures, & tables are in the appendix & that the detention & water quality facilities are shown in the Basin Map & Construction Drawings.	
X	X	X			Discuss integrating recreational or natural resource functions within drainage facilities	
	X	X			Discuss variance requests that have been submitted & include the request & approval as appendices	
Section V. Wetlands						
X	X	X			Note if jurisdictional or non-jurisdictional wetlands are on site, what the approach to these is, & provide discussion & details	
Section VI. Maintenance						
	X	X			Discuss access to all drainage infrastructure including types of easements & their conditions & limitations for use. Note that ex & proposed easements are shown in the Basin Map & Construction Drawings.	
X	X	X			Discuss maintenance requirements, frequency, & responsibility for all drainage infrastructure with a focus on water quality & detention facilities. Note the O&M Plan and Agreement are in the appendix	
Section VII. Permitting						
	X	X			Discuss all permitting requirements & the status of each including the State Construction Stormwater &/or Dewatering Permits, the City Floodplain Development Permit, the City Land Grading Permit, etc.	
	X	X			Note if a 404 permit is needed, why or why not, and if a nationwide (note which number) or individual permit will be pursued; if a 404 permit is needed, provide permit approval once received	
Section VIII. Conclusions						
	X	X			Compliance w/City & MHFD design criteria	
	X	X			Compliance w/City Comprehensive Basin Map	
	X	X			Effectiveness of design to prevent damage from stormwater	
	X	X			Influence of proposed improvements on the City's Comprehensive Basin Map recommendations	

Concept	Prelim	Final	Included	N/A	Drainage Report Items	Office use
Section IX. References						
	X	X			Design criteria	
	X	X			Studies, master plans, reports, & documentation; box or highlight pertinent text/data in each document & provide PDF comment to define project applicability	
	X	X			Each external reference provided shall include its original cover sheet;	
Section X. Appendices						
Appendix A – General Site Information						
X	X	X			Cover sheet with contents listed in order	
X	X	X			Basin Map	
X	X	X			FEMA FIRM with project site delineated/labeled	
X	X	X			NRCS soil report & map	
	X	X			Geotechnical report with information specific to the proposed improvements including boring logs with soils parameters (cohesivity, LL, PI, sulfate %, moisture, dry density, gradation, etc.), depth to groundwater at 24 hours or longer, and recommendations for subgrade preparation, bearing capacity, temporary shoring, side slopes, backfill, base sliding coefficient, factor of safety, seepage and cutoff design, topsoil thickness, organic content, soil types, swelling potential, permeability coefficients, percolation rates, and any other site-specific parameters determined to be applicable by the geotechnical engineer for the proposed improvements. The report should indicate the suitability of the site soils for green infrastructure. Depths of borings should extend a minimum of 5 feet below anticipated bottom of infrastructure. Report should provide recommendations on use of sulfate resistant concrete	
	X	X			Variance request(s) &approvals	
	X	X			Basin Map & Drainage Report checklists	
Appendix B – Hydrology						
	X	X			Cover sheet with contents listed in order	
	X	X			Excerpts of relevant master plans & reports w/relevant data highlighted w/PDF comment	
	X	X			Table of historic & proposed drainage subbasin data used for Rational Method calculations including area, imperviousness, C value, time of concentration, rainfall intensity, etc.	
	X	X			Table of CUHP or other hydrologic program input	
	X	X			Table of hydrologic calculations results including historic &proposed minor & major storm peak runoff at critical design points including the outfalls of all historic & proposed subbasins, drainage system confluences, & at outfalls from the site.	

Concept	Prelim	Final	Included	N/A	Drainage Report Items	Office use
	X	X			Digital copies of all modeling files (CUHP, SWMM, etc.) used to support the design, submitted electronically, via email	
Appendix C – Hydraulic Conveyance						
	X	X			Cover sheet with contents listed in order	
	X	X			Open channel calculations including Manning's n, cross section, slope, velocity, Froude number, & shear stress. Include HGL for design storm(s)	
	X	X			Hydraulic structure calculations including riprap sizing, low tailwater basins, drop & check structures, energy dissipators, etc.	
	X	X			Culvert design calculations including design flow(s) material, size, Manning's n, inlet/outlet control, tailwater rating, exit velocity, etc.	
	X	X			Inlet & street capacity calculations including MHFD-Inlet for each inlet	
	X	X			Storm drain capacity, including EGL & HGL during the minor & major events	
	X	X			Storm drain summary table including pipe ID, length, size, material, Manning's n, & slope and design flow, peak velocity, & headloss for minor & major events	
	X	X			Digital copies of all modeling files (RAS, HY-8, etc.) used to support the design, submitted electronically, via email	
Appendix D – Detention and Water Quality						
	X	X			Cover sheet with contents listed in order	
	X	X			Detention & permanent water quality requirements & design calculations, including MHFD-Detention spreadsheets, pond volume, pond inflow & outflow hydrographs, & outlet structure design	
		X			O&M Plan & Agreement	

BASIN MAP CHECKLIST

This is the checklist of items to include in the Basin Map submitted to the City for review. Any items not applicable to a project shall be specified within the text of the Drainage Report as well as marked N/A in the checklist. All applicable checklists shall be included with each submittal. The table below may not contain all the information necessary for a project, and other divisions or departments within the City may require additional information. Design guidance and criteria to be used to complete the Basin Map are in the City's Storm Drainage Design Criteria (SDDC).

Submittal: Conceptual Preliminary Final (circle one)

Concept	Prelim	Final	Included	N/A	Basin Map Items	Office use
General Formatting						
X	X	X			PDF sheets are 22" by 34" full size	
X	X	X			Scale of 1" = 20' to 1" = 200'	
	X	X			All sheets checked, sealed/stamped, signed, & dated by the Engineer	
X	X	X			Title block along bottom or right edge of sheet	
X	X	X			Bar scale, north arrow, & legend on each plan	
X	X	X			FEMA-designated floodplains w/in 200' of the site & proposed floodplains if floodplain is impacted	
Existing Conditions Basin Map						
X	X	X			Ex contours at 2' max intervals extending to 100' beyond property lines w/elevations labeled on NAVD 88 survey datum. LiDAR may be used for private property outside the development	
X	X	X			Ex street names & right-of-way location/width	
	X	X			Ex utilities including storm, gas, electric, FO, telephone, water, sanitary, etc.	
X	X	X			Ex irrigation or drainage facilities including channels, ditches, culverts, storm drainage system, detention, etc.	
X	X	X			Location & type of drainage facilities identified in the master drainage plan relevant to the site	
	X	X			Delineate & label existing drainage basins & subbasins & the outfall location of each; include flow arrows within each basin	
	X	X			Provide basin areas, C values, & peak flows from all subbasins; provide a table of ex minor/major peak flows at all design points including inlets to existing structures, pipes, & ponds (if applicable), & at outfalls from each subbasin & from the site	
X	X	X			Identify offsite development that will impact proposed development	
	X	X			If offsite drainage enters the site, show the inflow location & estimated minor & major storm peak runoff; show how the inflow is currently routed through the site	
	X	X			Identify the entire drainage path from each current site outfall to the nearest major drainageway; if the	

Concept	Prelim	Final	Included	N/A	Basin Map Items	Office use
					major drainageway is far away, another exhibit at a separate scale may be required	
Proposed Conditions Basin Map						
X	X	X			Proposed property lines, street names & right-of-way widths, A/B lot designations, & easements w/widths & notation of what each easement is for	
	X	X			Ex & proposed utilities including stormwater (w/flow arrows) gas, electric, FO, telephone, water, sanitary, etc.	
	X	X			Street slopes w/flow direction arrows at all slope change locations	
	X	X			Proposed site grading, including contours & slope labels; tie proposed grading into existing grading at limits of construction & screen back ex contours within the development for clarity	
	X	X			Delineate & label proposed drainage basins & subbasins & the outfall location of each, include flow arrows within each basin	
	X	X			Provide basin areas, C values, & peak flows from each subbasin; provide a table of pr minor/major peak flows at all design points including inlets to all proposed channels, structures, pipes, & ponds, & at outfalls from each subbasin & from the site	
	X	X			Identify proposed path from each proposed site outfall to nearest drainageway; note existing & proposed peak flow rates along this path	
	X	X			If offsite drainage will enter the site, show the inflow location & estimated minor & major storm peak runoff; show how the inflow will be routed through the site, including for detention & water quality purposes	
	X	X			Proposed storm drainage system including all inlets, manholes, junction boxes, & pipes. Label size, material, class, & slope of pipes & size, & type of inlet or manhole or junction box	
	X	X			Proposed culverts including length, slope, size, material, & class, & if a headwall with wingwalls or FES will be used	
	X	X			Proposed channels, swales, or ditches including bottom width, side slope, depths, lining material, minor & major storm design flow rate, velocity, & inundation limits	
	X	X			Proposed curb & gutter & cross pans including design flow for minor & major storm in each	
X	X	X			Location of detention and water quality facilities	
	X	X			Detailed pond grading; note the design WQCV, EURV, & 100-year volumes, WSEL, & discharge rates; include space for maintenance access	

GRADING PLAN CHECKLIST

This is the checklist of items to include in the Grading Plan submitted to the City for review. Any items not applicable to a project shall be indicated in the checklist. All applicable checklists shall be included with each submittal. The table below may not contain all the information necessary for a project, and other divisions or departments within the City may require additional information. Design guidance and criteria to be used to complete the Grading Plan are in the City's Storm Drainage Design Criteria (SDDC).

Submittal: Conceptual Preliminary Final (circle one)

Concept	Prelim	Final	Included	N/A	Grading Plan Items	Office use
General Formatting						
X	X	X			PDF sheets are 22" by 34" full size	
		X			All sheets checked, sealed/stamped, signed, and dated by the Engineer	
X	X	X			Title block along bottom or right edge of sheet	
X	X	X			Bar scale and north arrow on each plan sheet	
X	X	X			FEMA-designated floodplains & WSEL on all applicable plan views; proposed floodplains if being revised	
	X	X			Survey control points on each applicable plan view	
	X	X			Ex contours at 2' max intervals extending to 100' beyond property lines w/elevations labeled on NAVD 88 survey datum. LiDAR may be used for inaccessible private property outside the development	
X	X	X			Street right-of-way width & names on all plan views	
Cover Sheet						
X	X	X			Project name and location, submittal type (Preliminary, etc.), and month/year of submittal	
X	X	X			Sheet index	
X	X	X			Vicinity map showing & labeling project site & the nearest major arterial streets	
X	X	X			Name/contact information of Owner, Developer, Design Engineer, Land Surveyor, Landscaper, Architect, etc.	
	X	X			City acceptance signature blocks	
Notes Sheets						
	X	X			City General Notes	
	X	X			Legend including line types, symbols, abbreviations, etc.	
	X	X			Special project notes	
	X	X			Required utility notes	
Overall Plan Sheet						
X	X	X			Entire development site on one sheet at a defined, whole number scale	

Concept	Prelim	Final	Included	N/A	Grading Plan Items	Office use
	X	X			Location of City-recognized project benchmarks and min of 2 horizontal control points w/northings & eastings, elevations, & descriptions of each	
X	X	X			Key map of plan sheets	
	X	X			Boring locations & logs	
Plan View Sheets						
X	X	X			Scale of 1" = 20' to 1" = 200'	
X	X	X			Property lines, easements, & right-of-way w/widths, designated purpose, owner, and recording number, as applicable	
	X	X			Spot elevations at all lot corners, the lot high point, the midpoint of all lot lines, and & finished floor for all structures; Lot A/B designations & drainage flow arrows for each lot	
	X	X			Location of fixed objects and features such as wetlands, trees, poles, fences, buildings, walls, etc.	
X	X	X			Streets, bike paths, alleys, & sidewalks w/widths, grades & grade breaks for proposed & ex to remain	
X	X	X			Curb & gutter slopes w/flow direction arrows; line work for catch curb & spill curb shall be differentiated and shown in legend	
X	X	X			Proposed site grading, including contours at 2’ max interval & slope labels; use heavier line weight than for ex contours; index contours should be heavier than incremental contours	
	X	X			Plan location and directional flow arrows of all drainage facilities visible from the ground surface including open channels, curb & gutter, cross pans, swales, ditches, trickle channels, and culvert end sections; show widths, heights, & top & toe of slope as applicable	
	X	X			Plan location, size, & type of all inlets, manholes, and wingwalls	
	X	X			Plan location & directional flow arrows of irrigation ditches	
	X	X			Plan location of retaining walls & top & bottom of wall elevations at critical locations	
	X	X			Location of detention & water quality facilities & their appurtenances	
	X	X			Grading cross sections may be required for grading that is is complex or difficult to interpret from the contours; these may include at irregular ditch sections and/or locations with retaining walls	

CONSTRUCTION DRAWINGS CHECKLIST

This is the checklist of items to include in the Construction Drawings for drainage facilities submitted to the City for review. Any items not applicable to a project shall be indicated in the checklist. All applicable checklists shall be included with each submittal. The table below may not contain all the information necessary for a project, and other divisions or departments within the City may require additional information. Design guidance and criteria to be used to complete the Construction Drawings are in the City's Storm Drainage Design Criteria (SDDC).

Submittal: Conceptual Preliminary Final (circle one)

Concept	Prelim	Final	Included	N/A	Construction Drawings Items	Office use
General Formatting						
X	X	X			PDF sheets are 22" by 34" full size	
		X			All sheets checked, sealed/stamped, signed, and dated by the Engineer	
X	X	X			Title block along bottom or right edge of sheet	
X	X	X			Bar scale and north arrow on each plan sheet	
X	X	X			FEMA-designated floodplains on all applicable plan views; proposed floodplains if being revised	
	X	X			Survey control points on each applicable plan view	
	X	X			Ex contours at 2' max intervals extending to 100' beyond property lines w/elevations labeled on NAVD 88 survey datum. LiDAR may be used for inaccessible private property outside the development	
X	X	X			Street right-of-way width & names on all plan views	
Cover Sheet						
X	X	X			Project name and location, submittal type (Preliminary, etc.), and month/year of submittal	
X	X	X			Sheet index	
X	X	X			Vicinity map showing & labeling project site & the nearest major arterial streets	
X	X	X			Name/contact information of Owner, Developer, Design Engineer, Land Surveyor, Landscaper, Architect, etc.	
	X	X			City acceptance signature blocks	
Notes Sheets						
	X	X			City General Notes	
	X	X			Legend including line types, symbols, abbreviations, etc.	
	X	X			Special project notes	
	X	X			Required utility notes	
Overall Plan Sheet						
X	X	X			Entire development site on one sheet at a defined, whole number scale	
	X	X			Location of City-recognized project benchmarks and min of 2 horizontal control points w/northings & eastings, elevations, & descriptions of each	

Concept	Prelim	Final	Included	N/A	Construction Drawings Items	Office use
X	X	X			Key map of plan sheets	
	X	X			Boring locations & logs	
Demolition Sheet						
	X	X			If demolition items cannot be shown sufficiently and clearly on plan &/or overall plan sheets, a demolition-specific sheet must be added; also show ex drainage facilities to remain	
Plan View Sheets						
X	X	X			Scale of 1" = 20' to 1" = 200'	
	X	X			Items to be demolished & ex drainage facilities to remain if no separate demo sheet is used; all existing items shall be labeled	
X	X	X			Property lines, easements, & right-of-way w/widths, designated purpose, owner, and recording number, as applicable	
X	X	X			Streets, curb & gutter, & sidewalk w/widths	
X	X	X			Curb & gutter slopes w/flow direction arrows; catch curb & spill curb shall use different line types	
X	X	X			Proposed site grading, including contours at 2’ max interval & slope labels; use heavier line weight than for ex contours; index contours should be heavier than incremental contours	
	X	X			Ex & proposed utilities including gas, electric, FO, telephone, storm, water, sanitary, etc. along with dimensions indicating separation meets criteria; the full pipe width of each utility shall be shown whether by a single line of the appropriate thickness or by two lines representing the outsides of the pipe	
	X	X			Plan location & horizontal alignment of all longitudinal drainage facilities, along with directional flow arrows for each, including channels, curb & gutter, cross pans, storm drains, culverts, swales, ditches, trickle channels, access paths, etc. Show centerline, widths, heights, diameter, material & class, size, & top & toe of slope as applicable	
	X	X			Plan location, size, height & type of all inlets, manholes, outlets, forebays, wingwalls, retaining walls, detention & water quality facilities, etc. as applicable	
	X	X			Label all storm drainage facilities outside public right-of-way that are intended to be owned by the City as PUBLIC; private facilities must be labeled as PRIVATE	

Concept	Prelim	Final	Included	N/A	Construction Drawings Items	Office use
	X	X			Detailed dimensional plans of detention & water quality facilities & their appurtenances including detailed grading plans, forebay layouts, & WQCV, EURV, & 100-year design elevations (in plan & section), volumes & discharge rates	
Profile Sheets						
	X	X			Profiles of all storm drains & culverts. These may be in combined plan/profile sheets. Include pipe size, slope, flow direction arrow, material & class, & invert elevations. Include MH or junction box type, size, height, & rim elevations. Include ex & proposed ground and ex & proposed utilities	
					Major and minor peak flow rate & velocity for each pipe	
	X	X			Label all storm drainage facilities outside public right-of-way that are intended to be owned by the City as PUBLIC; private facilities must be labeled as PRIVATE	
Section & Detail Sheets						
	X	X			Section & detail views of all pond outlet structures including orifice plates and weirs	
	X	X			Details & sections of all wingwalls & retaining walls including elevations for top wall, top of retained ground, top of ground in front of wall, & bottom of footing, & location of subdrains	
	X	X			Detailed sections for streets, curb & gutter, ditches, swales, cross-pans, & channels of all kinds; more than one section will be required if dimensions vary	

SECTION 3
RAINFALL

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SECTION 3
RAINFALL

3.01 DESIGN STORMS

Minor and major design storms for design are established to minimize inconvenience, protect against recurring minor damage, and reduce maintenance costs caused by the minor storm and to eliminate substantial property damage and loss of life caused by the major storm. The goal is a functional drainage system at a reasonable cost. The storm drainage system may include streets, curb and gutter, roadside ditches, inlets, storm sewers, open drainageways, culverts, and detention and water quality facilities. In the City of Greeley, the minor storm is the 5-year event, and the major storm is the 100-year event. The level of protection required during the minor and major storm events varies and is included in the SDDC sections dedicated to each type of infrastructure.

3.02 RAINFALL INTENSITY

A rainfall analysis was completed for the City of Greeley using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 data. The equations and data in this section are based on this analysis. A detailed memo regarding the evaluation of NOAA Atlas 14 and the development of the rainfall intensity equation below is available from the City upon request.

Equation 3.02.1 shall be used to calculate rainfall intensity for a given time of concentration or to develop intensity-duration-frequency curves for runoff analysis using the Rational Method as discussed in Section 4.

$$I = P_1 \times \frac{25.7}{(t_c+5.78)^{0.779}} \qquad (3.02.1)$$

Where: I = peak rainfall intensity (in/hr)

P_1 = 1-hour rainfall depth (in), see Table 3.02.1

t_c = storm duration, time of concentration (min)

Rainfall intensities as a function of storm duration and recurrence interval are provided in Table 3.02.1. The values for P1 were taken directly from NOAA Atlas 14 for the station named GREELEY UNC (05-3553), but the rest of the data in the table was developed using Equation 3.02.1. The values in Table 3.02.1 are subject to revision and users of the SDDC are encouraged to check for updates.

Table 3.02.1. Intensity-Duration-Frequency Data

Return Period	P_1 (in)	I, Peak Rainfall Intensity for Storm Duration (in/hr)				
		5-min	10-min	15-min	30-min	60-min
2-year	0.858	3.46	2.57	2.07	1.36	0.85
5-year	1.13	4.56	3.39	2.73	1.79	1.11
10-year	1.41	5.69	4.23	3.41	2.23	1.39
25-year	1.86	7.50	5.57	4.50	2.95	1.83
50-year	2.27	9.15	6.80	5.49	3.59	2.24
100-year	2.73	11.01	8.18	6.60	4.32	2.69

3.03 CUHP RAINFALL DISTRIBUTIONS

Information in this section is based on Volume 1 of the Mile High Flood District's Urban Storm Drainage Criteria Manual with minor revisions and clarifications. The current version of the Colorado Urban Hydrograph Procedure (CUHP) was designed to be used with the 1-hour rainfall depths from NOAA Atlas 14 for small watersheds and 1-hour and 6-hour depths from NOAA Atlas 14 for large watersheds. CUHP rainfall distributions shall be used for runoff analysis using CUHP and CUHP-SWMM as discussed in Section 4.

A. Small Watersheds. Small watersheds are less than 15 square miles. A 2-hour design storm developed using 1-hour rainfall depths from NOAA Atlas 14 shall be used for small watersheds. Depth reduction factors (DRFs) are not required for watersheds with an area less than or equal to 2 square miles for minor events. They are also not required for watersheds of less than 15 square miles for major events. They are, however, required for watersheds with an area between 2 and 15 square miles for minor events. DRFs are included for use with SWMM modeling. See Volume 1 of the Urban Storm Drainage Criteria Manual and the CUHP User's Manual for further discussions about DRFs and how and when they are applied.

To obtain a temporal distribution for a design storm for a small watershed, the 1-hour depth is converted into a 2-hour storm automatically in CUHP for the 1-hour depth specified in the CUHP input file. The automatic conversion is the result of a calibration completed by the MHFD using known events within the MHFD boundary; although Greeley is not within the MHFD boundary, it is in a geographically similar location, and NOAA Atlas 14 rainfall values for Greeley shall be used as CUHP input values. The red rectangle in Figure 3.03.1 indicates where the NOAA Atlas 14 rainfall value for Greeley should be entered into CUHP.

Figure 3.03.1. Example CUHP Input for Greeley Point Rainfall

Comment	Example Greeley 100-year, 1-hour depth taken from NOAA Atlas 14 for use in CUHP		
1Hr Depth	2.73	NOAA Atlas 14 Point Precipitation Frequency Estimates: CO (Note: Use 60-minute recurrence interval depth)	
Return Period	100	Years	
Time	Depth	CurveValue	
0:05	0.027		0.01
0:10	0.082		0.03
0:15	0.126		0.046
0:20	0.218		0.08
0:25	0.382		0.14
0:30	0.683		0.25
0:35	0.382		0.14
0:40	0.218		0.08
0:45	0.169		0.062
0:50	0.137		0.05
0:55	0.109		0.04
1:00	0.109		0.04
1:05	0.109		0.04
1:10	0.055		0.02
1:15	0.055		0.02
1:20	0.033		0.012
1:25	0.033		0.012
1:30	0.033		0.012
1:35	0.033		0.012
1:40	0.033		0.012
1:45	0.033		0.012
1:50	0.033		0.012
1:55	0.033		0.012
2:00	0.033		0.012
2:05	0		

B. Large Watersheds. Large watersheds are 15 square miles or greater. 1-hour and 6-hour depths from NOAA Atlas 14 shall be used for large watersheds. MHFD recommends that large watersheds be evaluated using a storm duration of 6 hours. Depth reduction factors (DRFs) are required for large watersheds for all events. See Volume 1 of the Urban Storm Drainage Criteria Manual and the CUHP User's Manual for further discussions about DRFs and how and when they are applied.

Each design point within a large watershed will have a unique tributary area and DRF. The input hyetographs at each design point may be different depending on the location of the design point within the watershed. This variability may necessitate using multiple CUHP and SWMM models. See Volume 1 of the Urban Storm Drainage Criteria Manual and the CUHP User's Manual for further discussions about DRFs and how to get flows at various design points within large watersheds.

To develop the temporal distribution for the 6-hour design storm, CUHP starts with the 2-hour storm distribution used for small watersheds and uses it to develop the 3-hour distribution. The 2-hour distribution provides the first two hours of the 3-hour design storm. The difference between the 3-hour point precipitation and the 2-hour point precipitation is then distributed evenly over the third hour of the storm.

The 3-hour distribution in turn provides the first three hours of the 6-hour design storm. The difference between the 6-hour point precipitation and the 3-hour point precipitation is then distributed evenly over the last three hours of the 6-hour design storm.

Figure 3.03.2 shows the CUHP input for a large watershed for a 100-year storm. A depth reduction factor is automatically applied. It is not shown in the image, but the hyetograph has a duration of 6 hours.

Figure 3.03.2. CUHP Input Values for a Large Watershed

Comment	Example Greeley 100-year data taken from NOAA Atlas 14 for use in CUHP (assumed 20 sq mi watershed)				
1Hr Depth	2.73	inches	2hr Depth	3.16	inches
6Hr Depth	3.99	inches	3hr Depth	3.48	inches
Correction Area	20	Sq. Mi.			
Return Period	100	Years	Calculate	Clear	
Time	Adjusted Depth	Unadjusted Depth	NOAA Atlas 14 Point Precipitation Frequency Estimates: CO (Note: Use 60-minute recurrence interval depth)		
0:05	0.0314	0.0273			
0:10	0.0942	0.0819			
0:15	0.1444	0.1256			
0:20	0.2577	0.2184			
0:25	0.2637	0.3822			
0:30	0.4709	0.6825			
0:35	0.2637	0.3822			
0:40	0.2228	0.2184			
0:45	0.2031	0.1693			
0:50	0.1570	0.1365			
0:55	0.1256	0.1092			

SECTION 4
RUNOFF

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SECTION 4
RUNOFF

4.01 INTRODUCTION

The three methods approved to calculate stormwater runoff within the City are the Rational Method, the Colorado Urban Hydrograph Procedure (CUHP) developed and updated by the MHFD, and the Storm Water Management Model (EPA-SWMM) developed and updated by the EPA. All development must use one of these methods to calculate peak runoff rates and total runoff volumes as necessary to design the required stormwater infrastructure for the development.

Minor and major storm peak runoff rates shall be calculated at all critical design points. These typically include the following locations, but additional design points may be required.

1. Confluences of two or more drainage paths.
2. Changes in channel widths.
3. Entrances into and exits from the development.
4. Upstream ends of bridges and culverts.
5. Downstream ends of culverts if storm drainage systems discharge into the culvert barrel.
6. Inlets and junction boxes or manholes.
7. Roadway intersections.

4.02 RATIONAL METHOD

The Rational Method may be used to calculate peak runoff rates for watersheds totaling 90 acres or less and when only peak flow rates are required for design of stormwater infrastructure. Examples of infrastructure that only require peak flow rates for design are pipes, culverts, and inlets. The Rational Method may not be used to design detention basins. CUHP must be used to design detention basins. The methodology in Volume 1 of the USDCM, including imperviousness values, shall be followed for Rational Method calculations with the following revisions and clarifications.

1. Rainfall intensity shall be calculated in accordance with Section 3 of the SDDC.
2. Imperviousness values used to determine runoff coefficients for all areas tributary to a design point shall be based on the proposed fully developed condition.
3. Flow lengths used to calculate times of concentration shall also be based on the proposed fully developed condition.

The MHFD maintains the design spreadsheet UD-Rational that may be used to calculate runoff coefficients, times of concentration, rainfall intensity, and peak flow rates. UD-Rational is available on the MHFD website and may be used with the following revisions to the rainfall intensity equation coefficients in the "Rational Calcs" tab of the worksheet. These revisions are from a rainfall analysis completed for the City using NOAA Atlas 14 data discussed in Section 3.

1. Coefficient a should be changed from 28.50 to 25.70.
2. Coefficient b should be changed from 10.00 to 5.78.

3. Coefficient c should be changed from 0.786 to 0.779.

4.03 CUHP

CUHP may be used to calculate peak runoff rates and total runoff volumes for watersheds of any size and for the design of any type of stormwater infrastructure. CUHP must be used for the design of detention basins. The methodology in Volume 1 of the USDCM, including imperviousness values, shall be followed when using CUHP with the following revisions and clarifications.

1. 1-hour and 6-hour point rainfall values shall be those in Section 3 of the SDDC.
2. Catchment parameters including imperviousness and flow length shall be based on the proposed fully developed condition. Only regional detention may be included in large CUHP models with upstream basins that have detention. Subregional and onsite detention may not be included for off site basins.

CUHP basins shall be delineated in accordance with the criteria in the USDCM. If more than one basin is required to define the tributary watershed, the watershed must be analyzed using CUHP in combination with EPA SWMM (SWMM); this is discussed in the next section.

4.04 CUHP-SWMM

When a CUHP model includes more than one subbasin, SWMM must be used to route the hydrographs from the individual subbasins to the design point. Hydrograph routing is also required for the design of infrastructure such as detention ponds and volume-based stormwater control measures. The SWMM model receives runoff hydrographs from the CUHP model and routes the runoff through the larger watershed using the conveyance and storage elements such as channels, pipes, and detention ponds.

A CUHP model in combination with a SWMM model is typically referred to as a CUHP-SWMM model. The methodology in Volume 1 of the USDCM shall be followed when using SWMM. The SWMM User's Manual published by the EPA and available from their website provides extensive guidance and detail on the use of the software.

4.05 OFF SITE FLOW

Areas upstream of a development site must be evaluated to determine peak runoff flow rates and volumes anticipated to discharge into the development site. Developments must accommodate these peak runoff flow rates and volumes generated outside the development. Runoff generated offsite must be safely conveyed through or around the development without creating adverse impacts to any properties or to water quality in accordance with the criteria in the SDDC.

Calculation of off site flow shall assume a fully developed tributary area in accordance with the more stringent of the platted land uses and the City's zoning map. Regional detention may be included in the calculation, but subregional and onsite detention may not be included.

SECTION 5
OPEN CHANNELS

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SECTION 5
OPEN CHANNELS

5.01 INTRODUCTION

This section discusses open channel flow and presents criteria to be used for hydraulic design and evaluation of open channels, including roadside ditches. Channel rundowns are discussed in Section 9. Open channel flow occurs when water has its surface exposed to the atmosphere. Open channel flow occurs in streams, rivers, canals, drainage channels, and roadside ditches as well as in conduits such as culverts and storm drains that are not flowing full. Once water fully fills a conduit, flow in that conduit becomes pressure flow instead of open channel flow. Any work within a natural open channel may be subject to FEMA floodplain regulations. Information on regulatory floodplains is on the City's website.

Design criteria for open channels have expanded in recent years to account for the multifaceted benefit that open channels can provide a community and the negative impacts that can be realized when only flow conveyance is considered. These design criteria focus on mimicking natural streams to provide or preserve riparian habitat, floodplain connectivity, and ecological function while minimizing future maintenance needs. The most recent version of the Urban Storm Drainage Criteria Manual (USDCM) by the Mile High Flood District (MHFD) provides extensive guidance on wholistic open channel design and is referenced frequently in this section. Many other excellent references on channel hydraulics are available, including Chow (1959) and King and Brater (1963).

5.02 OPEN CHANNEL HYDRAULICS

The hydraulics of an open channel can be complex, ranging from steady state uniform flow to unsteady, rapidly varied flow. Most drainage design involves uniform, gradually varied, or rapidly varied flow states. Steady uniform flow occurs when the depth of flow remains constant. The calculations for both uniform and gradually varied flow are relatively simple and assume parallel streamlines. In contrast, rapidly varied flow calculations, used for elements like hydraulic jumps and flow over spillways, have solutions that are generally empirical in nature. This section presents basic equations and computational procedures for uniform, gradually varied, and rapidly varied flow for hydraulic jumps and weirs.

A. Uniform Flow. Open channel flow is considered uniform if the depth of flow is the same at every section of the channel. For a given channel geometry, roughness, discharge, and slope, there is only one possible depth for maintaining uniform flow. This is called the normal depth. For a prismatic channel cross section, the water surface will be parallel to the channel bottom during uniform flow. Uniform flow rarely occurs in nature and is difficult to achieve, even in a laboratory. However, channels are designed by assuming uniform flow because it is an adequate approximation.

B. Critical Flow. When critical flow exists for uniform flow, the channel slope is at the critical slope and the Froude number is 1.0. A slope flatter than critical will cause subcritical flow and result in a Froude number smaller than 1.0. A slope steeper than critical will cause supercritical flow and result in a Froude number larger than 1.0. When flow is at or near critical, it is unstable because minor changes in specific energy, such as from channel debris, will cause a major change in depth.

C. Gradually Varied Flow. The most common occurrence of gradually varied flow in storm drainage design is the backwater created by culverts, inlets, and channel constrictions. For these conditions, flow depth will be greater than normal depth in the channel and the water surface profile must be computed using a backwater technique, either the direct step or the standard step method. The direct step method is best suited to the analysis of simple prismatic channels, whereas the standard step method is best suited for irregular or nonuniform cross-sections.

D. Rapidly Varied Flow. Rapidly varied flow is characterized by very pronounced curvature of the streamlines. The change in curvature may become so abrupt that the flow profile is virtually broken, resulting in a state of high turbulence. Several common instances of rapidly varied flow include weir flow, orifice flow, and hydraulic jumps. Only hydraulic jumps will be discussed in this section. Weir and orifice flow are used almost exclusively for detention pond outlets and will be discussed in Section 10.

Hydraulic jumps may occur at grade control structures, inside storm drains or culverts, and at the outlet of a spillway and can be very erosive and affect hydraulic capacity. For grassed channels, the forces from a hydraulic jump must be controlled to prevent localized damage to the channel. Drops or other grade control structures can be used to direct the jump to an area specifically designed to resist the forces that come with it. A detailed evaluation of the hydraulic jump is not included herein, but design procedures are provided in Chow (1959) and Peterska (1978). The USDCM also has procedures and calculations that can be used.

5.03 OPEN CHANNEL DESIGN

A. Preliminary Design Methodology. Uniform flow may be assumed initially to develop an approximate channel design for planning purposes during conceptual design. These initial calculations for normal flow depth shall be based on Manning's equation shown as Equation 5.03.1. A spreadsheet shall be used to provide calculations if Manning's equation is used for analysis.

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S} \qquad (5.03.1)$$

Where: Q = flow rate (ft^3/s)
n = Manning's roughness coefficient (see Table 5.03.1)
A = area (ft^2)
S = Channel or pipe slope (ft/ft)
R = A/P = hydraulic radius (ft)
where P = wetted perimeter (ft)

Open channel flow velocity can be more easily calculated by rearranging Equation 5.03.1 to yield Equation 5.03.2. Equation 5.03.2 may be used to calculate runoff travel time for the Rational Method. It may also be used to design channel revetment.

$$V = \frac{1.49 R^{2/3} S^{1/2}}{n} \qquad (5.03.2)$$

Where: V = average velocity (ft/s)

The Froude Number shall be calculated for all initial open channel designs using Equation 5.03.3. Froude number requirements are discussed later in this section.

$$Fr = \frac{v}{\sqrt{gD_h}} \qquad (5.03.3)$$

Where: Fr = Froude number (dimensionless)
v = velocity (ft/s)
g = gravitational acceleration (32.2 ft/s^2)
D_h = hydraulic depth, A/T (ft)
where A = channel flow area (ft^2) and
T = top width of flow area (ft)

B. Final Design Methodology. The most general and widely used program is currently HEC-RAS, developed by the U.S. Army Corps of Engineers. When the 100-year design flow depth is 30" or more, a HEC-RAS model is required for final channel design and must include calculations for the minor and major storms. When the 100-year design flow depth is less than 30", Manning's n and Froude number calculations may be submitted that include Froude number, velocity, and depth for the minor and major storms. Additional information on the use of HEC-RAS is in the USDCM and at the U.S. Army Corps of Engineers HEC-RAS documentation website. Approval from the Stormwater Division is required prior to using another program.

C. Channel Roughness. As channel roughness increases, a given flow rate will have a greater depth and slower velocity. Conversely, a lesser roughness results in shallower depth and faster velocity. Selection of roughness coefficients for both the main channel and the overbanks is a critical part of the design and evaluation of an open channel. Channel roughness may be approximated three ways. The first is to use the values in Table 5.03.1 for various main channel and overbank conditions.

Table 5.03.1. Manning's Roughness Values

Location & Cover	Manning's n
Main Channel	
Sand or clay bed	0.03
Gravel or cobble bed	0.035
Troweled Concrete (for trickle channels)	0.014
Vegetated Overbanks	
Turfgrass sod	0.03
Native grasses	0.032
Herbaceous wetlands	0.06
Willow stands, woody shrubs	0.07

The second methodology is to use a retardance value for the vegetated overbanks. This is an iterative methodology developed by the NRCD and detailed in the USDCM. The third methodology is for calculating Manning's n for a void-filled or soil riprap-lined channel, shown by Equation 5.03.4, published by the MHFD in the USDCM.

$$n = 0.0395 D_{50}^{1/6} \quad (5.03.4)$$

Where: D_{50} = mean riprap stone size (ft)

Note that while Equation 5.03.4 is appropriate for computing channel capacity and flow depth, once the soil riprap is vegetated, velocity and shear calculations should be based on the roughness provided by the vegetation, not the riprap. Equation 5.03.4 also does not apply to grouted boulders. Section 9 discusses grouted boulder applications in detail. All boulders, riprap stone, and void-filled and soil riprap mixes shall be in accordance with the USDCM.

Note that using regular riprap is not allowed. When soil riprap or void-filled riprap is used, it shall be sized along with channel geometry to meet the criteria of this section for freeboard, velocity, and Froude number. All soil riprap and void-filled riprap shall be buried above the 2-year event to promote revegetation.

5.04 OPEN CHANNEL DESIGN CRITERIA

The MHFD has included a significant amount of text in Volume 1 of the USDCM that focuses on the preservation, enhancement, and restoration of stream corridors as well as the design of constructed channels using natural concepts. It highlights the functions and benefits of natural streams, recommends key actions that are necessary to preserve natural stream corridors, and covers several principles of stream restoration. It also applies the principles of stream restoration to the design of naturalized channels that will be high functioning and need much less maintenance than the traditional concrete- or riprap-lined trapezoidal channel previously specified. Localized use of soil riprap, void-filled riprap, and boulders in stream restorations and constructed channels is also discussed.

The design of open channels in Greeley shall follow the guidance in the USDCM for naturalized channels for bank stability, grade control, planform geometry, and cross section. Traditional concrete-lined and riprap-lined trapezoidal channels will only be considered through a variance. To safeguard building foundations in multi-family residential developments and apartment complexes, small concrete swales are permitted within 20 feet of building foundations. Specific City criteria for velocity, Froude number, and freeboard are included in this subsection.

Channels shall be revegetated in accordance with Section 12. When an open channel is adjacent to a roadway, the need for guardrail shall be determined in accordance with the latest versions of Volume 1 of the City's Design Criteria and Construction Specifications, which specifies criteria for the design of streets, and the Highway Safety Manual published by the American Association of State Highway Transportation Officials (AASHTO). Open channels not located on public property or right-of-way may be required to be located on an outlot not owned by the City.

A. Freeboard. For channels with a 100-year design flow of less than 20 cfs, at least 6" of freeboard is required during the 100-year event. For channels with a 100-year design flow of between 20 cfs and 400 cfs, 12" of freeboard is required. For channels with a 100-year design flow greater than 400 cfs, 18" of freeboard is required.

B. Velocity. The maximum normal depth velocity for the 100-year event is 5.0 feet per second regardless of the 100-year peak flow rate. The minimum desired velocity for the minor storm event is 2.0 feet per second. If no design is possible that meets both these criteria, the 100-year maximum velocity shall govern.

C. Froude Number. The maximum Froude number for the 100-year event is 0.8 for channels with cohesive soils or well-vegetated banks and 0.6 for channels with non-cohesive soils or poor vegetative cover. At least one soil sample for every 1,000' of channel alignment is required to confirm the cohesivity of the soils if the NRCS soil survey shows any Type A or B soils in the project area.

5.05 ROADSIDE DITCH DESIGN CRITERIA

The City intends to use curb and gutter and a storm drainage system along all new and improved roadways. Roadside ditches are not encouraged and will be subject to approval by the Stormwater Division. If a roadside ditch is approved, a fee will be assessed by the City that is commensurate with the anticipated cost of the enclosed storm drainage system that will ultimately need to be constructed at the site. The design of roadside ditches requires balancing velocity, capacity, available right-of-way, roadway slope, and cross-sectional geometry. The capacity requirements of a roadside ditch are based on the allowable flow depth and encroachment criteria in Section 6 for different roadway classifications.

This section discusses permissible velocities and Froude numbers for a roadside ditch. Roadside ditch hydraulic calculations shall be completed using Manning's equation. The Manning's roughness coefficients for calculating velocity, Froude number, shear stress, and capacity for other open channels will be used for roadside ditch calculations as well. The designer should note that if a ditch is expected to be vegetated there is a much higher potential for erosion until revegetation is complete. The use of erosion control measures such as turf reinforcing mat (TRM) prior to revegetation will minimize this potential. TRM is required if side slopes are approved to be steeper than 4H:1V or where 100-year velocities exceed 5 feet per second at any depth.

Roadside ditch flow with 100-year design depths less than or equal to 6" have no Froude number or velocity limitations. For ditch flow depths greater than 6", 100-year velocity shall not exceed 7.0 feet per second, and the Froude number shall not exceed 0.8 during the 100-year event. These criteria are in Table 5.05.1.

Table 5.05.1. Allowable Velocity and Froude Number for Roadside Ditches

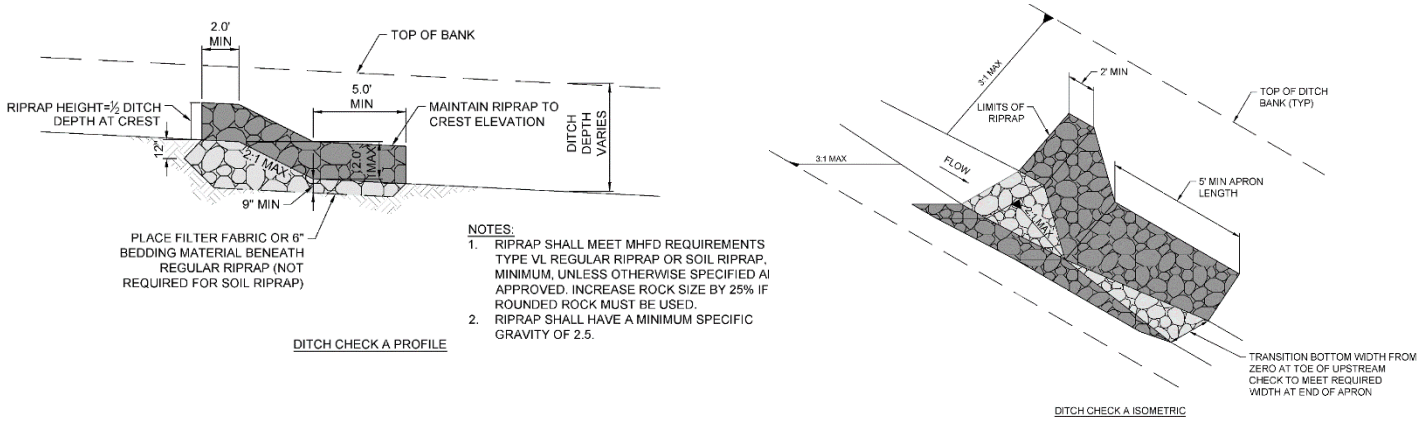
Design Component	Flow Depth ≤ 6"	Flow Depth > 6"
Velocity	No maximum	7.0 ft/s
Froude Number	No maximum	0.80

Roadside ditches should have side slopes no steeper than 4H:1V. If right-of-way is constrained, the ditch side slope adjacent to the roadway may be steepened to 2H:1V, and the ditch backslope,

the slope not immediately adjacent to the roadway, may be steepened to 1H:1V with approval from the Stormwater Division. Where right-of-way width is sufficient, roadside ditches shall have a flat bottom at least two feet wide, but ditches may be V-shaped if right-of-way is constrained. Roadside ditches should ideally be designed as grass-lined channels without the need for riprap revetment. If riprap revetment is required, buried soil riprap or void-filled riprap shall be used in accordance with the design guidance in the USDCM and the ditch shall be revegetated.

Where roadway slopes are too steep to accommodate a ditch design that will meet velocity or Froude number criteria, a flattened longitudinal ditch slope will be required. Ditch checks can be placed at intervals to make up for grade discrepancies. An example of a ditch check is shown in Figure 5.05.1. In no case shall a roadside ditch have a slope steeper than 4%, regardless of whether allowable velocity and Froude number values are met.

Figure 5.05.1. Ditch Check Schematic



5.06 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

5.07 REFERENCES

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SECTION 6
ROADWAY CONVEYANCE

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SECTION 6
ROADWAY CONVEYANCE

6.01 INTRODUCTION

This section discusses the conveyance of stormwater by roadways. The terms road and street may also be used interchangeably throughout to refer to any type of roadway. The primary function of roadways is the movement of traffic, but they also collect and convey runoff. The use of roadways as part of the drainage system must be limited to prevent interference with traffic. Roads must be designed to convey the runoff they collect to either a storm drain or open channel system. The roadway drainage system within the City is typically an enclosed storm drain system, discussed in Section 7, but in select locations may be an open channel system with roadside ditches, discussed in Section 5.

The City prefers to minimize sheet flow along roadways and will consider alternative approaches beyond the traditional enclosed drainage system. This may include elements such as trench drains along the gutter or slotted curbs that minimize the need for midblock manholes or cross pans at intersections. The user should coordinate with the Stormwater Division regarding alternative approaches to minimize sheet flow at the beginning of the project.

This section presents the limitations on stormwater in and along all roadways within the City regardless of the type of roadside conveyance used and regardless of if they are public or private. These limitations are established to maintain roadway function and safety during storm events. They are presented in terms of allowable flow depths at the curb face or the roadway crown and the width of roadway that must remain clear during a design storm event. Criteria vary based on the design storm and the street classification. When runoff in the street exceeds the allowable limits, a storm drain system, an open channel, or a combination of both is required to convey the excess flow. The most stringent criteria will apply.

6.02 HYDRAULIC CALCULATIONS

The capacity of any roadway section may be calculated in one of the two ways discussed in this subsection, both using resources provided by the MHFD.

A. Volume 1 of the USDCM includes detailed hydraulic calculations that may be used to calculate the hydraulic capacity of a roadway section. Special care must be used when ponding is allowed at the crown; the methodology is discussed in Volume 1. The recommended reduction factors for gutter flow on a steep slope must also be applied. Manning's n values of 0.016 for asphalt and 0.013 for concrete gutter shall be used, as recommended by the USDCM.

B. MHFD-Inlet, created by the MHFD to calculate street and inlet capacities, may also be used to calculate the hydraulic capacity of a roadway section. There is an option within MHFD-Inlet that may be selected to evaluate the product of gutter flow velocity and gutter flow depth at the curb (v*D product). This option must be selected to ensure flow velocity will meet the limits established later in this subsection. Manning's n values of 0.016 for asphalt and 0.013 for concrete shall be used, as recommended by the MHFD.

6.03 SUMP INLET REQUIREMENTS

Sump inlets are more prone to clogging than inlets on grade. Because sump inlets are at the lowest point in the vertical alignment of a street, a clogged sump inlet can cause significant flooding if an emergency overflow path is not provided. The City requires an emergency overflow path to be provided at all sump inlets to prevent flooding if the inlet becomes clogged. The overflow path shall be designed as an open channel in accordance with the Open Channels section of these criteria to convey the 100-year peak surface design flow for the sump inlet. The path of the peak discharge shall be contained within an outlot or easement on which construction is prohibited. See Section 13 for easement requirements. An outlot with common ownership such as a Property Owners Association (POA) or Homeowners Association (HOA) is required for single-family residential subdivisions; other land use types may use an easement provided construction on the easement is prohibited. The type of surfacing (e.g., pavement, landscape, turf grass, etc.) within the outlot or easement shall be shown on the Construction Drawings. Inundation limits during the 100-year storm shall be calculated and shown on the Basin Map for each sump inlet and discussed in the Drainage Report. The depth of ponding shall not exceed the maximum allowable water depth for the given street classification as summarized in this section of the criteria.

6.04 ALLOWABLE FLOW DEPTH & SPREAD

Each existing roadway within the City has been assigned one of eight street classifications based on its role within the roadway system and the volume of traffic it is expected to carry. These classifications are available from the City and will be assigned to proposed roadways as they are designed. The extent to which runoff from the minor or major design storm may encroach onto a roadway is based on street classification. Limiting the encroachment of stormwater onto a roadway section is the primary criteria by which public safety is maintained during a storm event.

Roadways will typically use either a roadside ditch or a curb and gutter section to convey stormwater along the roadway. Whether flow is conveyed by a curb and gutter section or roadside ditch does not affect the encroachment criteria because safety concerns remain the same for each street classification regardless of the type of roadside conveyance. The allowable encroachment onto the roadway for each street classification during the minor and major design storm is presented in Table 6.04.1. These criteria may include the width of the roadway that must remain free of water or the allowable depth of flow at certain points along the roadway cross section. Curb overtopping criteria applies only to streets with a curb and gutter section. In no case shall any roadway improvement, reconstruction, or expansion cause more stormwater encroachment on land or structures outside the public right-of-way than currently exists. The criteria in the table below apply to roads with roadside ditches, roads with curb and gutter sections, and culvert crossings. They do not apply to bridge crossings. Criteria for bridges are included separately in Section 8. Street inundation during both the minor and major storms must be analyzed for compliance with the criteria in this section.

Table 6.04.1. Maximum Allowable Flow Depth & Encroachment

Street Classification	Minor Storm[1]	Major Storm[2]
Arterial (Parkway, Major, Minor)	10’ clear each way	No depth at crown
Collector	10’ clear in center	Depth at crown ≤ 3”
Local (Commercial, Residential)	Flow may spread to crown	Depth at crown ≤ 6”
Local Low Volume	Flow may spread to crown	Depth at crown ≤ 9”
Alley	Flow may spread to alley edge	No additional criteria

[1] No curb overtopping. No encroachment is allowed on adjacent property.
[2] Depth at gutter flowline shall be less than 12”. Ponding shall be less than 12” below the finished floor of structures.

Where a roadside ditch is used in the absence of a curb and gutter system, it shall have sufficient capacity to meet the maximum encroachment and flow depth criteria in Table 6.04.1, except those criteria that reference curb overtopping, which do not apply. Roadside ditch design criteria are in Section 5.

6.05 ALLOWABLE VELOCITY

The City has no limitation on gutter flow velocity by itself, but for safety reasons, the product of the flow velocity (in feet per second) and depth (in feet) may not exceed 6.0 for the minor storm and 8.0 for the major storm in gutter sections. Allowable velocity in a roadside ditch is discussed in Section 5.

6.06 ALLOWABLE STREET CROSS-FLOW

Street cross flow is not desirable, especially at cross walks, due to safety concerns. Ideally, inlets will be located just upstream of intersections to capture runoff just before it reaches the intersection. However, the City does allow the use of cross pans to convey flow across a roadway in accordance with Volume 1 of its Design Criteria and Construction Specifications, which specifies criteria for the design of streets.

The Stormwater Division requires a minimum slope of 1% on all cross pans. Table 6.06.1 below includes the allowable street crossflow at intersections. While the use of cross pans is allowed, it is not encouraged. The City prefers to remove water from the roadway at the earliest opportunity or convey water under the roadway at intersections.

Table 6.06.1. Maximum Allowable Street Cross Flow

Street Classification	Minor Storm	Major Storm
Arterial (Parkway, Major, Minor)	None allowed	Max 6" depth above crown
Collector (Major, Minor)	Max 6" max depth above cross pan flowline (where cross pan allowed)	Max 12" depth above gutter flowline
Local (Commercial, Residential w/vertical curb)	Max 6" depth at street crown or in cross pan	Max 18" depth above gutter flowline
Local Low Volume (w/ rollover curb)	Max 6" depth at street crown or in cross pan	Max 18" depth above gutter flowline

Street crossflow is not allowed where a roadside ditch is used in the absence of a curb and gutter system.

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STORM DRAINAGE SYSTEM

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SECTION 7
STORM DRAINAGE SYSTEM

7.01 INTRODUCTION

A storm drain system refers to the system of inlets, pipes, manholes or junction boxes, outlets, and other appurtenant structures that are designed to collect and convey the minor storm runoff to a major drainage system. The storm drain system is a part of the local drainage system, which may also include curb and gutter, streets, roadside ditches, swales, and channels. This section presents both technical criteria and the general procedures for design and evaluation of pipes and inlets. Allowable roadway flow depth and encroachment is in Section 6.

7.02 DESIGN CRITERIA

A storm drain system is required when sump conditions exist and on Major and Minor Arterials to eliminate cross pans and ponding and icing near intersections. A storm drain system is also required if the allowable roadway capacity is exceeded during the minor storm event. All criteria and guidelines below apply to the minor storm event unless site conditions offer no viable overflow option for the major storm event. See the City's Standard Stormwater Details for additional requirements.

A. **Pipe Material**. Storm drain pipes shall be reinforced concrete pipe (RCP) or polypropylene pipe (PP). Storm drains that are not publicly maintained, have no anticipated vehicular load, and are less than 18" in diameter may be high density polyethylene (HDPE).

B. **Pipe Size**. The minimum allowable pipe size for publicly maintained storm drains, including those in easements or right-of-way, shall be 18". Contact the Stormwater Division for required minimum sizes for roof drain and underdrain connections.

C. **Pipe Cross Section**. All storm drains shall have a circular cross section. Elliptical and arched pipe should only be used when conditions prevent the use of circular pipe.

D. **Horizontal Pipe Alignment**. Storm drain horizontal alignments must be linear, and all storm drain pipes shall be accessible by CCTV camera. Manholes or junction boxes are required where there is a change in pipe size, slope, horizontal alignment, or material, and at all junctions of more than two pipes. Storm trunk line manholes shall generally be located offset from the face of all curb inlets so that storm drain alignments do not cut diagonally across intersections. Detail 8-3 in the City's Standard Stormwater Details provides an example.

E. **Horizontal Clearances & Utility Crossings**

1. The minimum horizontal clear distance between storm drains and sanitary sewers, water lines, or any other utility shall be 10'.

2. Storm drains outside the City right-of-way shall have a centerline alignment at least 30' from any building edge and at least 10' from any structure such as a fence or utility box or vault. Storm drains within a multifamily, patio home, or townhome development must be located in an outlot or stormwater easement on which no building may be constructed.

3. The City prefers that storm drains not be located under curb and gutter or sidewalk.

4. Any storm drain that crosses other utilities shall be perpendicular to those utilities. Any storm drain that crosses another utility requires a Public Space Permit. Any utility that crosses a storm drain shall be perpendicular to that storm drain. Any utility installations that cross existing storm drains also require a Public Space Permit. See Section 2 for additional information.

F. Vertical Pipe Alignment

1. The minimum depth of bury for storm drains shall be 12” or the depth recommended by the pipe manufacturer for an AASHTO HS-20 loading, whichever is greater, unless otherwise specified by the City.

2. The minimum allowable design slope for storm drains is 0.40%. The maximum allowable slope is established by allowable velocity. Manholes are required at all drops or changes in vertical alignment.

G. Vertical Clearances at Utility Crossings. This section is for open cut installations. Bored installations are in a later subsection. All utility crossings require a Public Space Permit.

1. The minimum clearance between a storm drain and a water main shall be 18". When a water line is below a storm drain, or less than 24" above it, the storm drain joints shall be coupled using a high performance, external joint coupler designed to prevent infiltration and exfiltration for a minimum of 10’ on each side of the crossing. No joint of the storm drain may be located directly above or below the water main; center a segment of storm drain over or under the water main.

2. The minimum vertical clearance between a storm drain and a sanitary sewer shall be 18”. When a sanitary sewer is above a storm drain, or less than 18” below it, the sanitary sewer shall have an approved encasement or be constructed of structural sewer pipe for a minimum of 10’ on each side of the crossing. No joint of the storm drain shall be installed directly above or below the sanitary sewer; center a segment of storm drain pipe over or under the sanitary sewer.

H. **Bored Utility Installations.** This subsection provides additional requirements for bored utility installations. Bored utility installations require a designed minimum of 3’ of vertical clearance below the storm drain pipe and 2’ of clearance above the storm drain pipe. The design clearance must be demonstrated by pothole data of all existing utilities along the proposed alignment. Bored installations require a Public Space Permit. If the stated clearances cannot be achieved, the Stormwater Division shall be contacted immediately to review the situation.

I. **Manhole Size.** The required diameter of the manhole barrel is dependent upon the size of the largest pipe connecting to it. Minimum manhole sizes are in Table 7.02.1 and assume the storm drain alignment passes straight through the manhole with no incoming lateral lines. If a storm drain system changes alignment or must accommodate incoming lateral lines at a manhole, a larger manhole may be needed to provide a minimum clear distance of 12” between the outsides of pipes. Manholes over 20’ deep require an intermediate platform. Manhole steps are required when the manhole depth exceeds 3.5’. See the City’s Standard Stormwater Details for details.

Table 7.02.1. Manhole Sizing

Max Pipe Dimension	Min Manhole Diameter
≤ 24”	4’ diameter
> 24 to ≤ 42”	5’ diameter
> 42”	6’ diameter or box base

J. **Manhole Location.** Manholes or junction boxes along storm drain alignments shall have their midpoints located no closer than 20’ apart and no farther than 400’ apart. Storm drain manholes shall not be placed in the center median of roundabouts. A manhole is also required at the transition between private and public storm drains.

K. **Storm Inlet Types**. Table 7.02.2 presents the types of inlets allowed for use in the City.

Table 7.02.2. Standard Inlets

Inlet	Location
City Type R	Streets or parking lots with curbs.
CDOT Type C	Along roadside or median ditches. Not allowed in streets or parking lots. A close mesh grate shall be used where pedestrians or cyclists may be present.
City Grated Type 13	Streets without curbs. Alleys, parking lots without curbs, or private drives with a valley pan. Use vane grates only along bike lanes, use valley grates otherwise.

The City’s standard inlets are based on standard inlets used by CDOT and the City of Denver, but they do have unique characteristics. Some of these include additional rebar in the top slab to tie to new sidewalk, manhole location details, and sloped inverts. See City Standard Stormwater Details for additional information.

L. **Storm Inlet Locations.** In addition to sump locations and where allowable roadway capacity is exceeded, storm inlets are also required immediately upstream of pedestrian ramps in lieu of along the curb return or between a curb ramp and the curb and gutter point of curvature. Figure 7.02.1 at the end of this section provides an example.

M. **Manning’s n**. Manning’s n values for pipe capacity and velocity calculations based on pipe material are in Table 7.02.3.

Table 7.02.3. Manning's n Values

Pipe Material	Manning's n
New Concrete Pipe Design	0.013
Existing Concrete Pipe Evaluation	0.015
Polypropylene (PP)	0.011
High Density Polyethylene (HDPE)	0.011

N. **Velocity.** The maximum flow velocity in any storm drain pipe shall be less than 16 feet per second at a normal depth of 0.8D to minimize the risk of hydraulic jumps and extreme head loss through junctions. The minimum flow velocity in any storm drain pipe shall be at least 3 feet per second at a normal depth of 0.25D to reduce sedimentation and promote positive drainage through the pipe.

O. **Energy & Hydraulic Grade Lines.** The storm drain system shall be designed to convey the minor storm without pressure flow, and the energy grade line (EGL) for the minor storm shall be at or below finished grade at all manholes, inlets, or other junctions. Inlets may not surcharge during the minor storm. If the major storm hydraulic grade line (HGL) is above the rim elevation of any structure, or if any structure is in a floodplain, the manhole cover(s) for that structure shall be bolted down.

   The EGL and HGL for both the minor and major storms shall be calculated and plotted for all storm drain systems. Hydraulic losses will include friction, expansion, contraction, and junction losses at a minimum. The methods for estimating these losses are presented later in this section.

P. **Outlets**. All storm drain outlets into open channels shall be constructed with a headwall and wingwalls or a flared end section. Riprap shall be provided at the outlet in the form of a blanket or low tailwater basin. Storm drain outlets into open channels shall meet the requirements of Section 8 for culvert outlets.

Q. **Connections to Existing Storm Drains.**

1. Underdrains are not permitted to discharge groundwater to the storm drainage system.
2. Any connection to an existing private storm drain system requires a signed Ownership and Maintenance Covenant (OMC). See Section 13 for details.
3. A privately owned and maintained manhole or storm drainage junction structure is required at the transition between private and public storm drains.
4. New storm drain connections to an existing storm drain system must be made at a manhole. Direct taps into an existing storm drain pipe are not allowed. When a new connection to an existing storm drain system is proposed, a video inspection of the existing storm drain system is required to the next downstream manhole to confirm its condition. The inspection video shall be provided to the Stormwater Division for review. If the video indicates any part of the existing system is in an advanced state of disrepair, the Stormwater Division may require rehabilitation or replacement of portions of the existing system prior to connecting a new storm drain.

5. A new storm drain connecting to an existing system must be 18” or larger unless it is a detention pond outlet pipe. Existing storm drains that are less than 18” in diameter must be replaced to meet current standards before a new connection is approved.

R. **Utility Conflict Structures.** The City has several storm manholes through which utility lines pass as well as utility manholes through which storm drains pass. These types of structures are no longer allowed. Any development site with these types of manholes must relocate the conflicting utilities, the storm drains, or both, to remove the utility conflict structures.

7.03 HYDRAULICS OF STORM INLETS

This section covers the general procedures for sizing and spacing of inlets in a storm drain system. Design calculations can be done manually, but this section focuses on using MHFD-Inlet to calculate street and inlet capacity. The USDCM provides additional details on the equations and methodologies that have been incorporated into MHFD-Inlet.

A. **Inlet Location.** Inlets on a continuous grade are located so that ponding will not occur even if the inlet is at capacity. Flow will bypass the inlet instead. In contrast, sump inlets are located at roadway sags or similar low points that will not allow water to bypass once the inlet reaches capacity. A sump condition can occur at a change in street grade from positive to negative or at an intersection due to the crown slope of a cross street. To help prevent ice build-up and allow for proper flow, consideration should be given to not locating inlets in areas that will be heavily shaded during the winter months, particularly on the north side of buildings and trees.

B. **Inlet Capacity.** Inlet capacity may be calculated using MHFD-Inlet developed by the MHFD, or by hand, using the calculation procedures in the USDCM. MHFD-Inlet is an Excel-based program that calculates both street and inlet capacities based on several parameters entered by the user. The procedure consists of defining the amount and depth of flow in the gutter and determining the theoretical flow interception by the inlet. The calculations within MHFD-Inlet are based on physical research completed at Colorado State University. The most recent version of MHFD-Inlet can be obtained via an internet search for MHFD-Inlet or from the MHFD website (https://mhfd.org/resources/software/). Additional information specific to inlets on grade and in sump conditions is included later in this section.

Table 7.03.4 shows which inlet within MHFD-Inlet should be used to approximate each of the City’s standard inlets.

Table 7.03.4. MHFD-Inlet Selection

Inlet	MHFD-Inlet Selection
City Type R Inlet	CDOT Type R Curb Opening
CDOT Type C Inlet	CDOT Type C Grate[2]
City Grated Inlet Type 13	CDOT/Denver 13 Valley Grate[1]
City Combination Inlet Type 3	User-Specified Combination

[1] When this inlet is along a bicycle lane, select a Denver No. 16 Valley Grate inlet.

[2] The MHFD-Inlet selection of a Type C inlet applies to both standard and close mesh options.

When selecting User-Specified Combination for the type of inlet, the program will ask what the grate type is. When an inlet is along a bicycle lane, select a Denver No. 16 Valley Grate. When an inlet is not along a bicycle lane, select a Denver No. 13 Valley Grate. Do not select a sweeper configuration.

Additional information required by MHFD-Inlet includes design flow, height of curb, distance from curb face to street crown, gutter width, street cross and longitudinal slopes, gutter cross slope, Manning's n for the street, maximum allowable spread from gutter flow line, maximum allowable depth at gutter flow line, and allowable flow depth at the street crown. If flow is allowed behind the curb, the allowable spread width behind the curb and side slope behind the curb, and Manning's n behind the curb must also be entered. The spreadsheet can use the Rational Method to calculate a design flow or will accept a flow entered by the user. If the inlet receives bypass from an upstream inlet, the bypass flow can be entered or retrieved from another MHFD-Inlet spreadsheet. Default clogging factors included in MHFD-Inlet shall be used to account for potential debris clogging, pavement overlaying, and varying design assumptions.

Manning's n values of 0.016 for asphalt and 0.013 for concrete shall be used, as recommended by the USDCM.

1. Continuous Grade Condition. The capacity of an inlet on grade is dependent on street slope, depth of flow in the gutter, height and length of curb opening, street cross slope, and the amount of depression at the inlet. Cost effective inlet design will allow for some bypass. The amount of carryover must be included in the drainage facility evaluation as well as in the design of the inlet.

2. Sump Condition. The capacity of each sump inlet is dependent on depth of flow in the gutter, height and length of curb opening, street cross slope, and the amount of local depression at the inlet. An overflow path must be designated for each sump inlet in case it loses functionality. The major storm peak design flow to the sump inlet must be safely conveyed within the overflow path without impacting adjacent structures.

C. **Inlet Spacing.** The optimum spacing of inlets depends on several factors, including traffic requirements, contributing land use, street slope, allowable street capacity, and distance to the nearest outfall. Sizing and spacing of the inlets should be based on an ideal interception rate of 70% to 80%. This spacing has been found to be more efficient than a spacing using a 100% interception rate; although, the downstream-most inlet will still need to be designed to intercept 100% of the flow. Considerable improvements in overall system efficiency can be achieved if the inlets are placed in local sumps created by street intersections.

Inlet spacing is typically an iterative process, and the designer may have to move inlet locations multiple times before determining the appropriate spacing to meet design criteria and maintain efficiency. After initial inlet locations are determined, the designer should recalculate the peak flow to each inlet and check that the allowable street capacity has not been exceeded. If the actual flow is less than the allowable street capacity, inlets may be spaced further apart to prevent overdesign of a system. Locating inlets is a balance between meeting criteria and efficient design. It is not usually possible to have optimum inlet spacing throughout an entire storm drain system.

7.04 HYDRAULICS OF STORM DRAINS

This section covers the general aspects of hydraulic design and evaluation of storm drains. Hydraulic design calculations can be done manually with a spreadsheet or by using a computer model. Both methods are briefly discussed below. The user is assumed to possess a basic working knowledge of storm drain hydraulics and is encouraged to review technical literature available on the subject as needed.

A. **Manual Calculations**. Manual storm drain hydraulic calculations shall be performed in accordance with the HEC-22 (Brown et al., 2013) or the latest version of the USDCM. Procedures and coefficients presented in HEC-22 shall be used for design unless specifically noted otherwise herein. HEC-22 includes a discussion of both open channel and pressure flow within a storm drain system and includes a design example.

1. **HGL and EGL.** Two of the critical design elements of a storm drain system are the HGL and the EGL. The HGL is a line that represents the water surface elevation. In pressure flow, the HGL is the level to which water would rise in a vertical tube at any point along the pipe. The EGL is an imaginary line that represents the total energy at any point in the system. Total energy includes elevation head, velocity head, and pressure head and is the HGL plus the velocity head ($V^2/2g$). The total energy at any location equals the energy at any downstream location plus the losses that occur between the two locations.

2. **Losses.** Losses, also called headlosses, are typically classified as either friction or form losses. Friction losses occur as water flows along the length of a pipe. Form losses occur at the exit from the system and at junction structures within the system. Because the City does not allow transitions or bends outside of manholes, form losses are restricted to exit losses when flow leaves the system and structure losses, such as through inlets or manholes. These are referred to by HEC-22 as inlet and access hole losses.

B. **Computer Model Calculations**. Computer models are often used to calculate the HGL and EGL of storm drain systems. The benefits of using a computer model include consistency, speed, and the ability to check the validity of the model with relative ease. One disadvantage of computer modeling is that errors can occur and be hidden if the model user is inexperienced. Three common programs used throughout Colorado include those listed below. Additional software may be used if approved by the City, provided it utilizes industry-standard calculation methods.

1. UD-Sewer 2009 is a simple and free program developed by the MHFD that is easy to learn. Note that while MHFD still provides UD-Sewer on their website as of the writing of this criteria, MHFD no longer supports this software.

2. Autodesk® Storm and Sanitary Analysis is a design tool which runs within the AutoCAD Civil 3D design software package by Autodesk.

3. StormCAD is a design tool which runs within the MicroStation design software package by Bentley Systems.

7.05 SYSTEM DESIGN METHODOLOGY

This section presents the general procedure used to design a storm drain system from conceptual through final design, mirroring the submittal phases discussed in Section 2. A typical local drainage system consists of flow in the storm drain and allowable flow in the gutter and street. These flows are ultimately discharged to a larger drainage system or an open channel with capacity for a much larger event.

A. **Conceptual Design.** The conceptual design of the storm drain system begins when a parcel is rezoning or annexing in the City of Greeley or if there is a large parcel being developed such as a large retail center. Conceptual plans and reports will be required to delineate the general development areas, major drainage paths, and drainage outfall locations. Allocation of space for drainage facilities and considerations shall be incorporated into the conceptual development plan that account for the entire development. The drainage engineer must have input into the development plan to ensure proper drainage planning for the entire development.

   Regardless of if a development will be fully constructed simultaneously or if it is expected to be constructed in phases over several years, a master storm drainage utility plan for the site must be developed to ensure each component of the system is sized to account for the full future development. Regardless of the timing of construction for each portion of the development, accommodation must always be included for stormwater management and conveyance that will also adequately function for the full future development.

B. **Preliminary Design.** The preliminary design of the storm drain system begins once a preliminary development plan has been prepared that delineates the general development areas, major drainage paths, and drainage outfall locations. Allocation of space for drainage facilities and considerations shall be incorporated into the preliminary development plan. The drainage engineer must have input into the development plan to ensure proper drainage planning.

   1. Gather Basic Data. The first step in any drainage project is the collection of basic data. Information typically required is as follows.

      a. Topographic maps of the development and drainage basins that show existing and proposed roadways, existing and proposed land uses, major drainage features such as creeks and streams, development area, and property boundaries

      b. Typical street cross sections

      c. Preliminary grading information, such as contours, profiles, and control elevations

      d. Soils information

      e. Existing and proposed utilities

      f. Existing irrigation facilities and requirements for maintaining facilities

      g. Rainfall information

2. Perform Hydrologic Analysis. Perform the hydrologic evaluation of the drainage basins for both the minor and major storms, typically using the Rational Method. Divide each basin into smaller subbasins and calculate the peak design flow for each hydrologic point of interest. The degree of basin subdivision will depend on the detail of information available and the experience of the engineer. Basin delineations must be completed at a minimum at each inlet location.

3. Complete Preliminary Sizing. Preliminary sizing should be completed for the minor storm. Beginning at the upper end of each basin, calculate the quantity of flow in the street until the allowable capacity of the street matches the design runoff. The storm drain system will start at this point, provided that no alternate method of removing runoff from the street exists. Removal of all the street flow by the storm drain system is not required, except at sump areas, and is typically not economical. The sum of the flow in the storm drain plus the flow in the street must be less than or equal to the allowable capacity of the street and storm drain.

   For preliminary sizing purposes, the diameter, type, and slope of pipe is generally sufficient. Manning's n values should be those in Table 7.02.3. In some instances, a profile may be required to check utility conflicts or to ensure compatibility with the major drainage system. The preliminary vertical alignment should not be steeper than the proposed street grade. The designer should also be aware of utility considerations, especially when crossing water and sanitary main and service lines.

4. Route the Major Storm. After sizing the storm drain system, route the major storm through the system and compare the flows to the allowable capacity. The combined total of the allowable street capacity during the major storm and the storm drain capacity during the major storm should equal or exceed the 100-year runoff. A plan and profile of the pipes, EGL, and HGL will be required. If the combined allowable capacity is less than the design flow, some of the following actions may be taken:

   a. Increase storm drain size.

   b. Increase street grade within acceptable limits or revise street classification to allow additional capacity.

   c. Revise major drainage system so that runoff is collected further upstream.

   d. Provide additional onsite detention within the development to decrease peak flow.

5. Evaluate the Preliminary Design. In addition to a construction cost estimate for the proposed improvements, the preliminary system can also be evaluated by developing alternatives and comparing the total benefits. The impact of the system outfall on downstream properties must also be identified and mitigated if problems exist.

C. **Final Design.** Final design consists of final revisions to the storm drain system model and preparation of plans, profiles, and specifications for the storm drain system in enough detail for construction. Basic data, hydrologic analysis, and inlet sizing performed for the preliminary design should be reviewed and verified. Drainage subbasin boundaries should be confirmed or revised as necessary, and design peak flows should be recalculated accordingly.

Pipe and inlet sizes and locations are then finalized while taking into account final street and storm drain grades, locations of existing and proposed utilities, and the design of the major drainage system. The EGL and HGL should be revised accordingly including energy losses at manholes and any other structures. If special transitions are required to reduce losses, the structural design of the facilities must include energy loss considerations.

7.06 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

7.07 REFERENCES

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SECTION 8
CULVERTS & BRIDGES

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SECTION 8
CULVERTS & BRIDGES

8.01 INTRODUCTION

Culverts and bridges convey surface water through or beneath an embankment such as a highway, railroad, or canal. Culverts are different from storm drainage system pipes in that they are open at each end. The size, alignment, and support structures of a culvert or bridge directly affect their capacity and the capacity of the larger drainage system they are a part of. An undersized culvert or bridge can force water out of the channel and cause flooding and damage. Culverts and bridges may significantly influence upstream and downstream flood risks, floodplain management, and public safety.

8.02 CULVERT SIZING AND DESIGN STANDARDS

A. **Materials.** Culverts shall be reinforced concrete pipe (RCP), reinforced concrete box (RCB), or polypropylene pipe (PP). Corrugated metal pipe (CMP) is not allowed. RCB may be precast or cast-in-place. Culverts that are not publicly maintained, have no anticipated vehicular load, and are less than 18” in diameter may be high density polyethylene (HDPE). Section 7 includes additional criteria.

B. **Size.** Culverts crossing public roadways shall have a minimum vertical dimension of 24” and shall be owned and maintained by the City. Roadside ditch culverts for driveways shall have a minimum vertical dimension of 12” and shall be maintained by the property owner, regardless of if the driveway culvert is in the public right-of-way. Culverts will be sized to meet allowable flow depth and encroachment criteria and maximum allowable headwater criteria. Flow depth and encroachment criteria are in Section 6, and allowable headwater criteria is later in this section.

C. **Structural Loading & Minimum Cover.** All culverts shall be designed to withstand an HS-20 loading, unless designated otherwise by the City, in accordance with AASHTO design procedures, appropriate ASTM standards, and the pipe manufacturers' recommendations. Trench installations shall be in accordance with the most recent edition of the CDOT M&S Standard Plans.

   The minimum cover in all instances shall be 12” for pipe culverts with a vertical dimension of 24” or less and 24” for pipe culverts with a vertical dimension greater than 24”. Box culvert cover requirements shall be in accordance with the CDOT M&S Standards. Minimum and maximum cover may be revised with an approved variance if documentation is submitted showing the culvert size, material, class, bedding material, bedding condition, cover material, and expected surface loading can support such a request.

   Subgrade compaction and bedding requirements based on recommendations from a geotechnical investigation must be provided for culverts with a vertical dimension exceeding 48” to minimize settling.

D. **Velocity & Outlet Protection.** A minimum flow velocity within the culvert of 3 feet per second is required so that sediment will not accumulate in the culvert. The minimum flow velocity should be calculated using the Manning’s equation and assuming open channel flow and a normal depth equal to 0.25 times the vertical dimension of the culvert. Manning’s n values are presented in Table 8.02.1.

Table 8.02.1. Manning's n for Culverts

Pipe Material	Manning's n
Concrete (RCP, RCB)	.013
Polypropylene Pipe (PP)	.011
High Density Polyethylene (HDPE)	.011

The design must also include revetment to protect the outlet from erosion caused by the maximum velocity exiting a culvert. Table 8.02.2 presents the required culvert outlet protection based on maximum culvert exit velocity. Maximum exit velocity shall be calculated using the major storm design flow and the methods described later in this section. Outlet protection shall be provided at both the inlet and outlet of every culvert until velocities fall below 5.5 feet per second.

The most common type of culvert outlet protection is riprap, either as a riprap apron or as a low tailwater basin. Procedures for designing a riprap apron or low tailwater basin downstream of a culvert outlet, including for multiple conduit installations, can be found in the MHFD's USDCM Hydraulic Structures chapter. These procedures are applicable for Froude numbers up to 2.5. Section 9 provides information on the design of culvert outlet protection.

Table 8.02.2. Required Culvert Outlet Protection

100-year Culvert Exit Velocity (V)	Required Protection
$V < 5.5$ fps	None
5.5 fps $\leq V < 16$ fps	Riprap apron or low tailwater basin
$V \geq 16$ fps	Energy dissipation structure

The culvert slope should be as flat as practicable to limit the amount of revetment that is required at the outlet. A riprap apron shall be used when the culvert is discharging to a well-defined channel that can be expected to have a tailwater elevation equal to at least one-third of the height of the discharging conduit. If a pipe or culvert discharges at an angle into a channel, the length of the riprap apron will require riprap to extend up the opposite channel bank if the design length is greater than the channel bottom width. A low tailwater basin may be used in lieu of a riprap apron when the receiving channel may have little or no tailwater or where the receiving channel is not well defined.

E. **Headwalls, Wingwalls, & End Sections.** All culverts in or crossing the public right-of-way must have headwalls and wingwalls in accordance with CDOT M-601-10 or flared end sections at the inlet and outlet. Private driveway culverts up to 30" in diameter may have projecting ends. Flared end sections at the downstream end of a culvert must have a toewall extending at least 3' below the pipe invert in accordance with the City's detail. Flared end sections may be used on pipes with diameters up to 48" and must include joint restraints in accordance with CDOT M-603-10. Headwalls must be used for pipes with a vertical dimension larger than 48". Headwalls and wingwalls shall be in accordance with the most

recent edition of the CDOT M&S Standard Plans and shall be located so that the grade between the back of the structure and the edge of the shoulder or back of walk is no steeper than 3H:1V.

F. **Allowable Headwater Depth.** Headwater is the depth of water at the upstream face of a culvert, measured from the culvert invert to the water surface elevation. Allowable headwater depth for the 100-year event shall be 1.5 times the culvert diameter (D), or 1.5 times the vertical dimension (H) for boxes . There are no criteria for the minor event. Allowable headwater may be limited by the street encroachment requirements in Section 6. An approved variance is required for 100-year headwater depths greater than 1.5D or 1.5H, and detailed calculations of outlet velocity and a narrative discussing the safety of such deep headwater is required.

G. **Roadway Overtopping.** See Section 6 for allowable flow depth over and encroachment into roads for the minor and major storm based on roadway classification. The following procedure shall be used to size a culvert to meet the roadway encroachment criteria:

1. Using the future developed conditions 100-year runoff, determine the allowable street overtopping from overflow rating curves developed from the street profile crossing the waterway.
2. Size the culvert for the difference between the 100-year runoff and the allowable overtopping.
3. The criteria are considered a minimum design standard and must be modified where other factors apply. For example, if the procedure results in structures being placed or remaining in the floodplain, the design may be revised to lower the headwater.

H. **Trash & Safety Grates.** Culverts can be a hidden danger in nearly every community. There have been dozens of instances of people being sucked into culverts during large storm events, often resulting in their death. Where a clear and present danger exists such as at a siphon; a drop in elevation adjacent to a sidewalk or road; a culvert at which daylight cannot be seen from one end to the other; a culvert smaller than 42" in diameter; culverts with bends or vertical drops; culverts that are near playgrounds, parks, and residential areas; or any location determined by the City, a grate at the inlet and outlet of the culvert may be required. For most pipes through embankments and under streets, grates will not be required. See the USDCM for additional design considerations, discussion, and potential exceptions.

The MHFD is actively researching effective safety grate designs, and it is anticipated that detailed written design guidance will be forthcoming. A presentation recorded at the 2022 MHFD annual symposium is available on the MHFD YouTube channel called *Diving into Safety Grates* that presents some initial draft guidance. A subsequent presentation recorded at the 2024 symposium titled *Safety Grate Update for Small Pipes and Culverts* provides updated information. Additionally, the MHFD published a memo in May 2024 titled *Safety Grate Recommendations for Circular Pipes*, . The information presented by the MHFD over the past few years has been used to develop the criteria below that shall be used to design culvert safety grates until the USDCM is updated to include formalized criteria. The SDDC user is encouraged to view the videos and read the memo for additional nuance and clarification. Note that it is likely that additional videos and memos may be published prior to new criteria being published, and the SDDC user should review these as they become available.

1. Slope the face of the grate at 1H:1V.
2. Provide an 18” offset at the top of the grate to serve as a platform.
3. Use a grate bar spacing of 5” with a 5” clear space at the bottom of the grate.
4. Design the grate to be hinged and removable.
5. Minimize the use of cross bars to limit clogging.
6. Provide a grate open area at least 4 times the open area of the culvert.
7. Use smooth steel pipes with a minimum outside diameter of 1.25". Use steel angles for ends and bracing. Provide corrosion protection on all grate elements.
8. Design the grate for a fully clogged condition at the 100-year water surface elevation or 250 psf, whichever is greater.

Hydraulic losses through the grate shall be calculated using equation 8.02.1:

$$H_T = 0.11(TV/D^2)(\sin A) \qquad (8.02.1)$$

Where: H_T = headloss through grate (ft)
T = thickness of grate bars (in)
V = normal velocity through grate (fps)
D = center-to-center bar spacing (in)
A = angle of grate from horizontal

This equation applies to grates normal to the flow. The normal velocity through the grate shall assume the grate is 50 percent clogged.

8.03 CULVERT HYDRAULICS

This section presents general procedures for hydraulic design and analysis of culverts. The user is assumed to possess a basic working knowledge of culvert hydraulics and is encouraged to review the technical literature on the subject that is included in Hydraulic Design Series 5 (HDS-5), Hydraulic Design of Highway Culverts, published by the FHWA) and the USDCM. The two primary types of culvert flow are inlet control and outlet control. Under inlet control, the cross-sectional area of the barrel, inlet geometry, and headwater are the factors that affect capacity. Outlet control involves the additional consideration of tailwater and the slope, roughness, and length of the culvert barrel. Figure 8.03.1, Culvert Design Form, included at the end of this section, is a template for culvert hydraulic analysis that can be used with the information and equations below. All culvert designs shall include an analysis to determine whether inlet or outlet control conditions govern for both minor and major storm runoff.

A. **Inlet Control.** Under inlet control conditions, the slope of the culvert is steep enough that the culvert does not flow full. The control section of a culvert operating under inlet control is located just inside the entrance. Inlets may be either unsubmerged or submerged. In an unsubmerged condition, the headwater height is not sufficient to submerge the top of the culvert and the culvert slope is supercritical. In this situation, the culvert inlet acts like a weir. In a submerged condition, the headwater submerges the top of the culvert, but the pipe does not flow full. In this situation, the culvert inlet acts like an orifice.

The equation governing the culvert capacity in the submerged condition is the orifice equation. However, because of the uncertainty in estimating the orifice coefficient for a

submerged culvert inlet, inlet control nomographs published in FHWA HDS-5 shall be used to determine headwater height for submerged inlets operating under inlet control. Nomographs are online in HDS-5. The most recent edition does not include nomograph 29B; all nomographs referenced in this section are included as Figure 8.03.2 at the end of this section. Table 8.03.1 provides the appropriate inlet control nomograph to use for various types of culverts and end treatments. The FHWA has not published inlet control nomographs for plastic pipe. In their absence, the nomographs for concrete may be used for round PP and HDPE with a smooth interior wall.

Some of the more commonly used nomographs are included at the end of this section, cumulatively designated as Figure 8.03.2, Common Nomographs. The remainder can be found in the second edition of HDS-5. Table 8.03.1 provides the appropriate chart to use for various types of culverts and end treatments. HDS-5 also provides the background calculations used to develop the nomographs.

Table 8.03.1. Inlet Control Nomograph Selection

Material	Cross Section	End Treatment	Chart
Concrete, Plastic	Circular	None (Projecting), Headwall	1B
Concrete, Plastic	Circular	Flared end section[1] (use scale 1)	55B
Concrete	Horiz. Elliptical	Headwall, Projecting (use scale 1 for FES)	29B
Concrete	Rectangular	Wingwalls, angle, and headwall bevel vary	8B-13B

[1] End sections conforming to fill slope are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control (HDS-5, 2012).

B. **Outlet Control.** Outlet control occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. Either subcritical or pressure flow exists in the culvert barrel under these conditions. Outlet control will govern if the headwater is deep enough, the culvert slope is sufficiently flat, or the culvert is sufficiently long.

Outlet control generally exists under two conditions. The first, and less common, occurs when headwater depth is not high enough to submerge the top of the culvert and the culvert slope is subcritical. The more common outlet control condition exists when the culvert is flowing full. A culvert with a submerged inlet and an unsubmerged outlet may also operate under outlet control, especially if it has a long barrel length or a flat enough slope. Culverts under outlet control may flow full or partly full, depending on various combinations of hydraulic factors.

Culvert capacity under outlet control is calculated using Bernoulli's equation. An energy balance is determined between the headwater at the culvert inlet and at the culvert outlet and includes inlet losses, friction losses, and velocity head. The general equation is expressed as:

$$H = h_e + h_f + h_v \qquad (8.03.1)$$

Where: H = total energy head (headwater elevation minus tailwater elevation) (ft)

h_e = entrance head loss (ft), $K_e V^2/2g$ h_v = velocity head (ft), $V^2/2g$

h_f = friction losses (ft)

K_e = entrance loss coefficient per Table 8.03.2

Friction loss is the energy required to overcome the culvert barrel roughness and is calculated by the following equation.

$$h_f = (29n^2L/R^{1.33})(V^2/2g) \quad (8.03.2)$$

Where: n = Manning's coefficient
L = length of culvert (ft)
R = hydraulic radius (ft)
V = velocity of flow (ft/s)
g = gravity, 32.2 ft/s^2

Table 8.03.2. Culvert Entrance Loss Coefficients, K_e, for Outlet Control

Structure and Entrance Type	K_e	Structure and Entrance Type	K_e
RCP, PP, HDPE		RCB	
Headwall, socket end of pipe	0.2	Wingwalls at 30° to 75° to barrel	
Headwall, square edge	0.5	Square edge at crown	0.4
Projecting from fill, socket end	0.2	Rounded or beveled top edge	0.2
Projecting from fill, square cut end	0.5	Wingwalls at 10° to 25° to barrel	
Mitered to conform to fill slope	0.7	Square edge at crown	0.5
Side- or slope-tapered inlet	0.2	Wingwalls parallel (side extensions)	
Beveled edges, 33.7° or 45° bevels	.02	Square edge at crown	0.7
Rounded (radius = D/12)	0.2	Side- or slope-tapered inlet	0.2
End section that conforms to fill slope[1]	.05	No wingwalls	
HDPE/PP [2]		Square edge on 3 sides	0.5
Projecting from fill	0.9	Rounded or beveled on 3 sides	0.2

[1] End sections that conform to fill slope are commonly available. From limited hydraulic tests, they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections have a superior hydraulic performance. These sections can be approximated by using the information given for the beveled inlet.

[2] Conditions not listed specifically for HDPE or PP with a smooth interior wall have the same coefficient as RCP. The "projecting from fill" value given for HDPE is an approximation based on published values for CMP.

Combining the equations yields the following equation, which can be used to calculate culvert capacity directly only when the tailwater is at or above the crown of the culvert outlet.

$$H = (K_e + 1 + 29n^2L/R^{1.33})(V^2/2g) \quad (8.03.3)$$

When the tailwater is below the culvert outlet crown, the tailwater depth used for calculations shall be the larger of the tailwater anticipated in the downstream channel at the culvert outlet and the average of the critical depth in the culvert and the culvert diameter, $(D+d_c)/2$. The FHWA has determined the average of the critical depth and the culvert diameter to be an adequate approximation for tailwater depth for culverts that flow partially full. Critical depth calculation is a direct process for a box culvert but an iterative one for a circular pipe that is easily accomplished with a spreadsheet. Critical depth occurs when the Froude number is

equal to 1.0. The flow area and top width will be those that occur at critical depth in the pipe. Many online tutorials are available.

$$F_r = \frac{v}{\sqrt{gD_h}} \qquad (8.03.4)$$

Where: Fr = Froude number
v = velocity (ft/s)
D_h = hydraulic depth (ft), A/T
T = top width of flow area (ft)
g = gravity, 32.2 ft/s^2
A = flow area (ft^2)

In addition to equation 8.03.3, outlet control nomographs published by the FHWA in HDS-5 can also be used to calculate the required headwater under outlet control conditions where the outlet is submerged. Outlet control nomographs can be found online in the second edition of HDS-5, publication number FHWA-NHI-01-020. Later editions do not have as many nomographs. Table 8.03.3 provides the appropriate outlet control nomograph to use for various types of culverts. The FHWA has not published outlet control nomographs for plastic pipe. In their absence, the nomographs for concrete may be used for round HDPE with a smooth interior wall. End treatments do not affect outlet control.

Table 8.03.3. Outlet Control Nomograph Selection

Material	Cross Section[1]	Chart
Concrete, Plastic	Circular	5B
Concrete	Horizontal Elliptical	15B
Concrete	Rectangular	33B

Culvert capacity shall be computed using the Culvert Design Form in Figure 8.03.1 at the end of this section. An example calculation for sizing a roadway crossing culvert is provided at the end of this section. The FHWA HDS-5, Hydraulic Design of Highway Culverts, offers extensive guidance on the design of culverts that are under roadways and that may be used in conjunction with the requirements of this SDDC.

C. **Evaluation of Results.** If the culvert selected will not fit the site, return to the design process, and select another culvert. Repeat the design process until an acceptable culvert configuration is determined. Compare the headwater elevations calculated for inlet and outlet control. The higher of the two is the controlling headwater elevation. The culvert can be expected to operate with that higher headwater for at least part of the time.

If outlet control governs and the headwater depth is less than 1.2D, it is possible that the barrel flows partly full through its entire length. In this case, caution should be used in applying the approximate method of setting the downstream elevation based on the greater of tailwater or (dc + D)/2. If an accurate headwater is necessary, backwater calculations should be used to check the result from the approximate method. If the headwater depth falls below 0.75D, backwater calculations are required.

D. **Outlet Velocity Calculation.** The outlet velocity may be calculated as follows:

1. If the controlling headwater is based on inlet control, determine the normal depth and velocity in the culvert barrel. The velocity at normal depth is assumed to be the outlet velocity.
2. If the controlling headwater is based on outlet control, determine the area of flow at the outlet based on the barrel geometry and the following:
    a. Critical depth if the tailwater is below critical depth.
    b. Tailwater depth if the tailwater is between critical depth and the top of the barrel.
    c. Height of the barrel if the tailwater is above the top of the barrel.

E. **Computer Applications.** Although the procedures and nomographs for analyzing culvert hydraulics are still used, engineers increasingly use computer applications to design culverts. The applications approved for use are the FHWA's HY-8 Culvert Analysis Program, Bentley's OpenFlows CulvertMaster, and the MHFD's MHFD-Culvert spreadsheet, all of which may be used to calculate roadway overtopping, inlet and exit velocity, and hydraulic grade line. Others may be used if approved by the Stormwater Division.

8.04 BRIDGES

Bridges may be required to cross major open channels. A bridge is any structure having a total opening width of 20' or more along the centerline of the roadway. Improperly designed bridges can cause excessive scour or deposition or may not be able to pass the design flow. Backwater caused by bridges can cause flooding of upstream property, overtopping of roadways, or costly maintenance. Bridge openings should have as little effect on the flow characteristics as is reasonable, consistent with good design and economics. The criteria in this section apply to bridges on public and private roads.

All bridges shall be designed in accordance with the latest edition of the USDCM and HEC-18, although the criteria in this SDDC will take precedence if there is a discrepancy. All bridges adjacent to roadways, regardless of category, must also adhere to the encroachment and overtopping requirements in Section 6. Design flow rates shall be those specified by FEMA or as calculated in accordance with the SDDC.

It is possible that a bridge designed to meet these criteria may be on a roadway that becomes flooded during the storm event the bridge is designed to pass. New bridges shall be designed to the standards of this manual regardless of adjacent roadway flooding because roadways that experience frequent flooding may be reconstructed in the future to achieve a greater level of protection.

A. **Bridge Sizing Criteria.** Bridge freeboard is the vertical distance between a design water surface elevation and the low chord of the bridge superstructure. The low chord of any public bridge shall provide a minimum freeboard.

    Criteria for bridge freeboard vary throughout Colorado from 1' to 4' depending on the jurisdiction and risk of debris. FHWA's Hydraulic Design Series (HDS) 1 (1978), 6 (2010), 7 (2012), or 20 (2012), AASHTO's Highway Drainage Guidelines (2007), or AASHTO's Drainage Manual (2014) all provide guidance on freeboard considerations.

In the City of Greeley, all bridges on Collector, Local, and Local Low Volume roadways, or with a 100-year flow less than 1,000 cfs, shall have a low chord elevation set at or above the energy grade line (EGL). All bridges on Arterial roadways, or where the 100-year flow is more than 1,000 cfs, shall have a low chord elevation set at least 1' above the EGL. The City may require more stringent freeboard requirements for any bridge based on specific site conditions.

B. **Hydraulic Analysis.** The hydraulic analysis of a bridge opening is a complicated undertaking. Design calculations for all bridges must be prepared and certified by a licensed Colorado Professional Engineer. The procedures for design as outlined in the FHWA's HDS-7, Hydraulic Design of Safe Bridges (2012) shall be used for the hydraulic analysis of the proposed design. HEC-RAS may be used to complete the hydraulic analysis of bridge openings provided the guidance in the publication is followed. All bridges are assumed to remain in place during all storm events and shall not be assumed to break away or otherwise be removed for modeling purposes.

C. **Inlet and Outlet Configuration.** Where bridge abutments and foundations are located below the 100-year water surface elevation, concrete wingwalls shall be tied to the existing side slopes to prevent erosion behind the abutments and to provide slope stabilization from the top of the embankment to the toe of slope. Riprap protection on the inlet and outlet transition slopes shall be provided to prevent erosion caused by eddy currents.

D. **Scour Analysis and Countermeasures.** Scour at bridge foundations can lead to the collapse of the structure. Velocity limitations through the bridge opening are intended to limit scour. Regardless of the results of the scour analysis, a maximum 100-year average channel velocity of 16 feet per second shall be allowed through a bridge opening.

Whenever a new or replacement bridge is designed, it is critical that scour depths at piers and abutments be estimated. The scour estimate must consider subsurface data and a hydraulic analysis of the proposed design.

The FHWA has published a set of Hydraulic Engineering Circulars to provide guidance for bridge scour and stream stability analysis. The set includes HEC-18, Evaluating Scour at Bridges, HEC-20, Stream Stability at Highway Structures, and HEC-23, Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance. The latest editions of each shall be used in concert with each other to evaluate stream stability, potential scour, and appropriate scour countermeasures. HEC-RAS may be used to provide the raw data required for the HEC-18 equations. HEC-RAS may also be used to evaluate scour, but the user must be experienced in the nuances HEC-RAS presents in evaluating scour and the potential errors that can occur. Using HEC-RAS default values will cause inaccurate results.

The potential for local scour (pier and abutment) and general scour (contraction, stream degradation, and pressure) should be evaluated using HEC-18 to determine the extent of the various types of scour as applicable to each site. HEC-20 should be consulted to determine the general stability of the stream and whether lateral channel movement should be anticipated. If there is potential for scour during the design storm shown in Table 8.04.1, countermeasures shall be designed in accordance with HEC-23. In all cases, the length of bridge piles shall be such that the design structural load may be safely supported entirely below the probable scour depth.

Table 8.04.1. Bridge Scour Design Standards

Roadway Classification	Design Storm for Abutment, Pier Cap, and Retaining Wall Design	Design Storm for Foundation Design
Arterial	500-year	500-year
Collector	500-year	500-year
Local	500-year	500-year
Local Low Volume	50-year	500-year
Alley	50-year	500-year

The type of bridge foundation and foundation elevations should be determined by the bridge structural design engineer. During the design of the bridge foundations, the design engineer shall consider the design loading, the findings of the geotechnical investigation, scour depth as calculated using the procedures in HEC-18, anticipated frost depth, pressure flow during the 100-year event, and any other factors the engineer considers appropriate in his or her professional judgement. If scour is anticipated, the engineer can either design scour countermeasures using the procedures in HEC-23 for the design storm listed in Table 8.04.1 or locate the bridge foundations below the anticipated depth of scour by a distance that provides a sufficient factor of safety in his or her professional judgement. Scour countermeasures will be required if the anticipated scour depth is more than 5 feet.

8.05 DESIGN EXAMPLE

This section presents a design example using the recommended procedure from HDS-5 to evaluate existing and proposed culverts. The methodology consists of evaluating the culvert headwater requirements assuming both inlet control and outlet control. The rating that results in the larger headwater requirement is the governing flow condition.

This example is rating an existing culvert. The culvert is a 48” RCP that is 150’ long with flared end sections on each end. The upstream invert is 5540.00; the downstream invert is 5538.95; and the slope is calculated at 0.007 or 0.7%. The low point of the embankment over the culvert is at elevation 5551.90.

From Table 8.02.1, Manning’s n is 0.013. From Table 8.03.2, the entrance loss coefficient, K_e is 0.5. Full pipe flow and velocity are calculated using Manning’s equation as 121 cfs and 9.6 fps. Use the following steps to complete the Culvert Design Form. The Culvert Design Form for this example is Figure 8.05.1 included at the end of this section.

1. Select incremental headwater values starting with the vertical dimension of the culvert and ending with the headwater at which the road will overtop. These are entered in Column 3. The headwater to pipe diameter ratio (Hw/D) is calculated and entered in Column 2. If the culvert is other than circular, the height of the culvert is used.
2. For each Hw/D value, the inlet capacity is read from the inlet control nomograph indicated in Table 8.03.1 and entered in Column 1. The equations in HDS-5 may also be used. Nomograph 55B will be used for inlet control.
3. For outlet control, the flow values in Column 1 are used to determine the H values in Column

4 using the appropriate outlet control nomograph. Nomograph 5B will be used for outlet control.

4. Enter tailwater (Tw) in Column 5 for each Q value in Column 1 in accordance with the tailwater rating curve developed for the downstream channel. The depths have been provided in this example but must be calculated, if they are not available, by approximating the normal depth for each flow in the receiving channel. If the tailwater depth is less than the diameter of the culvert, Columns 6 and 7 must be calculated per Step 5, and the larger of the tailwater depth and the value of Column 7 shall be used as ho. If the tailwater depth is greater than the diameter of the culvert, the tailwater values in Column 5 are entered into Column 8 as the values for ho, and Step 6 should begin (Step 5 being skipped)
5. Enter critical depth (dc) in Column 6 for each Q value in Column 1. Calculate the average of the critical depth and the culvert diameter and enter it into Column 7 as the ho value.
6. The headwater values (Hw) in Column 9 are calculated according to the equation: :

   $$H_w = \mathrm{H} + h_o - LS_o$$

   Where H is from Column 4, and ho is from Column 8 (for Tw > D) or the larger value between Column 5 and Column 7 (for Tw < D). Enter the Hw values in Column 9.
7. Compare the required headwater values from Columns 9 and 3 and record the higher value in Column 10. Record the type of control in Column 11 based on which control yields the higher required headwater. Calculate the headwater elevation by adding the controlling Hw values from Column 10 to the upstream invert elevation. A culvert rating curve can then be plotted from the values in Columns 12 and 1.

To size a new culvert crossing, the same form can be used with some variation from the basic procedure above. A desired capacity is selected based on hydrologic calculations, and the maximum allowable headwater is determined based on existing or anticipated embankment elevations. An inlet type configuration is selected, and the invert elevations and culvert slope are estimated based upon site constraints. A culvert material and shape are then selected and rated for both inlet and outlet control. If the controlling headwater exceeds the maximum allowable headwater, a different culvert configuration will be selected, and the procedure repeated until a satisfactory design is achieved.

8.06 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

8.07 REFERENCES

Federal Highway Administration (FHWA). 2001. Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

American Association of State Highway and Transportation Officials (AASHTO). 2007. Highway Drainage Guidelines.

FHWA's Hydraulic Design Series (HDS) 1 (1978), 6 (2010), 7 (2012), or 20 (2012), AASHTO's Highway Drainage Guidelines (2007), or AASHTO's Drainage Manual (2014)

FHWA's HDS-7, Hydraulic Design of Safe Bridges (2012) shall be used for the hydraulic analysis of the proposed design. H

Federal Highway Administration (FHWA). 1972. Capacity Charts for the Hydraulic Design of Highway Culverts, Hydraulic Engineering Circular (HEC) No. 10. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

Federal Highway Administration (FHWA), 1978. Hydraulics of Bridge Waterways. Hydraulic Design Series No. 1.

Federal Highway Administration (FHWA), 2009. Bridge Scour and Stream Instability Countermeasures, Experience, Selection, and Design Guidance. Hydraulic Engineering Circular No. 23, Third Edition. Volumes 1 and 2.

Federal Highway Administration (FHWA), 2012. Hydraulic Design of Safe Bridges, Hydraulic Design Series No. 7.

Federal Highway Administration (FHWA), 2012. Evaluating Scour at Bridges, Hydraulic Engineering Circular No. 18, Fifth Edition.

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Federal Highway Administration (FHWA). 2011. HY 8 Culvert Hydraulic Analysis Program. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

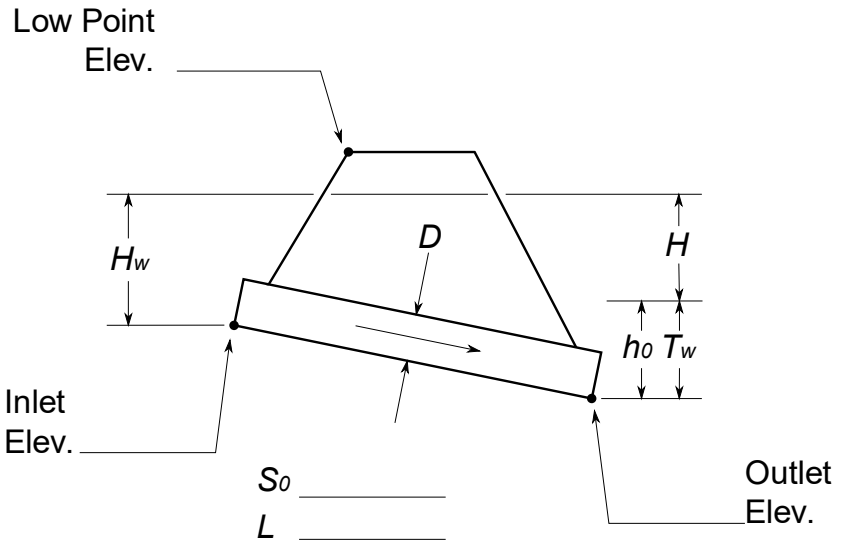
Urban Drainage and Flood Control District, 2017. Urban Storm Drainage Criteria Manual, Denver, CO

U.S. Army Corps of Engineers, 2010. Hydrologic Engineering Center, River Analysis System (HECRAS) Computer Program Version 4.1.0.

U.S. Army Corps of Engineers, 2010. Hydrologic Engineering Center, River Analysis System (HECRAS) User's Manual and Hydraulic Reference Manual

Figure 8.03.1 Culvert Design Form

City of Greeley Colorado Great. From the Ground Up.	Project:	Consultant:	Date:
	Route/Highway:	Engineer:	
	Mile Marker:	Other:	



Culvert Data

Size:	n:
Material:	Q_{Full}:
Inlet Style:	V_{Full}:
k_e:	

Outlet Control Equations

(1) $H_w = H + h_0 - LS_0$

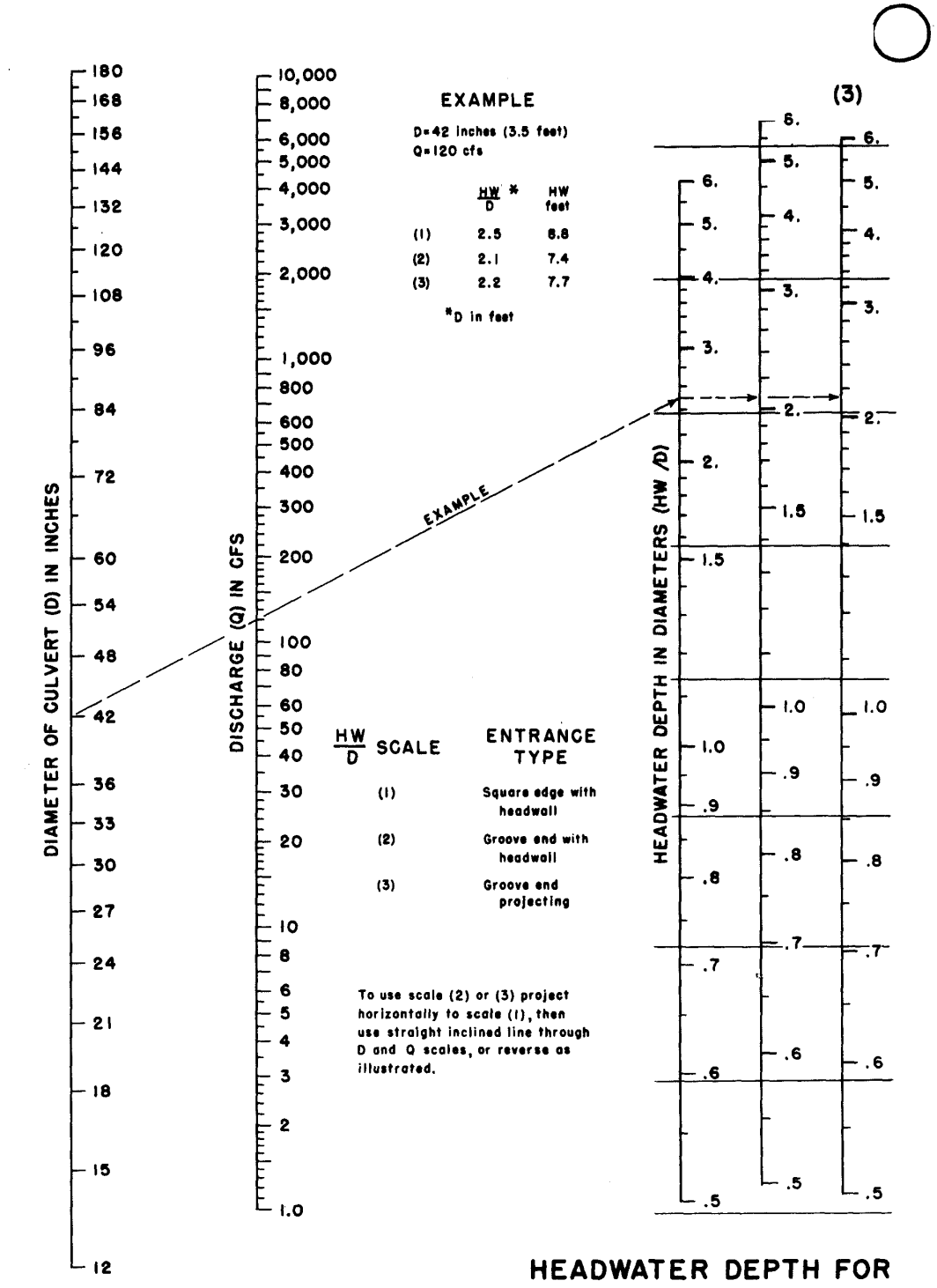
(2) For $T_w < D, h_0 = \frac{d_c+D}{2}$ or T_w (whichever is greater)
$T_w > D, h_0 = T_w$

(3) For Box Culvert: $d_c = 0.315\left(\frac{Q}{B}\right)^{2/3}$ (B = width of the box culvert)

Q	Inlet Control		Outlet Control						Design Curve		
					$T_w < D$		$T_w > D$				
	$\frac{H_w}{D}$	H_w	H	T_w	d_c	$h_0 = \frac{d_c + D}{2}$	h_0	H_w	H_w	Control Method	WSEL
Col 1	2	3	4	5	6	7	8	9	10	11	12

Figure 8.03.2 Common Nomographs
(Reference: HDS-5, Hydraulic Design of Highway Culverts)

CHART 1B

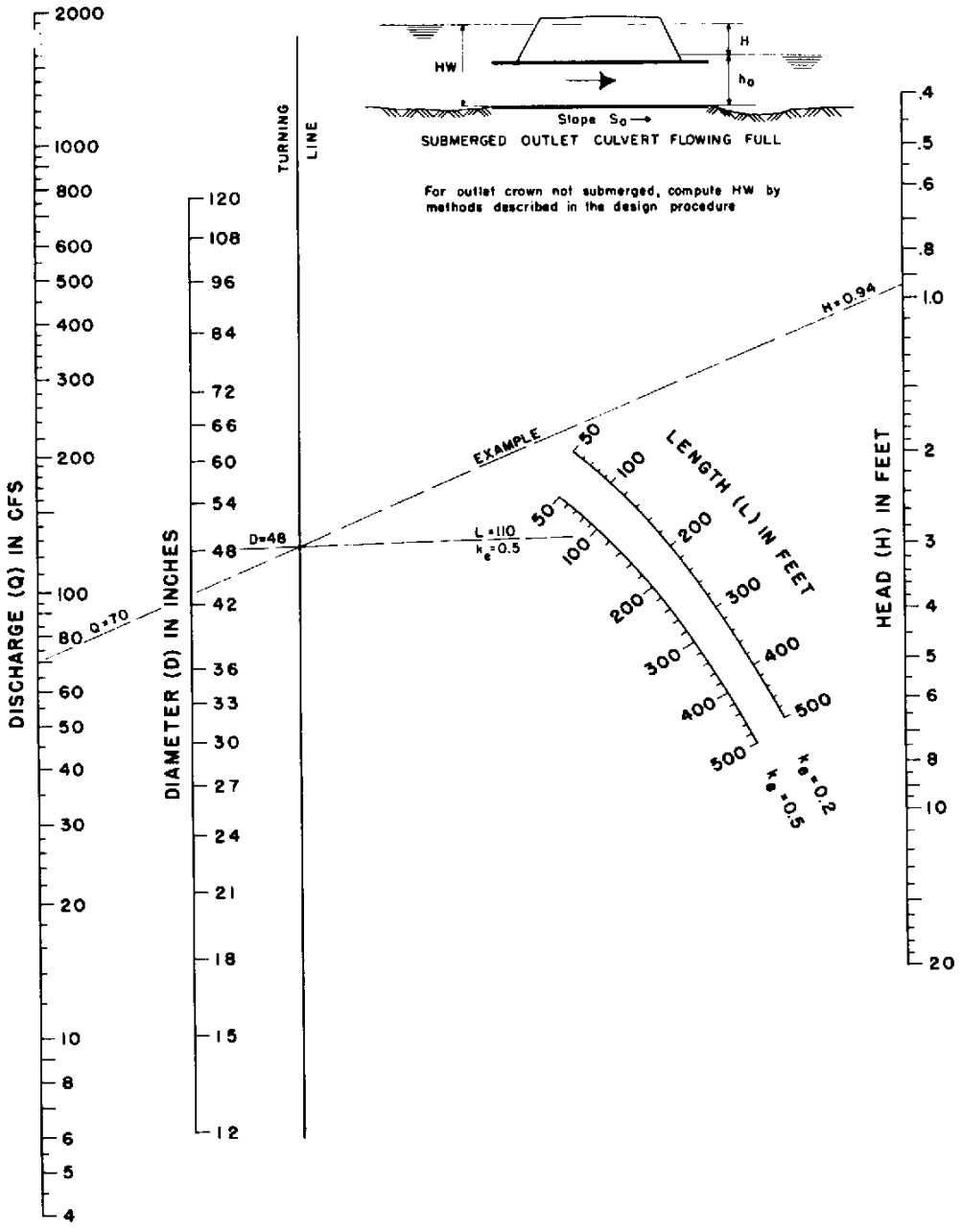


HEADWATER SCALES 2&3
REVISED MAY 1964

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

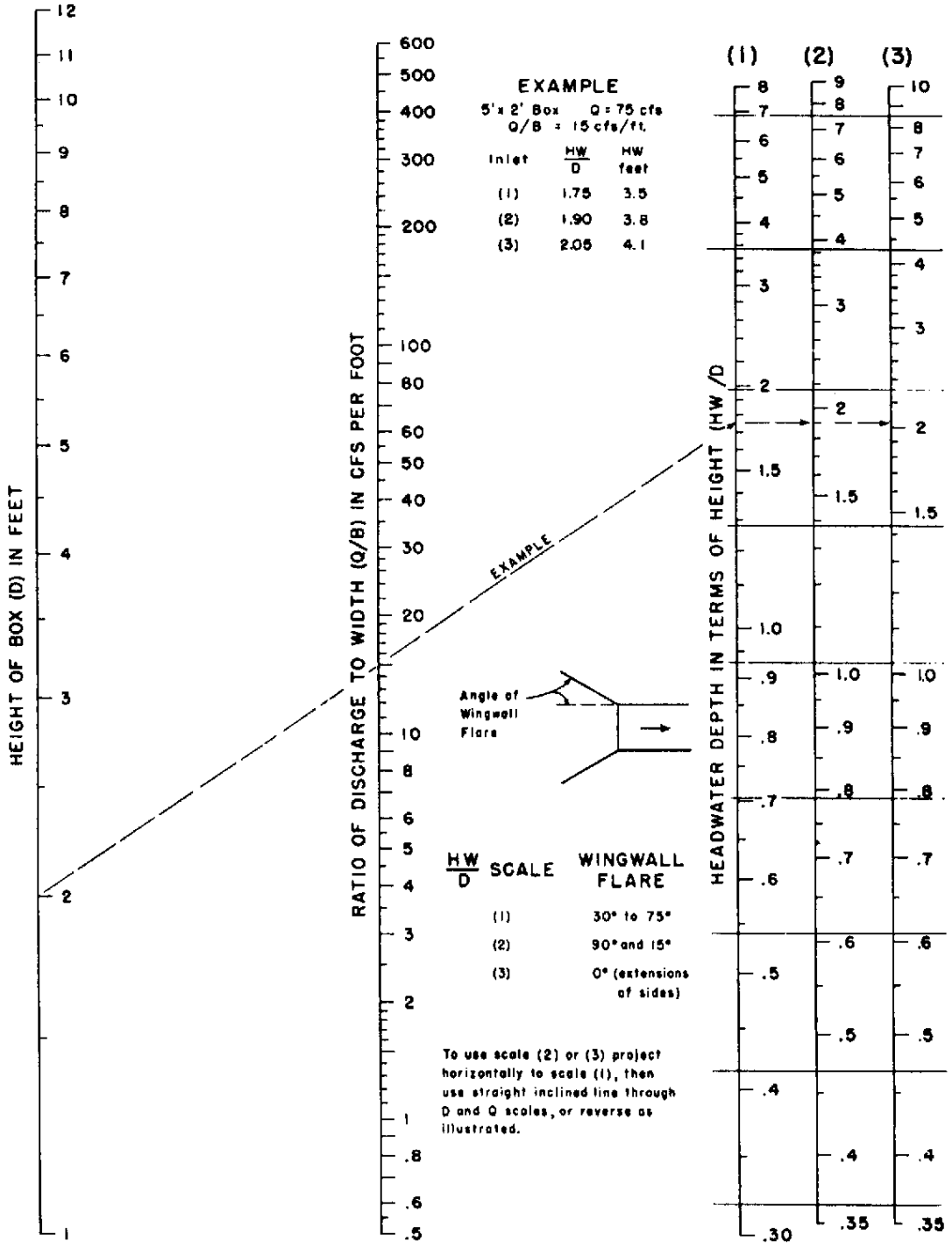
CHART 5B



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

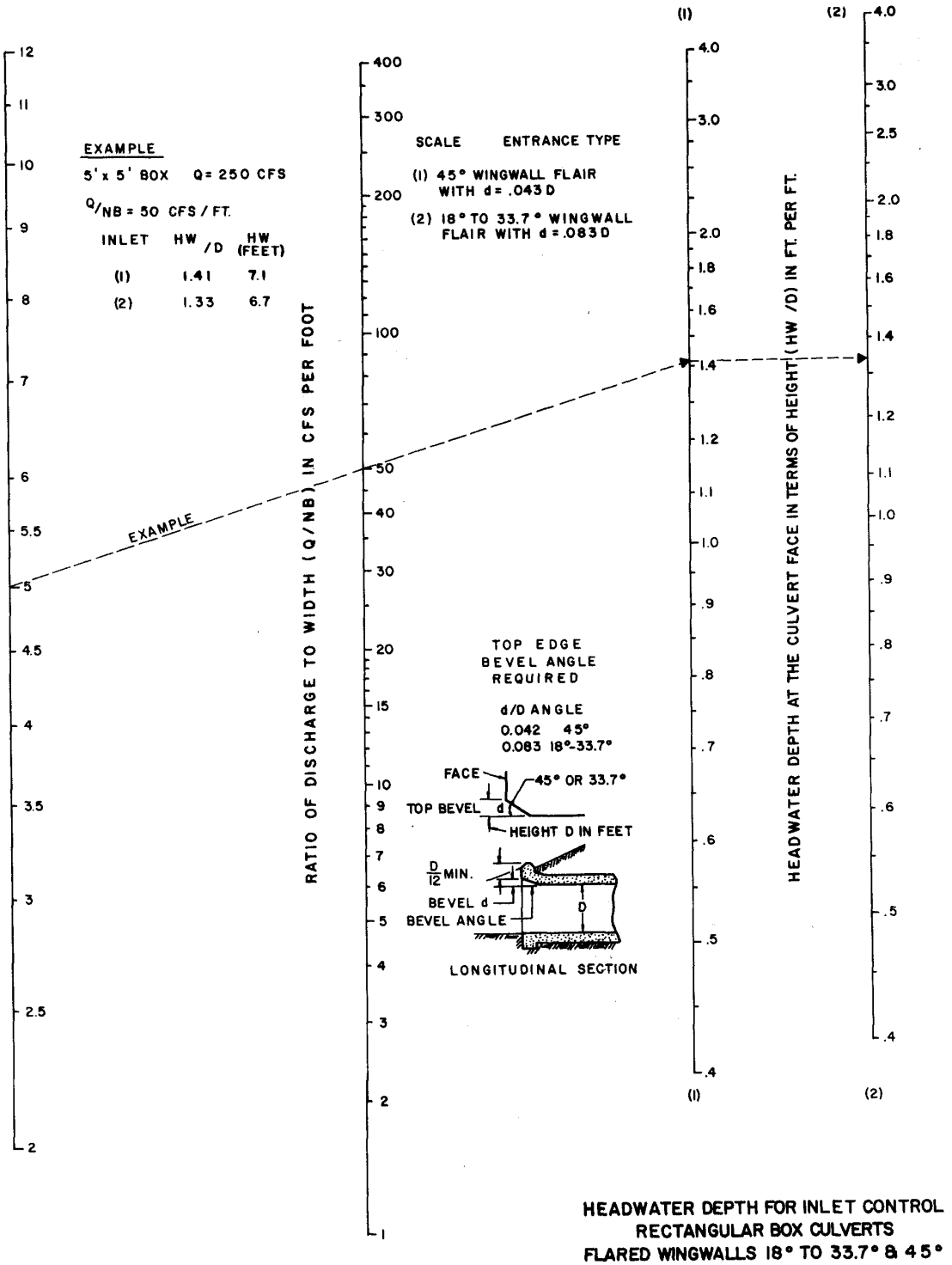
CHART 8B



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

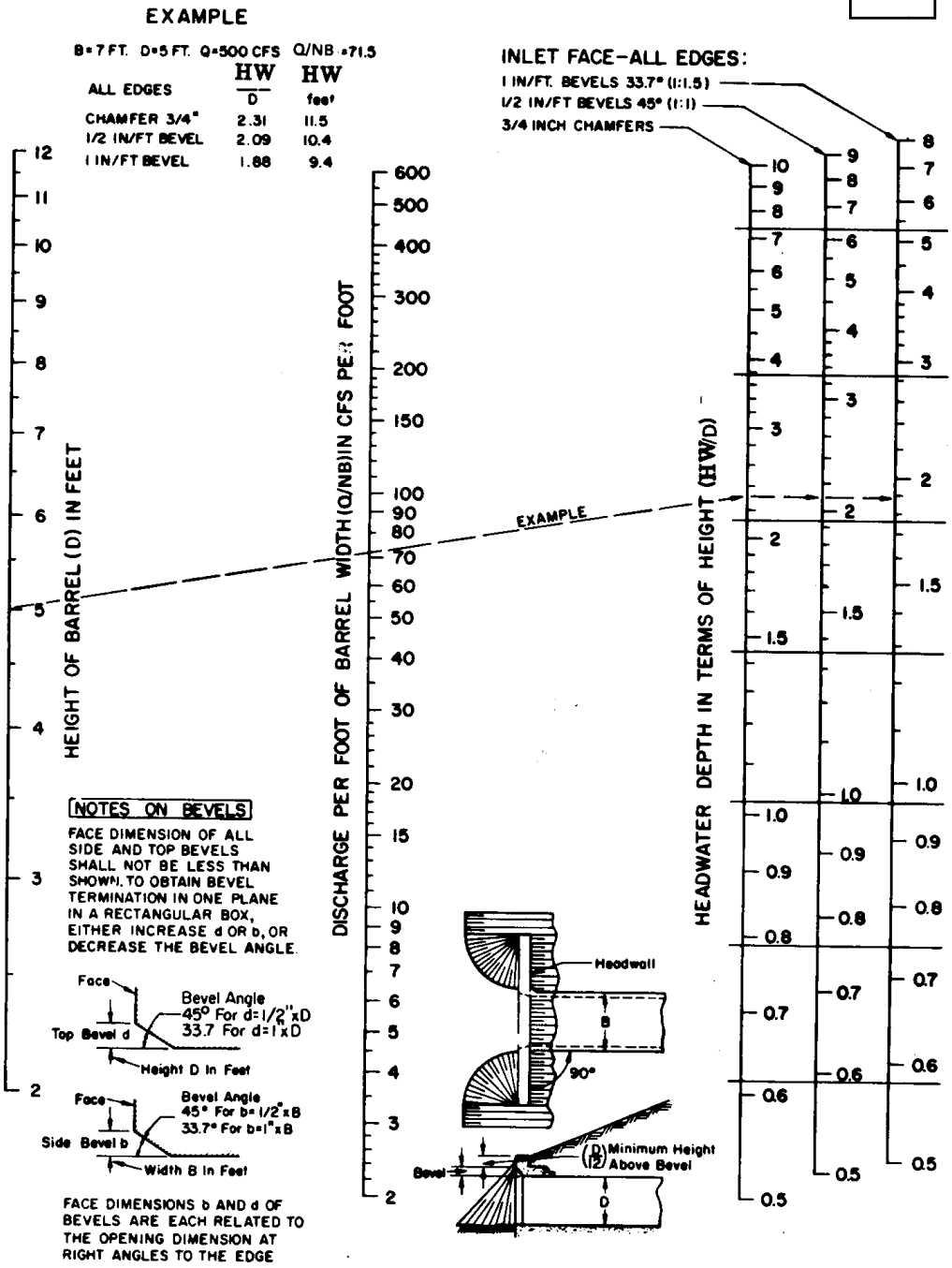
BUREAU OF PUBLIC ROADS JAN. 1963

CHART 9B



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS 18° TO 33.7° & 45°
WITH BEVELED EDGE AT TOP OF INLET

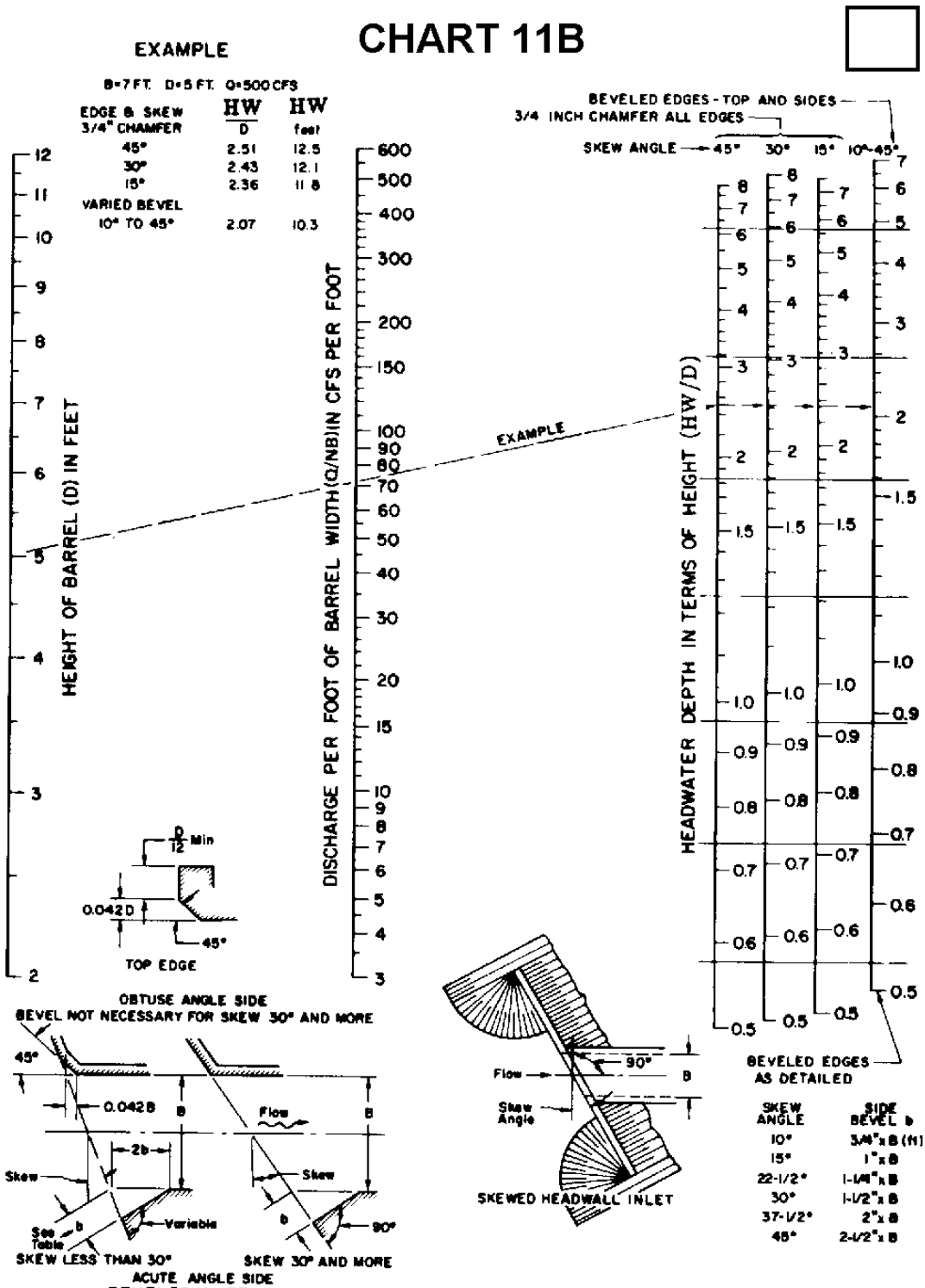
CHART 10B



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
90° HEADWALL
CHAMFERED OR BEVELED INLET EDGES

FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

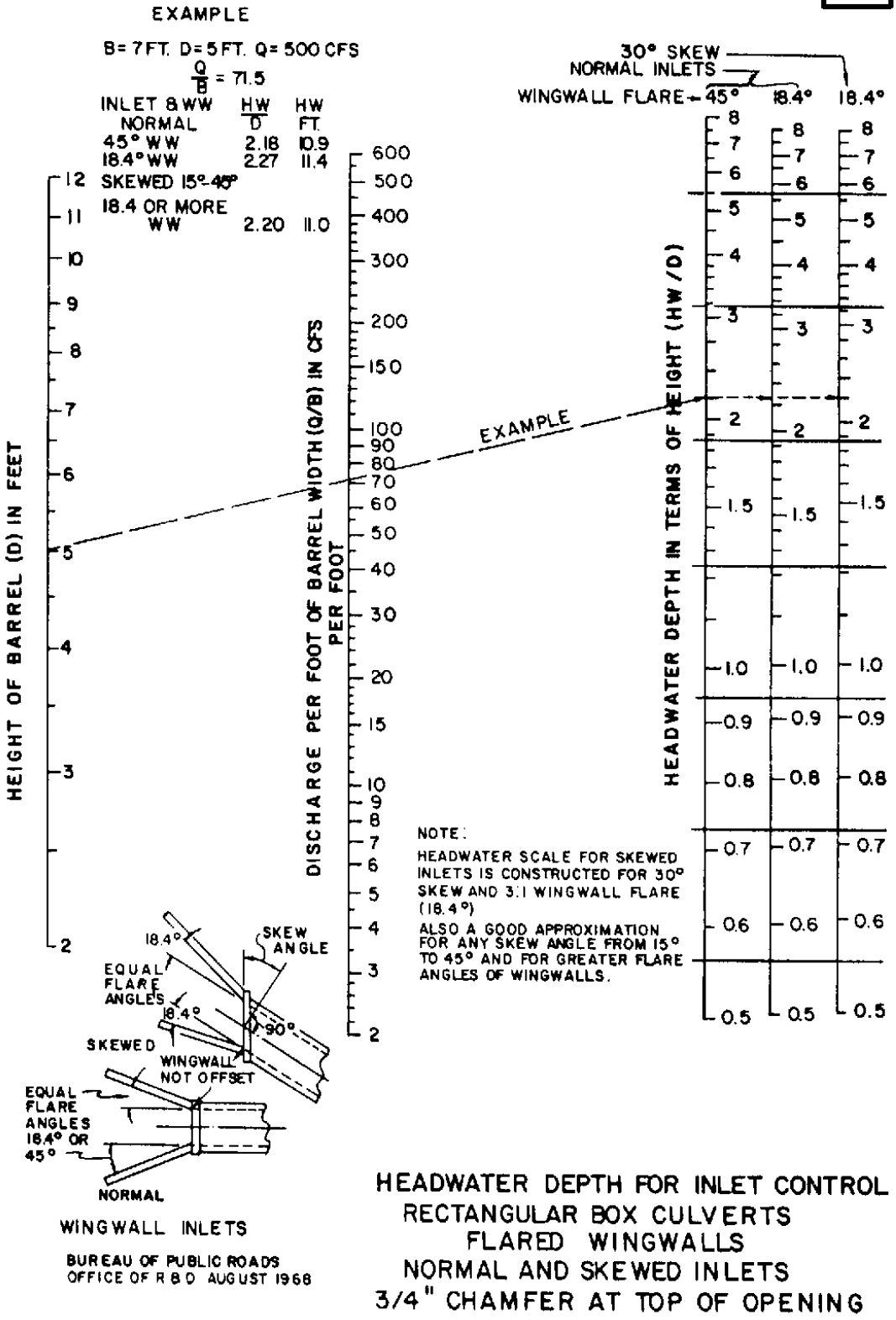
CHART 11B



FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

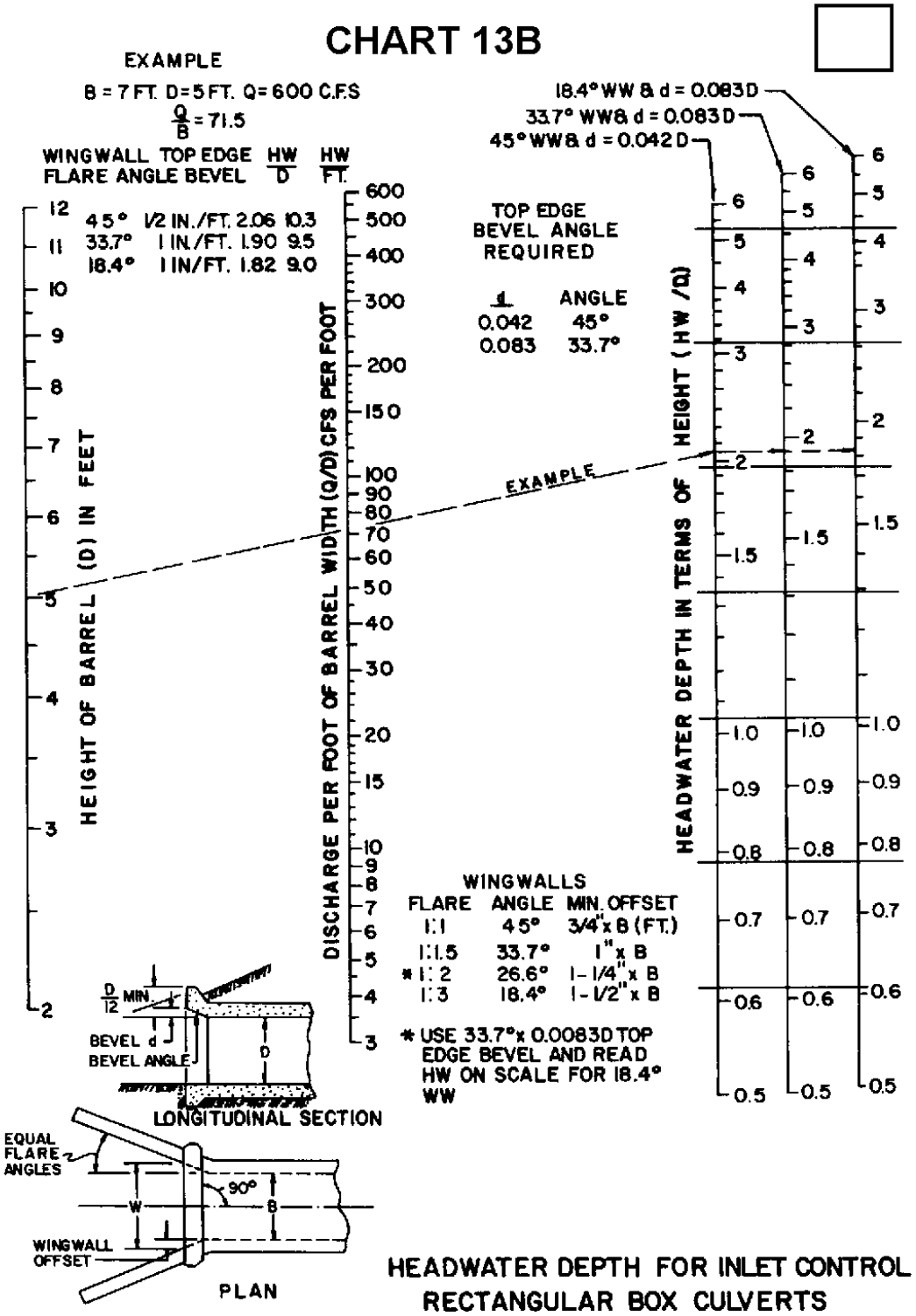
HEADWATER DEPTH FOR INLET CONTROL
SINGLE BARREL BOX CULVERTS
SKEWED HEADWALLS
CHAMFERED OR BEVELED INLET EDGES

CHART 12B



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
3/4" CHAMFER AT TOP OF OPENING

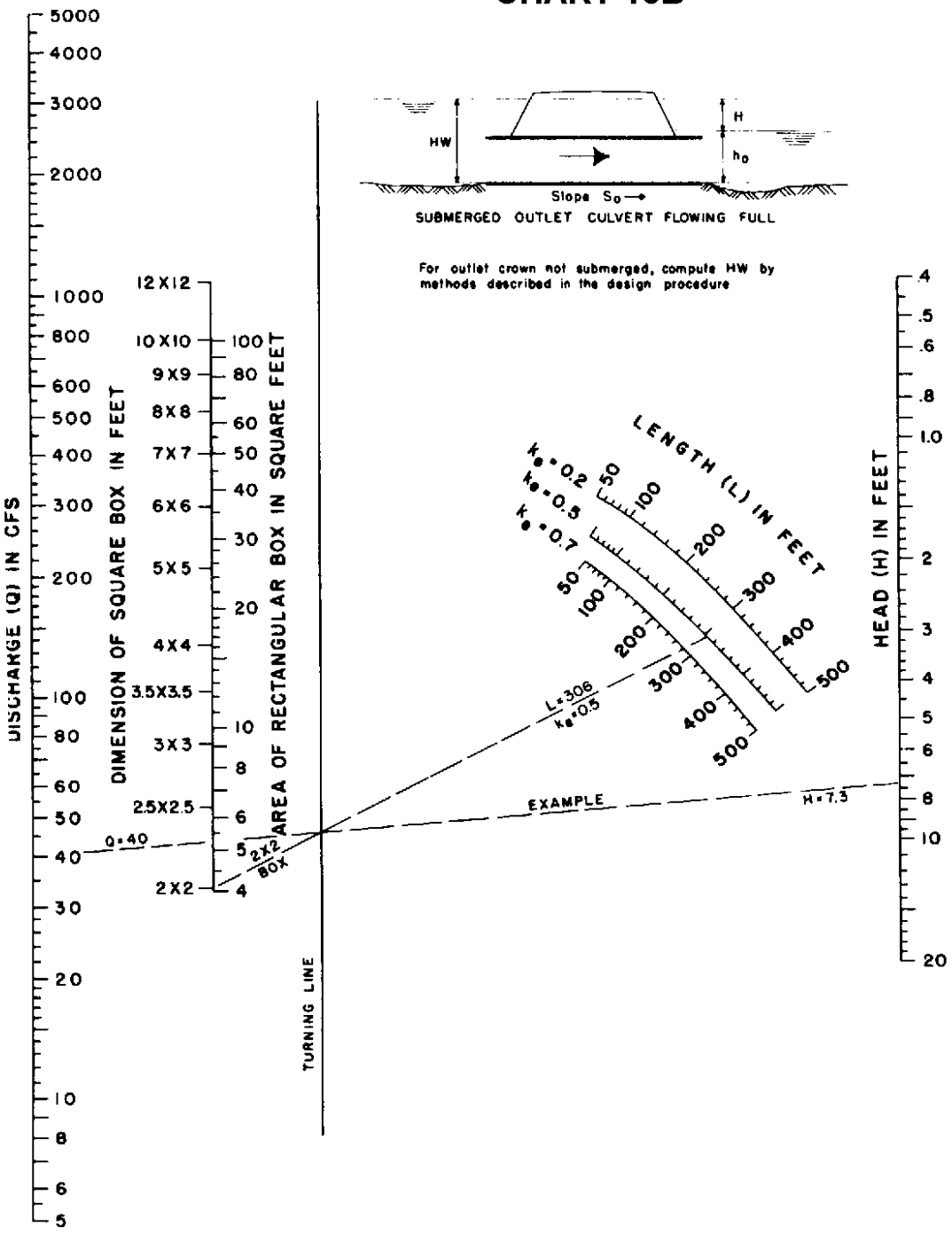
CHART 13B



BUREAU OF PUBLIC ROADS
OFFICE OF R & D AUGUST 1968

HEADWATER DEPTH FOR INLET CONTROL RECTANGULAR BOX CULVERTS OFFSET FLARED WINGWALLS AND BEVELED EDGE AT TOP OF INLET

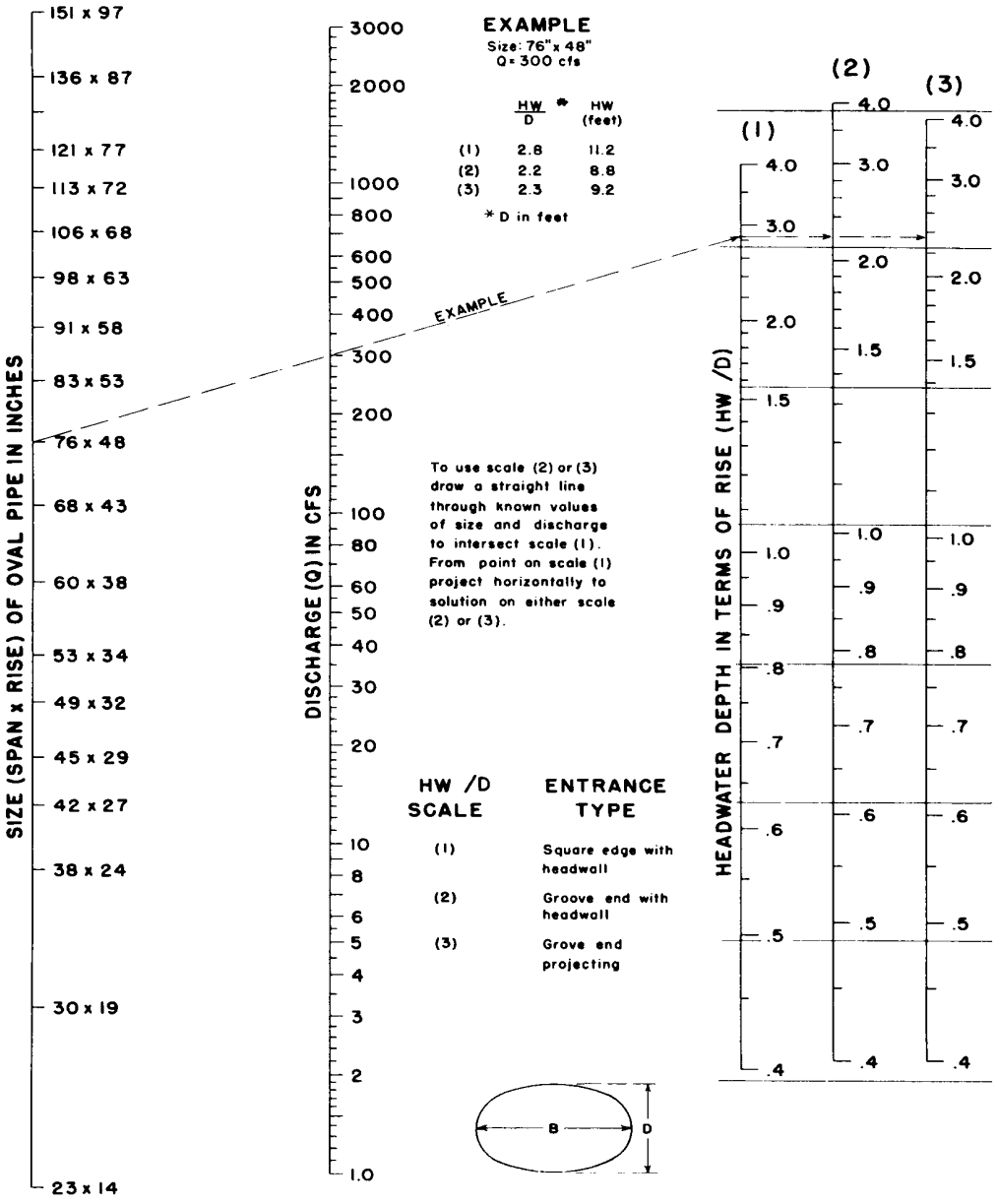
CHART 15B



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

AU OF PUBLIC ROADS JAN. 1963

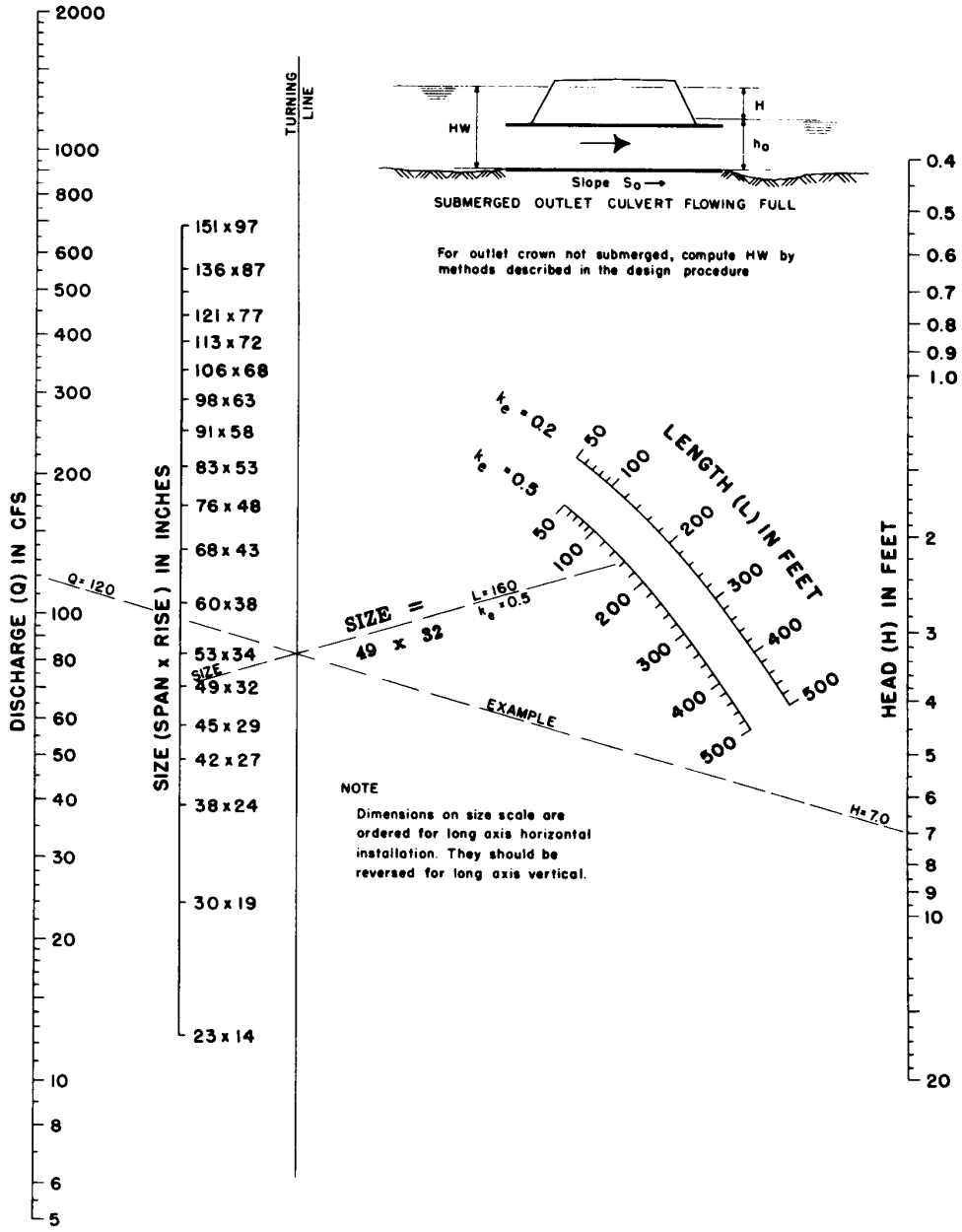
CHART 29B



HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

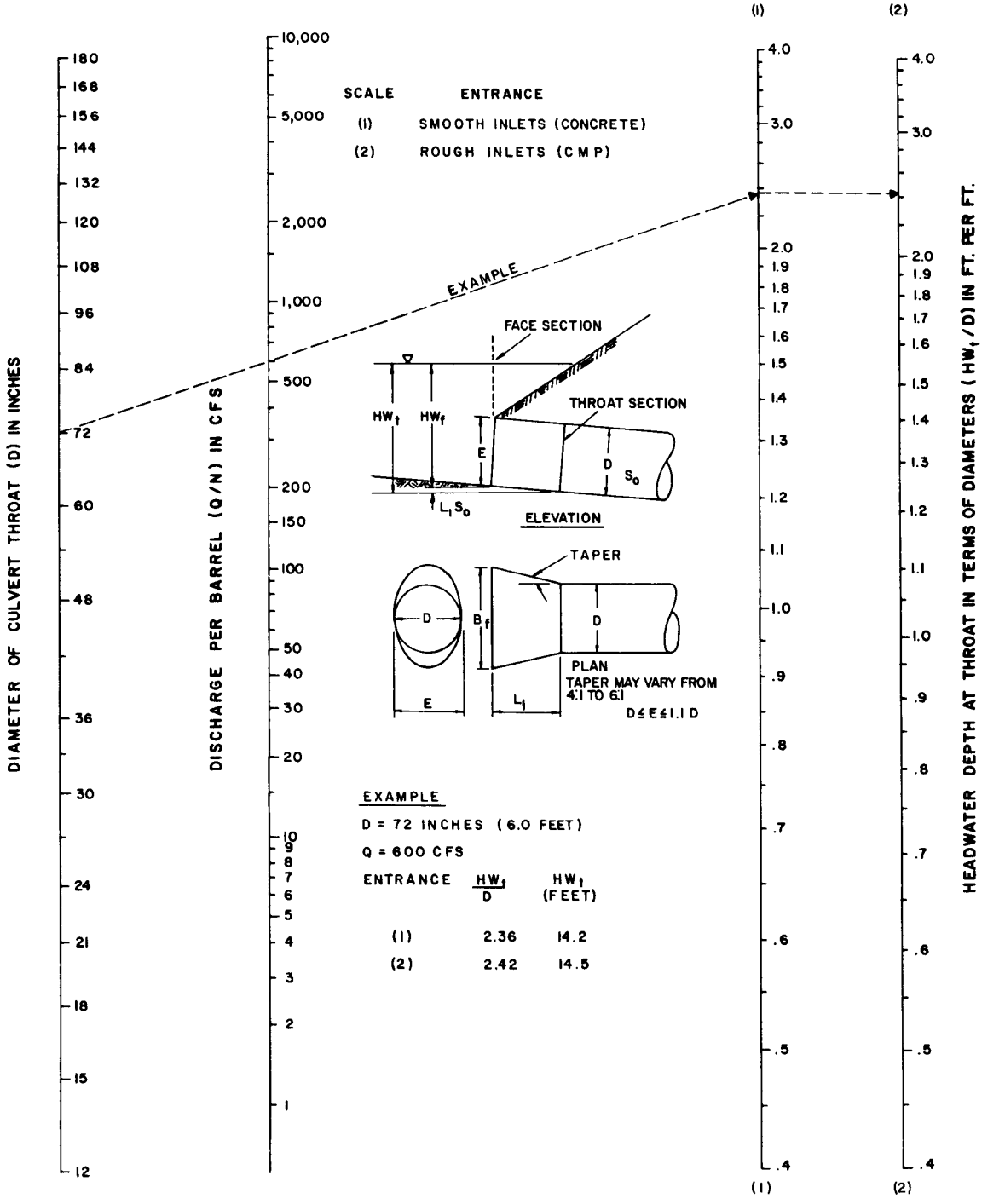
CHART 33B



HEAD FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

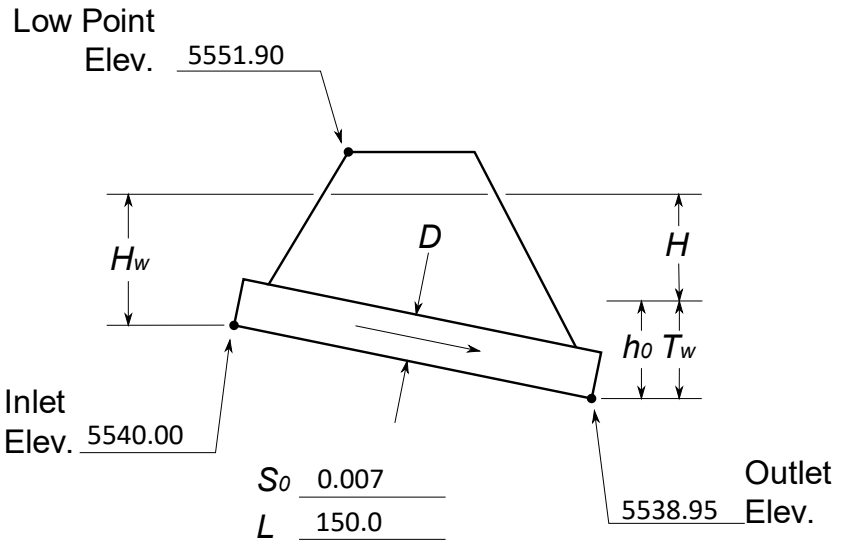
CHART 55B



THROAT CONTROL
FOR SIDE-TAPERED INLETS TO PIPE CULVERT
(CIRCULAR SECTION ONLY)

Figure 8.05.1 Culvert Design Example

City of Greeley Colorado Great. From the Ground Up.	Project: ABC Farms	Consultant: CO PE Services	Date: 9/12/2024
	Route/Highway: 83rd Ave	Engineer: Mary Smith	
	Mile Marker/Location: 200' south of 12th St	Other:	



Culvert Data	
Size: 48"	n: 0.013
Material: RCP	Q_{Full}: 121 cfs
Inlet Style: FES	V_{Full}: 9.6 fps
k_e: 0.5	Nomographs: 55B, 5B

Outlet Control Equations

(1) $H_w = H + h_0 - LS_0$

(2) For $T_w < D, h_0 = \frac{d_c+D}{2}$ or T_w (whichever is greater)
$T_w > D, h_0 = T_w$

(3) For Box Culvert: $d_c = 0.315\left(\frac{Q}{B}\right)^{2/3}$ (B = width of the box culvert)

Q	Inlet Control		Outlet Control						Design Curve		
					$Tw < D$		$Tw > D$				
	$\frac{Hw}{D}$	Hw	H	Tw	dc	$ho = \frac{dc+D}{2}$	ho	Hw	Hw	Control Method	U/S WSEL
Col 1	2	3	4	5	6	7	8	9	10	11	12
75	1	4	.99	1.5	1.33	2.67		2.61	4	Inlet	5544.00
106	1.25	5	1.95	2.0	1.58	2.79		3.69	5	Inlet	5545.00
139	1.5	6	3.40	2.5	1.81	2.91		5.26	6	Inlet	5546.00
166	1.75	7	5.00	3.0	1.98	2.99		6.94	7	Inlet	5547.00
186	1.975	7.9	6.40	3.5	2.09	3.05		8.40	8.4	Outlet	5548.40

SECTION 9
HYDRAULIC STRUCTURES

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SECTION 9
HYDRAULIC STRUCTURES

9.01 INTRODUCTION

Hydraulic structures control stormwater during a rapid change in flow direction or velocity to minimize localized erosion. Hydraulic structures include channel grade control structures such as drops, steps, riffles, and checks as well as rundowns and energy dissipators for pipe outfalls. Irrigation ditch crossings are also included in this section. Culverts, bridges, and weirs also cause rapid changes in flow, but these are discussed in other sections of the SDDC.

Each hydraulic structure is site-specific, and the criteria in this section are somewhat generalized. However, safety, access, lifespan, and environmental impacts should always be considered alongside hydraulic performance. The design of channel drops, checks, and rundowns along the front range has evolved considerably over the last few decades due to performance evaluations and maintenance concerns. It is reasonable to assume that the design of these structures will continue to be refined over time. This section relies heavily on design guidance in the USDCM so that the City of Greeley can benefit from the ongoing performance evaluations of recently constructed channel drops, checks, and rundowns.

The criteria to be used in the design of hydraulic structures shall be in accordance with the USDCM, Volumes 1 and 2. The specific criteria to be used within the City of Greeley are in the following sections.

9.02 GRADE CONTROL

Urbanization has led to increasing flow rates in channels, often leading to increased channel velocities and streambed degradation. Channel velocity can be reduced by flattening the slope of the channel invert. Grade control structures such as drops, checks, step pools, and riffles provide a localized drop in elevation that allows the rest of the channel to be constructed at a flatter slope. Design parameters and construction details for grade control structures are in Volume 2 of the USDCM. The City requires a geotechnical investigation that provides structural design parameters and recommendations if concrete or grouted boulder grade control structures are used. Requirements for the geotechnical report are in the Drainage Report Checklist under Appendix A.

9.03 OUTFALLS

Localized erosion will often occur at culvert and storm drain outfalls, regardless of if they are above the invert of the receiving channel. If a culvert or storm drain cannot be designed to discharge within 1 vertical foot of the channel invert, a pipe shall be used to convey flows to just above the channel invert as culvert rundown installations have a very high rate of failure and are not allowed due to the resulting maintenance and repair burden.

A. **Pipe End Treatments.** Flared end sections, toe walls, headwalls, wingwalls, or a combination thereof are required to minimize damage from erosion at pipe outfalls. Design criteria for pipe end treatments shall be in accordance with the USDCM, Volume 2, "Hydraulic Structures".

B. **Energy Dissipators.** Local scour is often seen at a pipe or culvert outlet where concentrated flows with high exit velocities have caused a scour hole beneath the outlet. Protection against scour at outlets shall be achieved by riprap aprons, low tailwater basins, or energy dissipation

structures. Rock sizing and configuration dimensions for riprap structures shall be those resulting from calculations performed in accordance with the USDCM, Volume 2 "Hydraulic Structures." When the Froude Number at the outlet of a culvert or storm drain exceeds 2.5, the USBR Type VI impact-stilling basin shall be used.

9.04 IRRIGATION DITCH CROSSINGS

A typical ditch crossing does not exist because each irrigation ditch crossing a drainageway will have its own unique design and requirements. Any proposed developments in the vicinity of irrigation ditches and canals, crossing or utilizing the ditches or canals for surface drainage, shall have the plans approved by the controlling ditch company in the form of an executed crossing agreement prior to acceptance by the City.

9.05 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

SECTION 10
DETENTION

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Appendices

SECTION 10
DETENTION

10.01 INTRODUCTION

The imperviousness of any site typically increases with development. Roofs, walks, roads, and parking all contribute to imperviousness. Rain falling on these areas no longer infiltrates into the ground as it did before development; it discharges from the site instead, impacting adjacent properties, storm drainage systems, and even larger drainageways when considered in the aggregate. Detention facilities mitigate these impacts by storing the additional runoff volume caused by development and discharging it from the site at pre-development rates. Detention helps to minimize peak flows in urbanized areas. Detention can include individual site options such as small, landscaped basins and larger regional and subregional facilities that serve multiple sites. Detention facilities can be designed to provide water quality treatment in addition to hydraulic detention. This section presents the City's criteria for when detention is required and guidance on how to design detention facilities.

10.02 APPLICABILITY & EXEMPTIONS

Full-spectrum detention is required for all new development and redevelopment projects and for all changes in land use. All new developments within areas designated by the Stormwater Division must utilize existing regional detention ponds to meet stormwater detention requirements. The requirement to use existing regional detention shall be discussed during the preapplication meeting.

A maximum of 5% of the total development or redevelopment site may discharge directly from the site, without hydraulic detention. The development site is the area within the limits of disturbance. Subdivided developments may use a single detention facility provided it captures runoff from at least 95% of the entire development. Detention facilities are not required to detain runoff generated outside the development that flows onto the site. Criteria for detaining runoff generated offsite are the same as those for providing water quality treatment for runoff generated offsite, included in Section 11.03, part E.

If a project has any of the following characteristics, it is exempt from the detention requirement, provided the additional undetained runoff will cause no adverse impacts to any properties or facilities.

1. Located in the downtown Redevelopment District and adds 5,000 square feet of impervious area or less. Low impact development (LID) principles to promote infiltration within the Redevelopment District are required to qualify for the exemption. Detailed guidance on LID can be found in Volume 3 of the USDCM.
2. At least 95% of the peak 100-year runoff from the project site is fully conveyed to a regional or subregional detention facility that has been sized to accommodate it.
3. Parcels that are 2 acres or larger, have one single-family dwelling, and have a total imperviousness of less than 10 percent. For this exception to apply low impact development principles must be included in the design.
4. Additions to buildings where the total impervious area, both existing and proposed, covers less than 5,000 square feet of impervious paved and roof surfaces.

5. Impervious area is increased by less than 1,000 square feet.
6. Project includes only fill areas that will not be paved over or otherwise made impervious.
7. Project site is designed to generate a peak runoff rate from each of the subbasins within the parcel equal to or less than the pre-development peak runoff rate for all storm events.
8. Other situations, as may be determined by the Stormwater Manager to be in the best interest of the City.

A variance request may be granted for single-family residential parcels provided low impact development principles are included in the design. These may include using pervious pavers or pavement for driveways and walkways and routing roof drainage across a vegetated pervious area prior to discharging it to a roadside ditch, storm sewer, or stream. Detailed guidance on low impact development can be found in Volume 3 of the USDCM.

Supporting analysis and certification by a professional engineer that exclusion from the detention requirement will cause no adverse impacts to any properties or facilities must be submitted to the Stormwater Division for the variance request to be considered. A variance from the detention requirements issued by the City does not eliminate potential liability to others. All detention facilities in the City are subject to oversight by the City.

10.03 PLANNING PRINCIPLES

The planning principles used to minimize the impacts of development on water quality shall also be applied to detention planning. The design engineer must adhere to all the principles and requirements in Section 11 when designing a detention facility. A discussion on how design of the site minimizes site runoff volume and peak flow rates shall be included in the Drainage Report.

10.04 TYPES OF DETENTION & CRITERIA

There are three basic approaches for locating stormwater storage facilities in relation to their upstream watersheds. These are regional detention, subregional detention, and onsite detention. These three approaches and the criteria associated with each are described in this section. The following criteria apply to all detention ponds.

1. The external toe of slope of the pond embankment must be at least 5’ away from the external easement or outlot line.
2. All ponds must have full maintenance access in accordance with Section 13.
3. The City will own and maintain public pipes discharging into the pond from public inlets or manholes located outside the pond outlot or easement; however, the pond owner or the party responsible for maintenance as indicated in the Ownership and Maintenance Covenant (OMC) shall own and maintain all infrastructure downstream of these pipes, including flared end sections, riprap, and forebays.
4. All connections between the detention pond outlet structure and the receiving public storm drain must occur at a manhole or junction box (point of connection) located closely adjacent to the access path around the top of the pond or at the downstream junction of the private and public storm drain system.

5. The pond owner and the party responsible for pond maintenance will own and maintain the outlet structure, the pipe between the outlet structure and the point of connection, and the manhole or junction box serving as the point of connection.

6. The City will own and maintain the storm drain downstream of the point of connection.

7. Ownership and maintenance of a pond varies on a case-by-case basis.

8. If there are proposed changes to imperviousness of any of the area tributary to any pond from the original design, the pond must be evaluated to ensure it is sized correctly.

A. Regional Detention. Regional detention basins serve multiple property owners in watershed areas ranging from about 130 acres to one square mile. Regional detention may be online or offline. Figure 12-1 in the USDCM provides an example configuration for an on-line regional detention approach. Regional detention facilities will be owned and maintained by the City. A fee will be assessed by the Stormwater Division to discharge runoff to a regional detention pond.

   In some cases, regional detention is effective for watersheds larger than one square mile and for multiple facilities arranged in series; however, due to hydrologic complexities, including the timing of peak discharges within a watershed, regional detention facilities, especially those in series, must be modeled and approved in the context of a formal master planning process.

   Because regional detention facilities will be owned and maintained by the City, a scoping meeting will be required before project submittal to establish roles and responsibilities among all stakeholders within the City before review. A meeting shall be scheduled with the following stakeholders to establish requirements for each regional detention facility including which City department will maintain which parts of the facility:

   1. Culture, Parks, and Recreation, including representatives from Parks, Natural Areas and Trails, and Forestry

   2. Water and Sewer

   3. Public Works
      a. Director
      b. Stormwater
      c. Transportation Services including staff responsible for bike paths and trails
      d. Streets or Infrastructure Services, including staff responsible for street sweeping

   4. Community Development
      a. Planning and Zoning
      b. Engineering Development Review

B. Subregional Detention. Subregional detention generally refers to facilities that serve multiple landowners or lots and have a total tributary watershed of less than 130 acres. Figure 12-2 in the USDCM shows a typical subregional detention approach in a commercial area. Most

detention facilities located within residential communities are subregional in that they serve multiple lots that are individually owned. Subregional detention facilities are located offline from the receiving stream.

Subregional detention ponds will not be owned or maintained by the City. Any detention pond serving more than one lot or landowner that is owned or maintained by the City is classified as regional detention. Subregional detention ponds in single-family residential subdivisions must be located on an outlot with common ownership such as a Property Owners Association (POA) or Homeowners Association (HOA); other land use types may be allowed to use an easement provided construction on the easement is prohibited. Specific requirements will be determined on a case-by-case basis. If any users are added to a subregional pond after final acceptance, the OMC and Operation and Maintenance Plan (O&M Plan) must be updated.

Ponds with an existing or future tributary area over 10 acres may result in hydrologic complexities, including the timing of peak discharges within a watershed. Each subregional detention facility with a tributary area over 10 acres must be modeled and approved in the context of a formal master planning process.

A draft O&M Plan and OMC will be required with the Final submittal as discussed in Sections 2 and 13. The City may request a meeting with the applicant upon submittal of any land use case including a subregional detention pond.

C. Onsite Detention. Onsite detention refers to facilities serving one lot, generally a commercial or industrial site, with a tributary area of less than 30 acres. Figure 12-3 in the USDCM shows a typical onsite detention approach. Onsite detention is not typically located or designed to effectively reduce downstream flood peaks along the receiving stream. Onsite detention facilities will be owned and maintained by the property owner. Onsite detention facilities will not be owned or maintained by the City.

10.05 GENERAL DESIGN CRITERIA

A. Full Spectrum Detention. All detention facilities shall be designed as 100-year full-spectrum detention facilities. Evaluation of traditional detention methodology that focused only on the minor and major storm events identified two main shortcomings. The first was that the increase in runoff caused by development during storms smaller than the minor storm can still produce severe erosion, loss of riparian habitat, and water quality degradation. The second was that traditional detention methodology often resulted in peak outflows being maintained for relatively long periods of time; this caused outflow hydrographs from adjacent independent basins to overlap and add to each other more than they would have prior to development. Full-spectrum detention addresses these shortcomings by controlling peak discharges over the full spectrum of runoff events from small, frequent storms up to the 100-year event. Full-spectrum detention also produces outflow hydrographs that replicate pre-development hydrographs.

The Mile High Flood District has invested a significant amount of energy into developing detailed design guidance for detention basins. The USDCM provides discussion on the applicability of detention; additional explanation for why full-spectrum detention is the

preferred approach; and calculations for sizing a detention facility and designing the outlet structure and other appurtenances.

The USDCM includes specific design guidance for extended detention basins in Volume 3, Chapter 4, Fact Sheet T-5. This design guidance must be followed when designing full spectrum detention ponds provided it does not conflict with City-specific criteria.

B. MHFD-Detention. The most recent version of MHFD-Detention.xlsm shall be used for sizing and designing all detention facilities in the City. There are multiple instructional videos and the MHFD-Detention Technical Manual that provide detail on how to correctly use MHFD-Detention. These are available in the Software section under the Resources tab on the MHFD website, and users of these Criteria are strongly encouraged to review these resources. Detention facilities in the City shall be designed with three zones, as described within MHFD-Detention, and may be extended detention basins, sand filters, or bioretention. Constructed wetlands may also be used if water rights are accommodated. Guidance on how to design these types of facilities is included in the Fact Sheets in Volume 3 of the USDCM.

C. City Requirements. The following are additional City design requirements for detention facilities.

1. All detention facilities require a minimum of one boring drilled near the proposed pond outlet between May 1 and October 1 to evaluate the depth of groundwater, determine the types of soils in the subgrade, and to provide recommendations for structural design. The boring depth shall be to at least 10’ below the bottom of the lowest proposed grade of the pond. Groundwater shall be measured at the time of drilling and one week later. The City does not allow detention facilities to have their lowest grade within 2’ of groundwater. A geotechnical analysis and report of the findings are required. Information must include the boring location, groundwater depth, the infiltration capacity of the soils, the pH of the soils, the bearing capacity of the soils, and the requirements for a stable subgrade for all structures and access paths. The City may require additional information based on site conditions and the scope of the design. The geotechnical engineer must be informed of the design intent prior to boring so additional information that may be applicable can be anticipated and provided.

2. Revegetation requirements for detention facilities are included in Section 12 Construction Water Quality and Revegetation.

3. Any additional uses of a detention or water quality facility, including but not limited to playground, parks, and paths, must be specifically approved by the Stormwater Division.

4. Detention facilities may not be located within the 100-year floodplain. Exceptions may be made for development in the Poudre River floodplain if detention may contribute to increases in peak flow in the river as opposed to reductions. Contact the Stormwater Division for additional information and criteria.

5. Detention facilities shall not require pumping to drain any volume beyond that in the micropool. Use of infiltration to drain any volume of water in excess of the WQCV is not allowed.

10.06 ALLOWABLE RELEASE RATES

The allowable release rate from the site is the metric by which new development and redevelopment must provide detention. Regardless of the current level of site development, detention shall limit peak stormwater runoff from the entire development site to peak historic (called predevelopment by MHFD-Detention) runoff rates for the 2-, 5-, 10-, 25-, 50-, and 100-year storms. Peak historic rates for development sites of all sizes shall be those values calculated by MHFD-Detention as predevelopment peaks. The default imperviousness value for historic conditions is 2%. More information on using MHFD-Detention to calculate peak historic runoff rates per acre is included in a later subsection.

Total site runoff is typically a combination of detention basin release and direct runoff from areas not draining to a detention facility, both of which must be considered. Post-development peak discharge from the full development site shall not exceed peak historic discharge from the site for any return period. The allowable peak discharge from a detention facility will be less than the allowable peak runoff from the whole site unless the entire site drains to the detention facility.

Only the portion of the site that will drain to the detention facility is normally defined within MHFD-Detention. For developments with any portion of the site directly discharging from the site without detention, a separate MHFD-Detention workbook or CUHP-SWMM model may be used to determine the total site peak historic runoff. Peak historic discharge rates from the detained and undetained portions of the development site for each storm event shall be clearly presented in the text of the Drainage Report. Clearly annotated copies of all MHFD-Detention worksheets shall be included as appendices.

The requirements in this section for allowable release rates are intended only for detention facilities that are offline. Contact the Stormwater Division for required release rates for online detention ponds located along an active channel.

10.07 REQUIRED STORAGE VOLUME

Detention facilities must provide a minimum of 1’ of freeboard above the maximum design water surface elevation outside the emergency spillway. For most facilities this will be the 100-year water surface elevation in accordance with these Criteria. Detention facilities intended to provide only water quality treatment will have a maximum design water surface elevation that corresponds to that volume. MHFD-Detention estimates the storage volumes required for each return period once the watershed information is entered. The final design of any detention facility using MHFD-Detention must include the actual design stage-area relationship from the construction plans. More information on using MHFD-Detention to estimate and confirm required storage volume is included in a later subsection.

10.08 USING MHFD-DETENTION

The two worksheets within MHFD-Detention that are used for design are the Basin worksheet and the Outlet Structure worksheet. The last three worksheets – Reference, User Tips and Tools, and BMP Zone Images – contain helpful information on how to use the MHFD-Detention as a design tool. Users of these criteria are strongly encouraged to review the information in these last three worksheets, in addition to the multiple instructional videos and the MHFD-Detention Technical Manual referenced previously. This subsection highlights some of the functionality of MHFD-Detention and how it should be used to design detention facilities within the City.

Information is also provided on how to use a CUHP-SWMM model in lieu of the single-basin CUHP model that is the default within MHFD-Detention.

A. Detention Type. Most detention basins will include water quality treatment. If no water quality treatment will be provided, the first drop-down menu on the Basin worksheet below Watershed Information should be set to Flood Control Only. Otherwise select the type of facility being designed.

B. Watershed Information. Enter the Watershed Information using a drainage basin representing the entire area that will drain to the detention facility. Required data includes the tributary watershed area; watershed length; overall watershed slope; proposed watershed imperviousness; and the percentage of the site with Type A, Type B, and Type C/D soils

C. Rainfall. Location for 1-hr Rainfall Depths on the Basin worksheet shall be set to User input and the P_1 values from Section 3 of these Criteria shall be entered into the blue-shaded cells in the Basin worksheet. The note for each cell indicates the return period for the P_1 value that should be used in each cell.

D. Evaluate Hydrology. Once the values are entered, click the Run CUHP button. MHFD-Detention will automatically develop the site hydrology, calculate peak historic runoff rates, and display peak historic rates in the table at the bottom of the Outlet Structure worksheet.

E. Define Zones and Basin Geometry. In the three cells used to Define Zones and Basin Geometry in the Basin worksheet, the Zone 1 Volume shall be the WQCV if water quality treatment will be provided. If water quality will not be provided, the Zone 1 Volume shall be the 2-year event. The Zone 2 Volume shall be set to EURV – Zone 1, and the Zone 3 Volume shall be set to 100-year minus Zones 1 and 2. Once these options are selected, MHFD-Detention calculates an approximate total detention basin volume. If a SWMM model is used to route flows to and through the detention facility, this volume is simply a starting point for sizing the basin; the actual volume required will be calculated based on the 100-year inflow hydrograph being routed through the detention basin outlet structure. Information on overriding the default CUHP inflow hydrograph with data from CUHP-SWMM is included in a later step.

F. Additional Basin Data. The remainder of the user inputs on the Basin worksheet shall represent the intended design and follow the recommended guidelines indicated as notes in each cell. If the design of the facility was completed in accordance with guidelines in the USDCM, the design values for these inputs will be within the recommended ranges of values for each variable. Note that the Total Available Detention Depth should be based on the maximum allowable 100-year water surface, not at the downstream embankment crest, to allow for at least 1’ of freeboard. MHFD-Detention will then calculate the stage-area relationship. This completes the preliminary work in the Basin worksheet. For final design, the user must input the Optional Override Stage and Optional Override Area values in the Basin worksheet that match the final grading plans for the facility. The next design steps occur in the Outlet Structure worksheet.

G. CUHP versus CUHP-SWMM. If the single-basin CUHP model included in MHFD-Detention is used for the site, the user may move on to the next step. If a CUHP-SWMM model is used for the site, the pond inflow hydrographs for both peak historic and peak post-development

runoff rates from the CUHP-SWMM models can be used to override those calculated by MHFD-Detention in the Outlet Structure. Using a CUHP-SWMM model for the site may be appropriate if the site tributary watershed cannot be easily described by a single subcatchment; if there are several different types of land use within the watershed with different slopes and flow paths; or if there are existing conveyance systems or detention facilities. If CUHP-SWMM is used, input and output files for both historic and post-development conditions must be included in an appendix to the Drainage Report. More information on CUHP-SWMM is in Section 4 of the SDDC.

The CUHP-SWMM model for the area draining to the detention facility must be evaluated for historic conditions using a 2% imperviousness for all CUHP basins. The resulting peak historic runoff rates for each design storm are then entered into the Routed Hydrograph Results table in the OPTIONAL Override Predevelopment Peak Q (cfs) row. The following row, Predevelopment Unit Peak Flow, q (cfs/acre) will automatically update. The user will then override the inflow hydrographs into the detention basin using the output from the CUHP-SWMM models for proposed development for each storm event. The override cells are somewhat hidden at the top of the Outlet Structure worksheet and approximately 20 to 30 columns to the right. The time interval shown to the immediate left of the table must be consistent with the hydrographs produced by CUHP-SWMM. Once the new values are inserted, the Routed Hydrograph Results table will update, and design of the outlet structure can begin. The video titled MHFD-Detention – Hydrology Overrides, available on the MHFD website, provides visual instructions on how to override default hydrology.

H. Outlet Structure Design. MHFD-Detention greatly simplifies designing the outlet structure to meet peak historic runoff rates. An Outlet Type must be selected from the drop-down menu at the top of the Outlet Structure worksheet for each Zone. When water quality treatment is provided, the lowest outlet is typically an orifice plate, which is a plate with multiple smaller orifices cut into it. If water quality treatment is not provided, the lowest outlet might be a vertical orifice, which is also a plate, but with a single, larger hole cut into it. The options available in the drop-down menu for Outlet Type will automatically only be those applicable to the design completed up to that point and notes are included in each cell to assist in the selection. The Reference tab has additional information.

The user should only enter additional design values into the User Input rows in the remainder of this worksheet that correspond to the Outlet Types selected at the top of the worksheet. For example, if there is no orifice plate, there is no need for the user to enter data describing an orifice plate. But each Outlet Type selected must have its design data entered for the worksheet to yield correct results. The Outlet Structure worksheet includes several button options to automatically size different components of the outlet structure. These include the following:

1. Sizing the orifice plate to release the WQCV over the required drain time.
2. Sizing the vertical orifice to drain Zone 2.
3. Sizing the outlet pipe and restrictor plate for a flow-restricted outlet pipe to match 90% of peak historic runoff rates.
4. Sizing the emergency spillway to pass the 100-year post-development peak runoff rate.

In the event there is a base flow into the pond, such as might occur with irrigation return flow, an additional orifice adjacent to the lowest design orifice can be included to pass the base flow. It should be sized to pass twice the anticipated base flow. An adjustable plate can then be installed that will allow an amount of flow from zero to twice the anticipated base flow to pass with minimal headwater. The pond owner must then adjust the movable plate so that the normal water surface in the pond is generally level with the top of the micropool. Because each condition is unique, additional design scrutiny from the City should be expected.

I. Results. Once the various outlet structure components have been sized, the user must review the Routed Hydrograph Results table at the bottom of the worksheet. While several of the values are of interest, there are only a handful that are critical for detention facilities in the City. If these criteria are not met, the outlet structure design must be adjusted until they are.

1. Peak Outflow for each design storm may not exceed the historic rates. Values in the line titled Ratio Peak Outflow to Predevelopment Q should not exceed 1.0 for any event.
2. Time to Drain 97% of Inflow Volume (hours) must not exceed 72 for a 5-year storm.
3. Time to Drain 99% of Inflow Volume (hours) must not exceed 120 for storms greater than the 5-year storm.
4. Maximum Ponding Depth must be at or below the emergency spillway and at least 12" below the surrounding embankment.

J. Final Design. Once the preliminary grading and outlet designs are complete, the user must enter the actual design stage-area information in the Basin worksheet. Review the updated values in the Routed Hydrograph Results table to ensure the outlet design is still valid. If a CUHP-SWMM model has been used, the stage-storage and stage-discharge tables within the SWMM must be updated with the information presented in the Stage-Storage-Discharge Table that is revealed when the Show Stage-Storage-Discharge Table button is clicked.

10.09 APPURTENANT STRUCTURES

This subsection covers the common elements that must be included in a detention facility including trickle channels, a micropool, forebays, an outlet structure, and a spillway. These items shall be designed in accordance with the Fact Sheets in the latest version of Volume 3 of the USDCM, but items of specific interest to the City are included herein. The design of maintenance access to each element must be provided during initial detention pond design. Detailed maintenance requirements are included in Section 13.

A. Trickle Channels. All detention ponds with unpaved bottoms require a main pond concrete trickle channel as well as a trickle channel from each forebay to the outlet. The minimum longitudinal slope of trickle channels shall be 0.5%. The trickle channel shall be wide enough to accommodate the maintenance equipment outlined in the O&M Plan. A Manning's n value of 0.014 shall be used.

B. Micropool. A micropool at the outlet is required. It may be internal or external to the outlet structure.

C. Forebays. There may be several inlets, or outfalls, into a detention facility. Each outfall shall be designed with a forebay to limit degradation of the pond banks or invert.

D. Outlet Structure. The outlet structure shall be designed using MHFD-Detention as detailed above. No outlet pipe longer than 10' shall be smaller than 18" in diameter. The invert of the outlet pipe shall be set at the top of the micropool. The outlet pipe shall discharge into a standard manhole or a drainageway with proper erosion protection. If orifice plates are used, they must be removable by maintenance personnel. The outlet structure shall be located along the embankment of the pond and accessible to maintenance staff when the pond is at its peak design water surface elevation. Outlet structures may not discharge to irrigation ditches or private property. If an outlet structure does not discharge to a public storm drain system, the path of the pond discharge must be contained within City right-of-way or an easement on which construction is prohibited.

E. Stockpile Areas. For regional and subregional facilities, all forebays and outlet structures shall be designed with stockpile areas for temporary storage and drying of mucked out material. A stockpile area should be designated directly adjacent to each structure to be cleaned out. Stockpile areas shall be located outside the low flow area and should be as flat as possible. Total stockpile area shall be twice the square footage of all forebays and the micropool.

F. Embankment. The steepest embankment slope shall be 4:1. No portion of the embankment or side slopes shall be within the right-of-way. Retaining walls may not be used as detention pond embankments.

G. Access Path Surfacing. The surfacing of access paths for ponds owned by the City shall be as specified by the Stormwater Division on a case-by-case basis. Regional ponds may require aesthetically pleasing surfacing.

H. Spillway. An emergency overflow spillway shall be provided in the event the outlet structure becomes clogged or a storm larger than the 100-year or other pond design storm occurs. The emergency spillway shall be located so that it can safely pass the peak 100-year flow into the pond without damage to the surrounding area or to downstream facilities. The invert of the emergency spillway should be set at or above the 100-year water surface elevation and shall not be in City right-of-way. The spillway shall not be located directly over the outlet conduit. This is due to the increased risk of scouring the fill over the pipe when the spillway is activated as well as to eliminate the need to remove common spillway materials such as grouted riprap or concrete to maintain or replace the outlet pipe.

   The overflow path from the spillway shall be designed as an open channel in accordance with the Open Channels section of these criteria to convey the 100-year pond inflow. The overflow path shall be contained within the City right-of-way or an easement or outlot on which construction is prohibited. The type of surfacing (e.g., pavement, landscape, turf grass, etc.) along the flow path shall be shown in the Construction Drawings. Inundation limits during the 100-year storm shall be calculated and shown on the Basin Map.

10.10 PARKING LOT DETENTION

The use of parking lots to provide detention is not preferred but will be evaluated on a case-by-case basis by the Stormwater Division. The following minimum requirements apply.

A. Ponding Depth. The maximum ponding depth is 18" during the 100-year storm and 6" during the 5-year storm. Calculations shall be provided showing the depth of ponding for each event.

B. Outlet & Release Rate. When a drop inlet is used as an outlet structure, the outlet pipe must be at least 12" in diameter. When a weir and a small diameter outlet pipe through a curb are used as an outlet structure, the outlet pipe must be at least 4" in diameter and no more than 4' long. If a 100-year full spectrum outlet cannot be designed using MHFD-Detention, the orifice and weir equations in the USDCM shall be used to limit the peak 5-year and 100-year release rates to no more than peak historic rates.

C. Repaving & Storage. Any repaving or materials storage shall not impact detention volume or release rates. Storage of materials that could pose a risk to water quality will not be allowed. Repaving and materials storage are subject to approval by the Stormwater Division.

D. Signage. All parking lot detention areas shall include the following signage in at least two locations. Sign panels at each location may be on a single signpost. Each sign panel shall have a minimum area of 1.5 square feet and contain the messages shown below.

1. *Flood Hazard Warning*. A sign warning of ponding during storm events must be included. Materials and geometry for the sign are subject to approval by the Stormwater Division. The sign shall contain the following message:

> WARNING
>
> This area is subject to periodic flooding depths ranging from a depth of X.X' [provide the design depth for the 5-year storm) to X.X' [provide the design depth for the 100-year storm].

2. *Snow Storage*. Snow storage is not permitted in parking lots that are used for detention. A sign prohibiting snow storage must be included that contains the following message:

> ATTENTION
>
> The City of Greeley prohibits this parking lot to be used to store snow from snow removal operations.

10.11 UNDERGROUND DETENTION CRITERIA

Underground detention presents serious challenges, including difficult and hazardous maintenance, the risk of a facility being forgotten, seepage concerns, and the uncertain lifespan of any materials subject to corrosion. Underground detention is only permitted in high-density commercial and industrial sites with a variance approved by the Stormwater Division. Variances may only be granted to applicants that have completed a detailed assessment of functionality, shown careful consideration of risk, and presented legally binding assurances to provide ongoing inspection and maintenance. A detailed O&M Plan must be provided.

Underground detention is not permitted for any type of residential site. All underground detention must fully drain by gravity. Under no circumstances shall pumping be required to drain the

facility, and underground retention is not permitted. When underground detention is approved, it must meet the following requirements:

A. Hydraulic Design. MHFD-Detention shall be used to design an underground detention system and its outlet to meet 100-year full spectrum release rates. A video is available from the MHFD that provides visual instruction on how to correctly use MHFD-Detention for underground detention.

B. Materials and Loading. Underground detention systems may be constructed of reinforced concrete or one of the many proprietary products that have been developed to provide underground detention. Materials and products must be approved by the Stormwater Division. The installation shall be designed for an HS-20 loading. The minimum diameter of each portion of the storage system shall be 48". If using proprietary products, shop drawings from the manufacturer must be provided.

C. Volume. The system shall be designed as a 100-year full spectrum facility unless otherwise approved. In some cases, the underground system may store a portion of the 100-year volume while the remaining portion is stored aboveground in a more traditional detention facility or in a parking lot. Combinations of underground and aboveground detention will be closely scrutinized by the Stormwater Division.

D. Access. Manholes for maintenance access shall be included in the design and their locations shall be approved by the Stormwater Division. Permanent buildings or structures shall not be placed above underground detention.

E. Outlet Pipe. The outlet pipe from an underground detention system shall have a diameter of at least 18" and be no longer than 25'. The outlet pipe shall discharge into a standard manhole or a drainageway with proper erosion protection. If orifice plates are used, they must be removable by maintenance personnel to facilitate cleaning the outlet pipe.

10.12 OIL & GAS EXTRACTION SITES

Detention criteria for oil and gas extraction sites varies from other detention criteria due to the more temporary nature of these sites. Detention requirements for oil and gas extraction sites are the same as for other sites with the following exceptions.

1. Concrete trickle channels and forebays are not required.
2. Embankment side slopes may be as steep as 3H:1V.
3. Revegetation is not required.

10.13 BASIN-SPECIFIC DETENTION REQUIREMENTS

Detention criteria may vary depending on the major drainage basin in which development will occur. Major drainage basin master plans throughout the City are available on the City's website and must be consulted prior to design. Any discrepancy between the criteria herein and those in

the most recent major drainage basin master plan must be discussed with the Stormwater Division to determine the applicable criteria.

10.14 EXISTING POND RETROFIT REQUIREMENTS

Additional stormwater may be discharged from a pond's tributary area if it is regraded or if the imperviousness of the tributary area increases. If a development proposes to discharge new or additional stormwater to an existing detention or water quality facility, several requirements must be met.

1. Detention volume requirements for existing and proposed conditions must be calculated to determine the required increase in storage volume using MHFD-Detention.
2. All pond owners must grant permission, via one or more signed agreements, for the development to discharge new or additional stormwater to the pond. The O&M Plan, outlot plat or easement, and OMC must be updated. If these documents do not exist, they must be created and signed by all parties.
3. The existing pond must be shown to meet current criteria. If it does not, the following options are available.
    a. The pond may be redesigned and regraded and a new outlet designed and constructed to meet current criteria. This will be required if the proposed pond volume is 25% larger or more than the existing pond volume.
    b. The development proposing the additional discharge may provide onsite detention to handle the additional discharge instead of using the existing pond. This can include underground detention or green infrastructure.

10.15 STATE REPORTING REQUIREMENTS

A. Embankments surrounding detention basins may be considered jurisdictional dams. Dams constructed for the purpose of storing water, with a surface area, volume, or dam height as specified in Colorado Revised Statues 37-87-105 as amended, shall require approval by the State Engineer's Office. These include dams which impound water above the elevation of the natural surface of the ground creating a reservoir with a capacity of more than 100 acre-feet, or which create a reservoir with a surface area greater than 20 acres at high water, or which exceed 10' in height measured vertically from the elevation of the lowest point of the natural surface of the ground along the longitudinal center line of the dam up to the bottom of the emergency spillway. These facilities are subject to state statutes shall be designed and constructed in accordance with the criteria of the State.

B. Detention basins may impact water rights. Senate Bill 15-212 became effective on August 5, 2015, as Colorado Revised Statute (CRS) §37-92-602 (8), *Concerning a Determination that Water Detention Facilities Designed to Mitigate the Adverse Effects of Storm Water Runoff Do Not Materially Injure Water Rights*. This statute provides legal protection for any stormwater detention and infiltration facility in Colorado, provided the facility does not materially injure water rights and meets the following criteria.

1. It is owned or operated by a governmental entity or is subject to oversight by a governmental entity.

2. It continuously releases or infiltrates at least 97% of all 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 such as coagulation, flocculation, and disinfection.

There are reporting requirements for any owner or operator of any detention facility constructed after August 5, 2015 that seeks protection under the new statute. A data sheet and online map-based compliance portal website has been developed that will allow owners and operators in the City to upload the required notification information. The notification requirement applies only to CMs constructed after August 5, 2015. CMs in existence before August 5, 2015, are defined in the statute as materially noninjurious to water rights and do not require notification.

The portal can be found at https://maperture.digitaldataservices.com/gvh/?viewer=cswdif. A document containing frequently asked questions, links to a video tutorial, and the link to the compliance portal can be found at http://www.crgov.com/DocumentCenter/View/12225 or via an internet search for the Colorado water rights compliance portal. The owner or operator must report new detention via the portal, and the City must approve the portal entry once it is complete. The owner or operator shall inform the City once the portal documentation is ready for approval.

10.16 OPERATION & MAINTENANCE

An Operation and Maintenance Plan (O&M Plan) is required for all detention facilities. An Ownership and Maintenance Covenant (OMC) is required for detention facilities used by more than one property or party. Detailed requirements are included in Section 13.

10.17 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

10.18 DETENTION CERTIFICATION & FINAL ACCEPTANCE

A Colorado licensed professional engineer shall observe construction, expansion, modification, and post-construction activities of detention facilities and all their appurtenances and certify that the detention facility was built according to the approved plans and specifications. The City's Detention Certification Form must be submitted with the as-constructed record drawings and details and approved by the Stormwater Manager prior to seeding of the detention facility before final acceptance of the development can occur. This form is available at the end of this section. Guidance on how to certify a detention or water quality facility is also included at the end of this section in a document titled Detention & Water Quality Certification Procedure.

A Detention Certification Form must be completed and submitted if any of the following occurs.

1. Construction of a new detention facility, expansion of an existing detention facility, or modifications to the grading or outlet structure of an existing detention facility.

2. Development, redevelopment, or land use change of any kind on any land draining to a detention facility.
3. Ownership of the detention facility is changed.
4. A detention facility is determined to be uncompliant after a City inspection.
5. Ten years has passed since the last Detention Certification Form was submitted.

DETENTION CERTIFICATION FORM

Final acceptance of projects that include any type of hydraulic detention, including volume-based water quality facilities, open detention basins, or underground storage, cannot occur without completed Detention Certification Form for each facility included with the project. It must be signed and stamped by a professional engineer. **The draft Operation and Maintenance plan must also be revised** to include the information in the as-constructed drawings, including all called-out elevations of weirs, inverts, etc., as well as the elevation at which the WQCV, EURV, and 100-year volume are stored, as applicable, and submitted with this form. A PDF copy of the spreadsheet used to calculate as-constructed elevations and volumes must also be included with this form.

Submittal Date _____ As-Constructed Survey Date _____

Land Use Case Number _____ Subdivision Name _____

Subdivision Location _____

Detention or Water Quality Facility Name _____

Parcel Number _____ Receiving Water _____

Drainage Report Title & Date Approved _____

Construction Drawings Title & Date Approved _____

Fill out the table below. The As-Constructed El. is the elevation at which the design volume is achieved within the as-constructed site. The % Difference is the increase or decrease in volume achieved at the design elevation. Any deficiency in volume should generally be less than 5%. If 5% is exceeded, attach a memo that discusses why the facility is still in substantial conformance with the design.

	WQCV	EURV	100-year
Design Vol. (AF)			
Design El.			
As-Constructed El.			
Vol at Design El. (AF)			
% Difference			

"I hereby certify that the _____ facility known as the _____, located at _____, and constructed under City of Greeley Land Use Case Number _____has been constructed in substantial conformance with the design in the approved construction drawings and that the design _____ will be detained and released in substantial conformance with the design in the construction drawings."

☐ By checking this box, I also hereby certify that the detention facility noted above has been entered into the CRS §37-92-602(8) compliance portal (https://maperture.digitaldataservices.com/gvh/?viewer=cswdif)."

SIGNATURE: _____

Registered Professional Engineer

State of Colorado No. _____

(Affix Seal)

DETENTION & WATER QUALITY CERTIFICATION PROCEDURE

Projects with a volume-based water quality or detention facility may use the procedure herein to determine if a volume-based water quality or detention pond (or other type of storage facility) has been constructed in substantial conformance with construction drawings for certification purposes when filling out the City's Detention Certification Form.

Step 1: Confirm the as-constructed survey provides enough information to determine conformance. This includes being completed on the project coordinate system used for design; contours as closed polylines with whole integer elevations assigned to each at an interval of 1 foot or less throughout the pond area to above the top of the pond embankment; breaklines at the toe of slope and top of embankment and at any other abrupt change in grade; the locations, diameters, and lengths of all structures, walls, weirs, orifices, and storm drain pipes into and out of the pond; elevations of all pipe inverts, slabs, channel inverts, tops of walls, weirs and orifices to the hundredth of a foot. If the as-constructed survey is missing any of this information, it should be requested immediately.

Step 2: Once the as-constructed survey is determined to be complete, compare the locations, elevations, lengths, and diameters of all hydraulic structures, walls, pipes, weirs, and orifices indicated in Step 1 with those indicated on the construction drawings. From these elevations, confirm the pond will drain in the direction intended by the construction drawings. All elevations should conform substantially, not necessarily exactly, with the construction drawings. The authority to determine substantial conformance is granted to a professional engineer.

Step 3: While there is more than one way to determine pond volume at a given elevation, Greeley requires the use of CAD to determine the area of each closed-contour polyline provided in the as-constructed survey. A spreadsheet must be created to evaluate the incremental volume achieved with each contour step. Note that the lowest point at which water can exit the pond is rarely a whole integer contour. The first elevation in the spreadsheet should be the lowest point at which water can exit the pond. This is shown in cell A3 in the example below. The corresponding area in B3 is assigned a value of zero. Additional information on how to create the spreadsheet follows the image.

	A	B	C	D	E	F
1	Elevation (feet)	Surface Area (square feet)	Incremental Depth (feet)	Volume (A+B+(A*B)^0.5)/3*H	Cumulative Volume (cubic feet)	Cumulative Volume (acre feet)
2						
3	5691.32	0	0.00	0	0	0
4	5692.00	3079.29	0.68	698	698	0.02
5	5693.00	4644.62	1.00	3835	4533	0.10
6	5694.00	10367.2	1.00	7317	11850	0.27
7	5695.00	18993.11	1.00	14464	26314	0.60
8	5696.00	35591.23	1.00	26861	53176	1.22
9	5696.72	57825.28	0.72	33308	86484	1.99
10	5697.00	66471.85	0.28	17388	103871	2.38
11	5698.00	101104.89	1.00	83185	187057	4.29

The following describes how each column is created.

1. The as-constructed centroid elevation of the lowest orifice out is assigned to cell A3 with a corresponding surface area of zero.
2. The whole integer contour immediately above this elevation, in this case 5692, is entered in cell A4 with the corresponding area it encloses. The process to complete columns A and B is the same for as many closed contours as the as-constructed survey contains. Row 9 in this example is an exception

and will be discussed later. For the initial evaluation, use only whole integer contours in column A above the lowest orifice out.

3. Column C is the difference between the elevations in column A, with the lower elevation subtracted from the higher elevation. For example, C5=A5-A4.

4. Column D is used to calculate incremental volume. The accepted formula is in column D and is considered more accurate than simply an average. For example, D6=[B5+B6+(B5+B6)^0.5]/(3*C6).

5. Cumulative volume in column E starts with zero in E3 and increases as elevation increases. E4=E3+D4, E5=E4+D5, and so on. This volume is cubic feet. The values in column F are the values in column E divided by 43560 square feet/acre. This conversion may not be necessary for small ponds that have their volumes listed in cubic feet or cubic yards. The appropriate conversion should be made. The cells C4 through F4 can be copied directly downward through the bottom of the table.

6. Once the table is established, the elevation at which the WQCV is achieved must be established. The spreadsheet makes this an easy process of trial and error. Begin by determining which two whole integer contours the design WQCV falls between and insert a row into the spreadsheet in this location. For this example, the design WQCV is 1.99 acre-feet, which falls between 1.22 and 2.38 acre feet. The elevation of the WQCV is unknown so a trial value of 5696.2 was inserted. Cell B9 must be an interpolation of the areas assigned to 5696 and 5697. Guidance on interpolation can be found on the internet if needed. The formula for interpolating in this case is:

$$\frac{(B10 - B8)}{(A10 - A8)} \times (A9 - A8) + B8$$

   Once the equation in cell B9 is properly established and checked, cell A9 can be changed until the value in cell F9 equals the WQCV.

7. In practice, it is impossible to construct a water quality pond exactly per plan given that most design plan elevation callouts are to the hundredths of a foot . Some evaluations may result in the WQCV, and other volumes of interest, being achieved at a lower elevation than the plan shows, and some may result in it being higher. The same can be said for all the other relevant elevations such as pipe inverts, orifice centroids, and weir crests. The two most important factors to consider are whether the volume of interest is detained in the general manner intended by the design and whether that volume can be generally expected to drain in the time intended by the design.

   These goals may be accomplished at slightly different elevations and with slightly different grading configurations than indicated in the design provided the pond will store and release the different design volumes as intended. For example, the required WQCV may be 1.20 acre-feet designed to occur at elevation 5520.20 and the required EURV may be 2.40 acre-feet designed to occur at elevation 5522.20. When the as-constructed survey is evaluated, only 1.00 acre-feet of storage occurs below elevation 5520.20, and the design WQCV of 1.20 acre-feet is not stored until elevation 5522.50. This means only 83% of the design WQCV is stored at the design WQCV elevation. However, if the outlet has been designed so that water cannot leave the site until reaching an elevation above 5522.50, it is reasonable to say the WQCV will be detained and discharged in accordance with the design. How each design volume will be achieved and managed needs to be evaluated using the as-constructed drawings. While the authority to determine if the pond is in substantial conformance is granted to the professional engineer completing the certification, the City may audit the certification and accompanying documentation and reject the certification if it does not agree with the finding.

SECTION 11
PERMANENT WATER QUALITY

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SECTION 11
PERMANENT WATER QUALITY

11.01 INTRODUCTION

Stormwater pollution is rapidly growing in importance as a national and local environmental issue. As communities add roads, parking lots, cars, and homes, an increase in impervious area profoundly changes how rain and snowmelt move across the land. Stormwater runoff picks up trash, oil, sediment, yard waste, paint, and other pollutants and carries them to the storm drainage system, which then drains directly into our lakes, streams, and rivers, polluting our water and natural habitats. This section provides guidance and criteria to reduce the discharge of pollutants to State waters that is frequently associated with increases in impervious area.

In these criteria, the terms permanent stormwater control measure, stormwater control measure (SCM), or simply control measure (CM) all refer to a permanent facility or mechanism used to reduce the discharge of pollutants to State waters. CMs provide post-construction stormwater management or water quality treatment in perpetuity and must be maintained over time. Regulatory language in other documents may use the terms control measure or temporary control measure to refer to a product or practices used during construction. The SDDC will refer to these temporary products and practices used during construction as best management practices (BMPs), which are discussed in Section 12. This section discusses when permanent stormwater control measures are required and the design criteria they must meet to satisfy the City's MS4 Permit, which is the Statewide standard MS4 general permit COR090000, available at https://cdphe.colorado.gov/wq-municipal-ms4-general-permits.

11.02 REGULATORY BACKGROUND

Under the Clean Water Act (CWA), the Environmental Protection Agency (EPA) established the National Pollutant Discharge Elimination System (NPDES). The NPDES stormwater permit system regulates stormwater discharges from municipal separate storm sewer systems (MS4s), construction activities, and industrial activities.

In Colorado, the authority of the EPA to issue NPDES permits is delegated to the Colorado Department of Public Health & Environment (CDPHE). MS4 permits are issued under the Colorado Discharge Permit System (CDPS) for discharges of urban stormwater into streams, rivers, and lakes, in compliance with the provisions of the Colorado Water Quality Control Act and the Federal Water Pollution Control Act, as amended. The permitting process helps keep State waters clean enough to support recreational use and aquatic life. The City of Greeley has and administers an MS4 Permit that authorizes discharges from the City's storm drainage system provided those discharges are in accordance with the conditions of the permit. One of the conditions of the permit is that the City must require CMs to be installed in new development and redevelopment to reduce pollutants in stormwater.

11.03 APPLICABILITY & EXEMPTIONS

The City requires permanent CMs for all applicable development, including temporary development such as oil and gas extraction sites. Routine maintenance activities are generally not considered development.

A. Applicable development sites include:

1. New development, expansion, or redevelopment that will disturb 1 acre or more.
2. New development, expansion, or redevelopment that is part of a common plan of development or sale. A common plan of development or sale is defined in the City's MS4 Permit as "a contiguous area where multiple separate and distinct construction activities may be taking place at different times, on different schedules, but remain related." Contiguous area also includes areas that are not immediately adjacent to each other but are separated by one-quarter mile or less at their closest point. An example of this is a 10-acre residential development that is platted with 20 single-family parcels with some parcels on one side of a road and others on the other side.
3. If a single lot is less than 1 acre but part of a common plan of development, each lot must have permanent CMs designed and installed if CMs have not been installed to serve the entire development. This includes developments where large overlot grading developers complete grading and sell individual lots to homebuilders. Contact the Stormwater Division for more information.
4. Include any of the following land uses: auto service/fueling station, auto repair, auto body work/paint, auto wash/polish, equipment repair, lumberyard, nursery, asphalt plant, concrete batch plant, industry, manufacturing, crushing gravel/rock, milling, mining, sawmill, silviculture, junkyard, sludge, sanitary landfill, truck terminals, impound yard, motor vehicles parking/storage, or storage of pesticides, herbicides, fertilizer, or other potentially hazardous materials. Any site that has a reportable quantity for a hazardous material is also an applicable development site.

B. Specific types of development are exempt from permanent CM requirements in accordance with the City's MS4 Permit as of the date of these criteria, including:

1. Roadway pavement management, including resurfacing, milling and overlay, white topping, black topping, curb and gutter replacement, concrete panel replacement, and pothole repair.
2. Roadway redevelopment that adds less than 1 acre of impervious area per mile of roadway or does not add more than 8.25' of paved width to the existing roadway.
3. Above or underground utility work that does not permanently alter terrain, ground cover, or drainage patterns.
4. Single family sites or agricultural zoned lands greater than 2.5 acres where the total impervious area is less than 10 percent.
5. Non-Residential and Non-Commercial development sites with a site, watershed, or MS4-specific study that indicates water will infiltrate and not result in concentrated surface flows during the 80th percentile storm.
6. Sites with land disturbance to undeveloped land that will remain undeveloped after construction.
7. Stream stabilization.
8. Bike and pedestrian trails.
9. Oil and Gas exploration.

C. Applicable development sites in the downtown "Redevelopment District" require on-site CMs regardless of any variance for detention.

D. On-site CM requirements may be waived where a regional CM is sized with the capacity to accommodate flows from the fully developed site and the regional CM is publicly owned and maintained. A waiver is contingent upon the developer providing evidence that the existing regional CM has capacity to receive the additional flow and an inspection from City staff to ensure the regional CM is functional.

E. On-site CMs are not required to treat runoff generated outside of the development if these offsite flows can be intercepted and routed around or through the site in a separate conveyance system. This is the City's preference, where practicable. If runoff generated offsite cannot be separated from runoff generated on-site, CMs must be sized to treat runoff from their entire tributary area. All offsite irrigation flow and stormwater must be passed through or around the development without creating adverse impacts to any properties or to water quality.

11.04 DESIGN STANDARDS

The City of Greeley requires that all applicable development sites incorporate CMs to provide stormwater quality treatment. Due to the variability of factors such as land use, extent of development, existing improvements, and physical characteristics of the site such as soils, slope, and runoff, CMs designed for each site may vary considerably. The City's MS4 Permit includes three base design standards for permanent stormwater CMs at any applicable development site as well as three additional design standards that apply to sites meeting certain requirements. If a developer excludes any portion of the applicable development site from treatment, a narrative must be included in the Drainage Report that explains why it is impractical to capture the entire site and why an additional control measure cannot be implemented. All CM designs shall meet one of the following design standards.

A. Water Quality Capture Volume (WQCV) Standard – CMs meeting the WQCV Standard shall be designed to "provide treatment and/or infiltration of the WQCV and:

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

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

B. Pollutant Removal (TSS) Standard – CMs meeting the Pollutant Removal Standard shall be designed to "treat at a minimum the 80th percentile storm event. The control measure(s) shall 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.

1. 100% of the applicable development site is captured, except the permittee may exclude up to 20 percent not to exceed 1 acre of the applicable development site area when the permittee 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 permittee 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)."
2. Underground proprietary structures such as separators that discharge to a storm sewer system are commonly used to meet the Pollutant Removal Standard. It is also possible to show that the Pollutant Removal Standard is met by moving runoff slowly across a large area using Stokes law. Stokes law is used to calculate the rate of fall of particles. This mechanism and calculation were developed by the EPA. These are discussed later in this section.

C. Runoff Reduction (Infiltration) Standard – CMs meeting the Runoff Reduction Standard shall be 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 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. The City prefers to use the Runoff Reduction Standard where site soils are in Hydrologic Soil Group A or B.

D. 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 of the WQCV Standard above, and the intention to use a regional CM is included in the Permanent Stormwater Quality Control Plan for the site.

E. Applicable Development Site Draining to a Regional WQCV Facility – This design standard is different from the one immediately above in that stormwater from the site may discharge to a water of the state before reaching the WQCV facility. Extensive additional requirements apply, and the design engineer should consult the most recent version of the City's MS4 Permit.

F. Constrained Redevelopment Sites Standard – Alternative methods of compliance have been established for constrained redevelopment sites that have greater than 75% impervious area where it is "not practicable to meet any of the design standards" above. An evaluation must be provided of the ability to install a control measure on the site without reducing surface area covered with the structures. Constrained redevelopment sites must meet one of the following design standards:

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

2. Provide for treatment of the 80th percentile storm event. The CM shall 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 shall drain to the CM. This standard does not require that 100% of the applicable redevelopment site area be directed to a CM as long as the overall removal goal is met or exceeded.
3. Infiltrate, evaporate, or evapotranspirate, 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.

11.05 PLANNING

Chapter 1 of Volume 3 of the USDCM includes a section on ways to minimize the impacts of development on water quality, including ways to minimize site runoff. This document should be reviewed to gain a better understanding of planning principles as they relate to water quality. A discussion on how the site design minimizes site runoff and impacts to water quality shall be included in the Drainage Report.

Several site and functional considerations need to be incorporated into the design of permanent control measures. The City will evaluate the design of the site and the associated permanent CMs based on the functional planning guidance and requirements in this section.

A. Consider stormwater quality treatment needs early in the development process to integrate stormwater treatment CMs into the site. Site considerations should include topography and natural drainage patterns, area, land use, and access to ensure the CM will function and be easily maintained at the site.

B. Centralize water quality treatment for larger developments and integrate them with site operations to minimize land use, achieve greater economy of scale, and reduce the number of CMs requiring maintenance.

C. Develop creative site layouts to reduce runoff by reducing impervious areas and by slowing runoff through pervious and vegetated areas. Maximize the potential for infiltration by minimizing directly connected impervious areas (MDCIA) in accordance with the USDCM. This can include routing downspouts along grass swales and incorporating vegetated areas to receive sheet or concentrated runoff from parking lots and driveways. Grass buffers, grass swales, and bioretention can all be used for these purposes.

D. Incorporate water quality treatment into detention facilities when detention is required. Subsection 11.08 includes different requirements for ponds that combine non-potable irrigation water with detention storage.

E. No permanent structures that are not part of the detention pond function (e.g., forebays, micropools, outlet structures, etc.) may be located anywhere within any detention pond, including along or on top of the embankments.

F. Consider using innovative facilities or concepts to provide water quality treatment as technology and performance data collection evolve.

G. Minimize the impacts to receiving waters, air quality, wildlife habitat, vegetation, and natural landforms and protect areas with high ecological value such as those with mature trees, stream corridors, wetlands, and soils with high infiltration rates.

H. No pond may discharge to an irrigation ditch.

I. Developments must plan for and construct centralized facilities instead of relying on facilities designed to serve individual buildings or development that will be phased over time. Temporary facilities constructed to bridge the timing gap presented by phased development are not allowed.

J. Incorporate additional benefits within stormwater CMs where possible. Land intensive CMs such as detention ponds and vegetative strips should be designed to incorporate recreational or aesthetic features such as open space and landscape values whenever possible.

K. Evaluate both construction and long-term operation and maintenance costs to ensure an economical design. More detailed information on operation and maintenance considerations is in Section 13.

11.06 APPROVED CONTROL MEASURES

Stormwater quality treatment must meet applicable MS4 Permit Design Standards using one or more of the following CMs, as presented in the USDCM, Volume 3, Treatment BMPs. Approved control measures include quantifying runoff reduction, grass buffers, grass swales, bioretention, extended detention basins (EDB), sand filters, constructed wetland ponds, constructed wetland channels, and permeable pavement. The City maintains an unpublished list of approved underground and proprietary CMs that may be used without a variance. Contact the Stormwater Division for the current list. Other underground or proprietary CMs and additional types of CMs may be approved by variance. Section 11.07.C provides additional information on underground and proprietary CMs that may be approved by variance.

11.07 DESIGN CRITERIA

The MHFD has developed detailed permanent CM design guidance and criteria that are available in the USDCM. This document is referenced repeatedly in this section and provides extensive discussion on the topic of stormwater quality treatment. When referenced for design, the most recent version of the USDCM shall be used as the MHFD continually provides updates based on performance and maintainability of the CMs discussed.

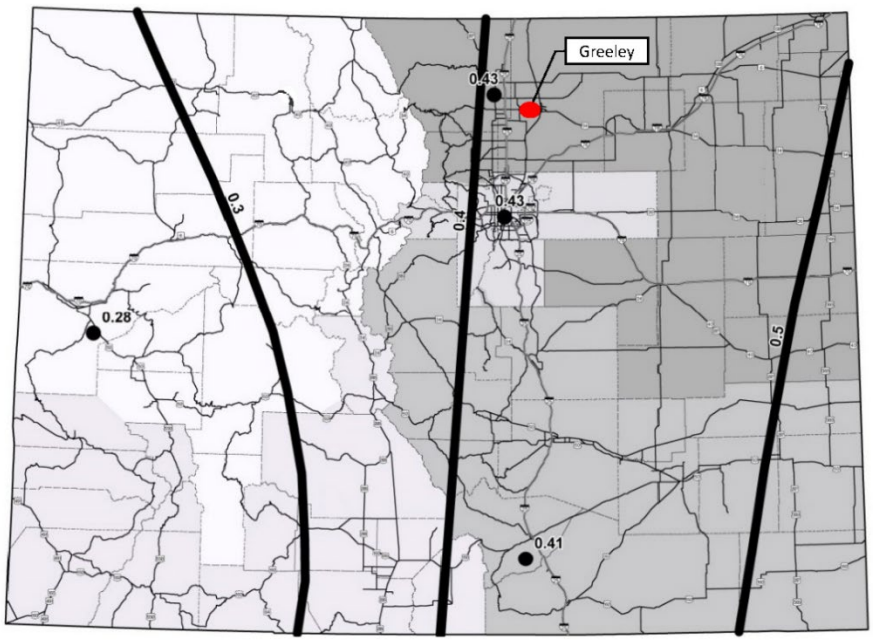
All CM design elements recommended by the USDCM shall be incorporated into the design. All outfalls, forebays, trickle channels, micropools, outlets, spillways, embankments, filter layers, underdrains, freeboard, access, and any other design element of a CM shall be designed according to the design specifications included in Volume 3 of the USDCM.

A. WQCV. The WQCV is a volume of water designated for treatment that has been determined to provide the most water quality benefit for the cost to construct the improvements required to treat it. Volume 3 of the USDCM provides detailed discussion on the development of the WQCV. Capturing, storing, and slowly releasing the WQCV of a site will meet the City's requirements for permanent water quality treatment by storing it long enough that pollutants settle out. WQCV treatment CMs acceptable for use in the City include bioretention,

extended detention basins, sand filters, and constructed wetland ponds. Guidance on how to design these to meet the WQCV Standard is included in the Fact Sheets in Volume 3 of the USDCM. Other types of CMs may be considered on a case-by-case basis.

1. The first step in designing a WQCV CM is calculating the WQCV. Two variables are required to calculate the WQCV. The first is the total imperviousness of the area draining to the CM. The total imperviousness of a site can be determined by taking an area-weighted average of the different imperviousness values for the site. The second variable is the design drain time of the CM. Recommendations for design drain time for different types of WQCV treatment CMs can be found in Volume 3 of the USDCM. The most common WQCV CM is an extended detention basin, for which the recommended drain time is 40 hours. WQCV drain time coefficients are in Table 11.07.1 below.
2. The general equation to calculate the WQCV for a site within the City of Greeley is the same one used for the Denver metro area, given in Equation 11.07.1. A map showing the variance in the average runoff producing storm across Colorado is shown as Figure 11.07.1. The precipitation depth of the average runoff producing storm in Greeley can reasonably be assumed to equal that in Denver, which is 0.43".

Figure 11.07.1. Map of the Ave Runoff Producing Storm Depth in Colorado



$$\text{WQCV} = \text{a}(0.91I^3 - 1.19I^2 + 0.78I)/12 \qquad (11.07.1)$$

Where: WQCV = water quality capture volume (watershed inches)
a = WQCV drain time coefficient (see Table 11.07.1)
I = imperviousness as a decimal percentage

Table 11.07.1 Drain Time Coefficients for WQCV Calculations

Drain Time	Coefficient, a
12 hours	0.8
24 hours	0.9
40 hours	1.0

Watershed inches can be converted to a volume in acre-feet using Equation 11.07.2.

$$V = \frac{WQCV}{12} A \qquad (11.07.2)$$

Where: V = required storage volume (acre-feet)
A = area draining to the CM (acres)

3. Effective Imperviousness. Sites that implement low impact development (LID) principles such as green infrastructure and minimizing directly connected impervious area (MDCIA) may reduce the imperviousness value used in the WQCV calculation to reflect the site's effective imperviousness.

   a. The effective imperviousness is dependent on the level of MDCIA implemented for high-level planning applications. Level 1 includes designing impervious surfaces to drain over a grass buffer or other pervious surface prior to reaching any stormwater conveyance system. Level 2 is an enhancement to Level 1 and includes eliminating curb and gutter or using slotted curbs; low-velocity pervious grass- or rock-lined swales instead of storm sewers, and pervious street shoulders. Guidance on calculating effective imperviousness for Level 1 and Level 2 MDCIA can be found in Volume 3 of the USDCM.

   b. Where a detailed site plan has been developed and the square footage of directly connected impervious area, unconnected impervious area, receiving pervious area, and separate pervious area have all been defined, a more detailed effective imperviousness can be determined using the methods in Volume 3 of the USDCM. If a detailed site plan with this information has not been created and evaluated, no credit for MDCIA will be allowed.

4. Bypass Capacity. WQCV CMs will likely receive more runoff than they were designed to treat during larger storm events. The design of any treatment facility designed to store and release the WQCV must include bypass capacity for the 100-year peak inflow rate into the facility. This is often provided in the form of an overflow weir set at the elevation of the design WQCV. The flow path downstream of the overflow weir must also be designed to safely convey the 100-year peak rate to prevent damage to downstream infrastructure. Design guidance is provided in the Fact Sheets in Volume 3 of the USDCM.

5. Detention and the WQCV. When a site requires detention in addition to permanent water quality treatment, a single facility should be designed to serve both needs. Detention facilities that are also water quality treatment CMs have outlets to provide for both the

stormwater quality treatment and detention release rates. See the USDCM for guidance. Subsection 11.08 includes exceptions for ponds that combine non-potable irrigation water with detention storage.

B. Infiltration. The City prefers using infiltration to provide water quality treatment, especially where site soils are in Hydrologic Soil Group A or B. CMs acceptable for use in the City that can be designed to infiltrate the WQCV include grass swales, bioretention, extended detention basins, sand filters, and permeable pavement systems. Other types of CMs may be considered on a case-by-case basis.

1. Infiltration testing is required when infiltration CMs are planned. Infiltration rates must be established by a double ring infiltrometer test performed by a geotechnical engineer at each proposed infiltration site at the proposed elevation of the bottom of the filter material prior to beginning detailed design.

    a. Infiltration CMs must have a high enough subsoil permeability to infiltrate the entire WQCV of the area draining to them within 6 hours without the use of underdrains.

    b. Infiltration CMs are not allowed within 300’ of any active waterway. Infiltration CMs located between 300’ and 1000’ from an active waterway must not drain the WQCV in less than 4 hours. If subgrade soils at these CMs result in infiltration of the WQCV in less than 4 hours, a sand layer must be designed to slow the infiltration of the WQCV to a minimum of 4 hours. There are no additional restrictions on infiltration CMs located more than 1000’ from an active waterway.

2. Permeable pavements may be considered with a legally binding maintenance agreement in place as an alternative to conventional pavement in pedestrian areas and lower-speed vehicle areas. Permeable pavements will be considered impervious materials for detention and water quality calculations and must be designed and installed in accordance with manufacturer’s recommendations. Permeable pavements are not allowed:

    a. For treatment of tributary areas with high sediment yields that could easily clog the system

    b. In the public right-of-way

    c. On slopes steeper than 5 percent

    d. In areas receiving runoff from bare or nearly bare earth

The BMP Fact Sheets in Volume 3 of the USDCM should be referenced for further specific guidance on the design of infiltration CMs.

C. Flow-Based Treatment. CMs that treat a design flow rate instead of a design volume can be proprietary structures such as a vortex separator or constructed facilities such as a Media Filter Drain, grass swale, or vegetated buffer. Proprietary structures typically function by gravitational separation, vortex separation, filtration, or by screening and retaining pollutants within the structure. In addition to the Media Filter Drain which can meet the MS4 Permit independently, constructed facilities can include multiple facilities constructed in series to achieve a cumulative result that meets the MS4 Permit. The use of underground CMs may be approved by variance, but they are generally discouraged as more frequent maintenance is

typically required to maintain adequate performance; they often have high long-term costs; and they are often very large while treating only a small flow rate. Proprietary CMs that require removable or replacement cartridges, confined space entry procedures, or remote camera operation for routine inspections are typically not allowed.

1. The two most recognized national programs that test the TSS removal of proprietary structures are in Washington state and New Jersey. Proprietary structures that may be approved by variance for use in the City are those that have been tested by one of these programs and have received one of the following:

    a. General or Conditional Use Level Designation for the Pretreatment or Basic test protocols of the Washington State Department of Ecology (WSDOE) Test Assessment Protocol – Ecology (TAPE) for emerging stormwater treatment technologies

    b. Certification by the New Jersey Department of Environmental Protection (NJDEP) with verification by the New Jersey Corporation for Advanced Technology (NJCAT) that the manufactured treatment device (MTD) is adequate for TSS removal.

    c. The City may consider allowing a proprietary structure that is not approved by WSDOE or NJCAT provided that, as part of the Drainage Report, a qualified professional engineer submits adequate documentation, as determined by the City, of the manufacturer's test data showing similar performance to that required by either the WSDOE or the NJCAT. The level of scrutiny during review for approval of such devices may be significant.

    d. The proprietary structure ultimately chosen for water quality treatment should be evaluated based on the category it is certified for to ensure that it will meet specific site needs. Things to consider when choosing a proprietary structure include the design flow rate to be treated, the anticipated peak flow rate through the system, and the target pollutants to be removed by the system.

    e. The TAPE program has also approved the Media Filter Drain, which is an infiltration trench developed by the Washington State Department of Transportation (WSDOT) for use along highways. It has been very successful in removing metals such as zinc and copper from highway runoff and is currently being used along some highways in Colorado.

    f. Proprietary CMs must be designed to provide water quality treatment for the 80th percentile storm event peak flow rate from the area they are treating. Bypass capacity must be included for the 100-year peak flow rate from this same area. If bypass capacity is not included within the structure, it must be provided before the structure in the form of a diversion for higher flows provided the first flush flows pass to the CM.

2. Treatment in Series. Treatment in series is a very effective way to provide water quality treatment and is highly encouraged. Treatment in series, also referred to as a treatment train, involves passing stormwater from one CM to the next, with each CM providing additional treatment. The CMs used in a treatment train are positioned so CMs that can handle a larger, coarser pollutant load are first, while those CMs that are more suited to a

smaller, finer pollutant load are last. This allows for longer periods between required maintenance, especially for the CMs that provide more refined removal.

11.08 COMBINED NON-POTABLE & DETENTION PONDS

Ponds that include a permanent pool for non-potable irrigation storage while also providing volume above the permanent pool for stormwater detention are known as combined ponds. Combined ponds are not encouraged in the City of Greeley and are not allowed without a variance. The variance request must include a detailed narrative and associated documentation explaining why no other option is available. For a variance request to be considered, water quality treatment meeting the requirements of the MS4 Permit must be provided for all sheet and concentrated inflows prior to runoff entering the pond. Written approval by the City's Water and Sewer Department is also required.

11.09 STATE LOW RISK DISCHARGES

Swimming pools, jacuzzies, and fishponds are considered low-risk discharges. The low-risk discharge policy (WQP27) can be found at https://cdphe.colorado.gov/clean-water-policies. All provisions of the low-risk discharge policy must be followed.

11.10 CERTIFICATION REQUIREMENTS

A Detention Certification Form must be completed for each CM designed to meet the WQCV or Runoff Reduction Standard. Information on certification is in Section 10.

11.11 STATE REPORTING REQUIREMENTS

State reporting is required for all permanent control measures that detain or infiltrate stormwater. Detailed requirements are in Section 10.

11.12 OPERATION & MAINTENANCE

An Operation and Maintenance (O&M) Plan is required for all CMs. An Ownership and Maintenance Covenant (OMC) is required for CMs used by more than one property or party. Detailed requirements are included in Section 13.

11.13 ACCESS AND EASEMENTS

Access and easement requirements are included in Section 13.

11.14 REFERENCES

Figure 11.07.1. Map of the Average Runoff Producing Storm's Depth (Modified from UDFCD, 2016)

SECTION 12
CONSTRUCTION WATER QUALITY & REVEGETATION

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SECTION 12
CONSTRUCTION WATER QUALITY & REVEGETATION

12.01 INTRODUCTION

Stormwater pollution is rapidly growing in importance as a national and local environmental issue. Site grading disturbs stabilized ground and increases the potential for erosion and sediment transport. Construction of roads, parking lots, buildings, and homes can result in trash, oil, lubricants, solvents, sediment, chemicals, paint, and other pollutants being transported to our lakes, streams, and rivers, polluting our water and natural habitats. This section provides guidance and criteria to reduce the discharge of pollutants to State waters that is frequently associated with construction activities.

In these criteria, the term best management practice (BMP) refers to a product or practice used during construction to prevent or reduce erosion, spills, and the discharge of pollutants to State waters. BMPs are often removed at the completion of construction. They are not maintained once construction is completed. Regulatory language in other documents may use the term control measure (CM) or temporary control measure to refer to these products and practices used during construction. However, the SDDC reserves the term control measure for a permanent facility or mechanism used to provide water quality treatment in perpetuity that is maintained over time. Control measures are discussed in Section 11. This section discusses how to implement BMPs during construction and other construction water quality requirements needed to satisfy the City's MS4 Permit and the State permit for Stormwater Discharges Associated with Construction Activities.

12.02 REGULATORY BACKGROUND

Construction activities occurring within city limits must abide by all federal, state, and local regulations. Under sections 401, 402, and 404 of the Clean Water Act (CWA), the Environmental Protection Agency (EPA) established the National Pollutant Discharge Elimination System (NPDES). The NPDES stormwater permit system regulates stormwater discharges from municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. The authority of the EPA to issue NPDES permits is delegated to the Colorado Department of Public Health & Environment (CDPHE). The CDPHE implements and enforces the NPDES Programs through the Colorado Discharge Permit System (CDPS) program, which issues a General Permit for Stormwater Discharges Associated with Construction Activities, also known as the Construction Stormwater Discharge Permit. The CDPS helps maintain the quality of State waters to provide drinking water, recreational use, and aquatic habitat. The City of Greeley administers its MS4 Permit that authorizes discharges from the City's storm drainage system provided those discharges are in accordance with the conditions of the permit. The City has implemented the following ordinances to meet the conditions of its MS4 Permit:

A. City of Greeley Ordinance #33, 1994 (incorporated into Title 20, Chapter 4 of City Code), which established the City's Stormwater Management Program.

B. City of Greeley Ordinance #15, 1996 (incorporated into Title 12, Chapter 3 of City Code), which requires erosion control for construction activities.

C. City of Greeley Ordinance #32, 1999 (incorporated into Title 20, Chapter 3 of City Code), which requires a CDPS permit to connect a drainage system or discharge non-stormwater

from industrial, commercial, or sanitary point sources to a storm drain and provides for disconnection of any connection made without a CDPS permit, regardless of if the connection is unused.

12.03 APPLICABILITY & EXEMPTIONS

This subsection includes three common permits that may be required by the CDPHE. Applicable permits for all construction activities must be obtained prior to starting work.

A. The applicability of the Construction Stormwater Discharge Permit may change over time, and the applicability of the current permit shall supersede that herein. The following construction activities currently require a Construction Stormwater Discharge Permit and must abide by the conditions of the permit and the criteria within this section:

   1. Construction activity that will disturb one acre or more.
   2. Construction activity that is part of a common plan of development or sale. A common plan of development or sale is defined in the Construction Stormwater Discharge Permit as "a contiguous area where multiple separate and distinct construction activities may be taking place at different times, on different schedules, but remain related."
   3. Stormwater discharges that are designated by the CDPHE Water Quality Control Division as needing a stormwater permit because the discharge:
      a. Contributes to a violation of a water quality standard or
      b. Is a significant contributor of pollutants to state waters.

B. Construction activities that involve dewatering operations must also apply for a Construction Dewatering Permit from the CDPHE.

C. Construction activities that occur within waterways or discharge dredge or fill material to waterways also require a CWA Section 404 permit. A CWA 401 Certification is also required for any project that requires a 404 permit.

12.04 PERFORMANCE & DESIGN CRITERIA

One of the conditions of the MS4 Permit is that the City must ensure BMPs are implemented to reduce potential pollutants associated with construction activities. The Construction Stormwater Discharge Permit requires that all BMPs implemented must follow good engineering, hydrologic, and pollution control practices. This includes following the industry best practices and standards in this subsection. Others may be required.

A. BMPs must be selected, designed, implemented, and maintained to address all potential pollutant sources at a construction site. At a minimum, the following types of construction activities require BMPs:

   1. Land disturbance and storage of soils.
   2. Vehicle tracking.
   3. Loading and unloading operations.

4. Outdoor storage of construction site materials, building materials, fertilizers, and chemicals.
5. Bulk storage of materials.
6. Vehicle and equipment maintenance and fueling.
7. Significant dust or particulate generating processes.
8. Routine maintenance activities involving fertilizers, pesticides, detergents, fuels, solvents, and oils.
9. Concrete truck/equipment washing, including the concrete truck chute and associated fixtures and equipment.
10. Dedicated asphalt and concrete batch plants.
11. Other areas or operations where spills can occur.
12. Non-industrial waste sources such as worker trash and portable toilets.
13. 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.

B. Appropriate BMPs must be implemented prior to the start of construction activity, control potential pollutants during each phase of construction, and be continued through final stabilization.

C. BMPs must be inspected, maintained, and replaced to remain in effective operating condition. The qualified stormwater manager must ensure availability of enough BMP materials to perform anticipated BMP maintenance and replacement throughout the project.

D. BMP details and design procedures shall be as presented in the most recent version of either of the following references, unless noted otherwise in part 12.05D. These documents are updated regularly and can be found via an internet search.

1. Mile High Flood District (MHFD), Urban Storm Drainage Criteria Manual (USDCM), Volume 3 Stormwater Quality.
2. Colorado Department of Transportation (CDOT) Erosion Control and Stormwater Quality Guide and Standard Plan M-208-1.

E. Use of alternate BMPs not specified in the above documents is subject to written approval by the City.

12.05 STORMWATER MANAGEMENT PLAN

The City's required stormwater management plan, typically referred to as the SWMP, has two parts. The first is the Construction Site Erosion and Sediment Control Plan, frequently referred to as simply the Erosion and Sediment Control Plan, or ESCP, which is a construction plan sheet or sheets that provides a visual representation of the location and size of the BMPs that will be installed on the construction site and maintained throughout the duration of construction. The second is the SWMP Report, which is a narrative document that identifies the qualified

stormwater manager and discusses procedures that will be followed on site. This subsection discusses requirements for the SWMP.

A. The Construction Stormwater Discharge Permit includes required SWMP contents. Many of these SWMP requirements are detailed in the stormwater management plan guidance published by the CDPHE and available at https://cdphe.colorado.gov/wq-construction-compliance-assistance-and-guidance or via a web search for CDPHE stormwater management plan guidance. The information required at the time of this SDDC update is included in the list below along with where each item should be included in the SWMP.

   1. Identifying a qualified stormwater manager for the site (SWMP Report)
   2. A narrative spill prevention and response plan (SWMP Report)
   3. A list of other CDPS permits associated with the site (SWMP Report)
   4. A narrative materials handling plan (SWMP Report)
   5. Identifying potential sources of pollution (SWMP Report)
   6. Identifying how BMPs will be implemented (ESCP and SWMP Report)
   7. A narrative site description (SWMP Report)
   8. Site maps (ESCP)
   9. Temporary, final, and long-term stabilization plan (ESCP and SWMP Report)
   10. Site inspection reports (SWMP Report)

B. In addition to the requirements from the CDPHE, the City requires that the ESCP and SWMP Report include a water control plan that identifies how any stream diversions or dewatering operations will be completed. The water control plan will include anticipated flow rates and equipment to be used. Water from dewatering operations shall not be connected to any sanitary sewer or underdrain that discharges to a sanitary sewer.

C. The SWMP is a living document. Both the SWMP Report and the ESCP must be updated throughout the course of work to accurately reflect site conditions.

D. The ESCP must include initial, interim, and final plan sheets and must show all BMPs at a reasonable scale; multiple sheets may be necessary for large sites. BMP construction details from the MHFD or CDOT must be included. The General Erosion Control Notes in the City's Standard Stormwater Details must also be included.

   1. The initial ESCP must include all BMPs that will be installed prior to the start of construction. These BMPs shall include, where applicable:
      a. Staging areas. Recycled concrete is prohibited for staging areas.
      b. Concrete washout locations.
      c. Temporary sanitary facilities or portable toilets.
      d. Vehicle tracking BMPs at all site egress locations. Recycled concrete is prohibited for vehicle tracking control.
      e. Perimeter controls.

f. Construction fencing delineating site boundaries and/or any areas where existing conditions will be preserved during construction.

g. Inlet protection on existing MS4 features such as storm drain inlets or along curb and gutter, as necessary, to prevent sediment from accumulating in inlets, storm drains, channels, and ponds.

2. The interim ESCP must include all BMPs that will be utilized during construction. Interim ESCPs shall include, where applicable:

   a. All BMPs included on the Initial ESCP.

   b. Temporary stream diversions.

   c. Sediment control BMPs such as check dams, sediment basins, sediment control logs, silt fence, or others. Note that permanent CMs such as ponds may only be used as sediment control BMPs prior to concrete work within the CM. If a permanent CM is used as a sediment control BMP during construction, all accumulated sediment must be removed, and the full design capacity must be restored and confirmed by survey, prior to concrete work.

   d. If construction ceases on a site or part of a site for more than 14 days, temporary erosion control BMPs such as erosion control blankets, soil binders, mulching, temporary seeding, or others shall be required.

   e. Material stockpiles.

   f. Annotations or multiple plan sheets, where necessary, to indicate project phasing.

3. The final ESCP must include all BMPs that will be installed following active construction to achieve site stabilization. Final stabilization is required within 14 days of the completion of construction of any portion of the site. Final ESCPs shall include, where applicable:

   a. Final stabilization BMPs such as seeding, mulching, and/or erosion control blanket.

   b. A final site and grading plan indicating the path of all stormwater flow and the location of detention facilities and permanent stormwater control measures.

   c. BMPs shown in the initial and interim plans should not be included in the final ESCP.

E. Routine visual construction site inspections are required by both the City's MS4 Permit and the Construction Stormwater Discharge Permit and must be completed to ensure all BMPs remain in effective operating condition.

1. The contractor shall designate a qualified stormwater manager to complete documented site inspections. Inspections will begin before the start of active construction with an initial inspection of all BMPs installed in accordance with the initial ESCP. Routine site inspections of all BMPs, pollutant sources, and permitter controls will continue at regular intervals for the duration of active construction on one of the following two schedules:

   a. One inspection every 14 calendar days along with post-storm event inspections within 24 hours after the end of any precipitation or snowmelt event that causes surface erosion.

b. Once every 7 days.

2. When construction activities have been completed, including final stabilization, sites must be inspected every 30 days at minimum.

3. All inspections must be recorded in the SWMP Report.

F. Review and approval of the ESCP and SWMP Report by the Stormwater Division is required for issuance of a Land Grading Permit. Upon issuance of the Land Grading Permit, the Contractor must contact the City to inspect the initial site BMPs prior to construction. The City will also perform its own regular site inspections. A site that does not comply with the approved provisions of the ESCP or SWMP Report may be assessed a reinspection fee, receive a fine or a stop work order, or have its Land Grading Permit revoked. Major modifications to an approved ESCP or SWMP Report, including changes to hydrology, must be submitted to and approved by the Public Works Director prior to implementation.

12.06 REVEGETATION

Revegetation is required to achieve final stabilization and to terminate the Construction Stormwater Discharge Permit and the City's Land Grading Permit. A two-year warranty on all seeding and sodding is required. Additionally, any land or infrastructure dedicated to the City will require the owner or developer to initiate a two-year maintenance contract to oversee the establishment of vegetation in accordance with the City's Clean, Safe, and Beautiful policy.

Final stabilization for all construction except detention facilities is achieved when all surface disturbing activities at the site are complete and a uniform vegetative cover has been established with a plant density of at least 70% of pre-disturbance levels, as determined by the Stormwater Division, or an equivalent amount of permanently stable surface has been constructed. Permanently stable surfaces include permanent pavement or concrete, hardscape, xeriscape, stabilized driving surfaces, landscape rock, wood mulch, and landscape pavers. Detention facilities require a plant density of at least 85% of pre-disturbance levels. This subsection includes additional revegetation requirements and standard practices to ensure successful reestablishment of vegetation.

A. Noxious Weeds. Only the vegetation specified in the landscaping plans or the final stabilization portion of the SWMP plan shall count toward plant density. No noxious weeds shall be allowed. Noxious weeds can be prevented by:

1. Pretreating the project site to remove invasive or noxious species.

2. Selecting an appropriate and diverse early-seral seed mix with the potential to fully occupy the site's botanical niches.

3. Minimizing or eliminating the use of nitrogen, because exotic weeds are often preferentially stimulated over native species.

4. Monitoring the nontarget species and noxious weed seeds that are often present in a seed mix.

5. Developing an iterative weed management plan based on regularly scheduled monitoring.

B. Seed Mixes. The City has several standard seed mixes. Seed mixes also apply to sod. The mixes and the conditions for which they are commonly used can be found in the City's Standard Stormwater Details. For stormwater facilities, including open channels and detention and water quality facilities, different seed mixes may be required for different portions of the site. Requirements for vegetation buffers and seed mix selection can be found in the City's Clean, Safe, and Beautiful policy.

C. Soil Amendments. The topsoil to be used at the site shall be tested prior to final design of the site. Recommendations for soil amendments shall be provided by a Certified Professional Agronomist, a Certified Horticulturist, a Colorado State University Certified Master Gardner, a Local Seed Company, or a combination of the above and submitted to the Stormwater Division as part of the Drainage Report. The recommended amendments shall be quantified in the landscaping plans or the final stabilization portion of the SWMP plan.

D. Land Grading Permit. If a developer in possession of a Land Grading Permit desires the City to issue a subordinate Land Grading Permit to a new owner, the site must be seeded with a temporary or permanent seed mix and mulched prior to City approval of the subordinate land grading permit.

E. Detention Facilities. All vegetated detention facilities and CMs shall be seeded or sodded. If the detention site serves as usable open space, a temporary or permanent irrigation system may also be required. The Stormwater Division must approve any trees or shrubs specified within a detention facility or other CM. If allowed, trees must be planted at least 100' from the outlet structure to prevent interference with hydraulic function. Before the two-year warranty on seeding or sodding has expired, the Stormwater Division shall certify that the density of approved vegetation within the disturbed area is at least 85% of pre-disturbance levels for all areas not covered by other permanently stable surfaces. Until these requirements are met, the detention facility will remain the responsibility of the developer, and maintenance shall not be transferred to the City or any HOA, POA, or other entity.

F. Open Channels. All open channels shall be revegetated with seed or sod. Trees are not allowed in open channels. Final stabilization is achieved when a uniform vegetative cover has been established along the channel banks and other disturbed areas with a plant density of at least 70% of pre-disturbance levels. The channel invert and permanently stable surfaces are excluded from the calculation. Temporary irrigation may be required for seed establishment. Before the two-year warranty on seeding or sodding has expired, the Stormwater Division shall certify the plant density of approved vegetation. Until these requirements are met, the open channel will remain the responsibility of the developer, and maintenance shall not be transferred to the City or any HOA, POA, or other entity.

G. Irrigation Systems. All underground irrigation systems shall be covered under a guarantee or warranty to ensure that the City receives quality irrigation materials that are installed and maintained in a thorough and careful manner. Materials, equipment, and workmanship shall be covered against defects for a period of two years from the date of final acceptance. The guarantee or warranty shall apply to originally installed materials and equipment and replacements made during the guarantee or warranty period. The guarantee or warranty must include prompt repair or replacement of faulty components and restoration of landscaping, structural features, or the general premises damaged by the faulty system.

12.07 FINAL ACCEPTANCE

Final acceptance will be granted once all surface disturbing activities at the site are completed and a uniform vegetative cover has been established or an equivalent amount of permanently stable surface has been constructed. Exceptions may be granted for single family lots that are left unstabilized to allow the new resident to stabilize the site to his or her preferences provided perimeter erosion control logs are correctly installed adjacent to all unstabilized area. The Stormwater Division will complete a final site inspection and issue final acceptance in writing.

12.08 PERFORMANCE SECURITY

As a condition for the issuance of the Land Grading Permit, applicants must provide a performance security in the form of cash, surety bond, or irrevocable letter of credit. The amount of the performance security shall be 125% of the estimated cost of the work specified in the ESCP to ensure compliance with City requirements. The performance security, less any deductions, shall be released once the Stormwater Division determines all work has been successfully completed and final stabilization has been achieved.

SECTION 13
ACCESS, EASEMENTS, OPERATION, & MAINTENANCE

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SECTION 13
ACCESS, EASEMENTS, OPERATIONS, & MAINTENANCE

13.01 GENERAL REQUIREMENTS

Section 13 covers requirements for access, easements and outlots, operations, and maintenance for storm drainage facilities in the City of Greeley. An easement or an outlot is required for all stormwater facilities located outside the right-of-way that are not on public property. The easement or outlot delineation must include space to access the facilities for operation and maintenance, regardless of the entity responsible for maintenance. Additional requirements may be applicable. Finally, an Operations and Maintenance Plan (O&M Plan) and Operation and Maintenance Covenant (OMC) are required for all stormwater quality and detention facilities. Some open channels, ditches, and swales may also require an O&M Plan and an OMC. The specific details of these requirements are discussed in the sections below.

13.02 OUTLOTS & EASEMENTS

The City generally uses two methods to designate the spaces in which stormwater facilities are located, and the method used will be established during the development review process. The first method is an outlot, which is a tract of land platted in a subdivision or development. The outlot on which a stormwater facility is located typically has common ownership, and the responsibility for maintenance of the stormwater facility is often shared among multiple users of the facility. The second method to designate space for stormwater facilities is an easement. The City recognizes two types of easements to be used convey, store, or treat runoff. The type of easement is dependent on whether the runoff is underground or on the surface.

A. A stormwater easement is used for underground facilities that convey, store, or treat runoff in a conduit or other enclosed facility. These may include storm drains, culverts, inlets, manholes, and underground detention and water quality facilities. The need for an easement for underground stormwater facilities on public property outside the right-of-way will be determined on a case-by-case basis. A stormwater easement may be required for stormwater facilities on private property if the City determines the facility may pose a risk to the public if it is not maintained. The City will not own or maintain stormwater facilities located on private property or within a stormwater easement.

B. A drainage easement is used for surface water management facilities that convey, store, or treat runoff. These may include ditches, swales, channels, and open basin detention and water quality facilities The need for a drainage easement for surface water management facilities on public property outside the right-of-way will be determined on a case-by-case basis. A drainage easement may be required for surface water management facilities on private property and will be determined on a case-by-case basis. The City will not own or maintain stormwater facilities located on private property or within a drainage easement.

13.03 OUTLOT & EASEMENT REQUIREMENTS

This section lists the requirements for easements and outlots used for stormwater facilities. The space, access, and use requirements and limitations are the same, regardless of whether an outlot or an easement is used.

A. Storm Drain Pipes & Culverts. When a storm drain or culvert is not in a dedicated street right-of-way, the need for an outlot or stormwater easement will be determined at the time of

review. The minimum easement or outlot width for storm drains and culverts shall be in accordance with Table 13.03.1. The easement or outlot must include the full width of all necessary access paths from City right-of-way. Access requirements are discussed later in this section.

Table 13.03.1. Required Storm Drain and Culvert Easement Widths

Pipe Diameter or Culvert Width	Easement or Outlot Width
Less than 36”	20’
36” up to 84”	25’
Wider than 84”	Exterior width plus 10’ min on each side

B. Detention & Water Quality Facilities. The easement or outlot must extend at least 5 feet beyond the outside toe of the embankment or area of excavation for underground facilities. The easement must also include the full width of all access paths from City right-of-way or other access easement. Access requirements are discussed later in this section.

C. Open Channels & Swales. The easement or outlot must extend to at least 5 feet beyond the top of the channel or swale side slope provided the channel or swale is designed to convey the 100-year event within its banks. If the channel or swale is designed to convey an event smaller than the 100-year event, the easement or outlot must extend to the limits of the 100-year water surface. The easement or outlot must also include the full width of all access paths from City right-of-way. When drainage swales along subdivision lot lines are required to convey onsite runoff in accordance with the subdivision grading requirements in Section 1, a drainage easement dedicated to the public shall be designated on the plat with plat notes meeting the requirements of this section.

D. For all facilities using easements, the easement name, which shall be “STORMWATER EASEMENT” or “DRAINAGE EASEMENT,” and the easement width or dimensions shall be labeled on the Construction Drawings and preliminary and final plats.

E. All stormwater facilities shall be located as centrally as feasible within the easement or outlot while maintaining required separation from all other utilities and accounting for the depths of other utilities where necessary.

F. No permanent structures, fences, trees, shrubs with mature height greater than 3’, or other obstructions are permitted that will impede the flow of stormwater or the ability of maintenance personnel to adequately inspect, maintain, and service the facility within the easement or outlot. No berms shall be constructed over storm drain pipes, culverts, or underground detention and water quality facilities or in open channels. Any obstructions or grading discovered by the City that conflict with these restrictions will be removed at the owner’s expense.

G. Easements not dedicated with a plat, shall be dedicated by a separate document and recorded prior to City acceptance of the Construction Drawings.

13.04 EASEMENT VACATION

Development may require vacating an easement. The City of Greeley Development Code Application Manual discusses the procedures and requirements for vacating easements and right-of-way. Vacation of an easement will require documentation of the original purpose of the easement and discussion of how revised site conditions negate the need for the easement.

13.05 ACCESS REQUIREMENTS

The easement or outlot delineation must include an area suitable for drivable access from City right-of-way to the stormwater facility to allow for inspection, operation, and maintenance, regardless of the entity responsible for these. This includes easements and outlots for culverts, bridges, hydraulic structures, and all detention and water quality facilities located outside the right-of-way. Access to maintain detention and water quality facilities is especially critical as the function of these facilities is largely dependent on regular maintenance. Requirements for the access portion of the easement or outlot may vary by the type of facility and appurtenant structure based on the anticipated inspection, repair, and maintenance activities. All easements and outlots used for access must be at least 12' wide and have an inside turning radius of at least 25'. Additional requirements are included in this section. The Stormwater Division may require alternate criteria for unique facilities or configurations.

A. Open Basins. Access roads located fully within an easement or outlot shall be provided from the right-of-way to all detention and water quality facility structures including forebays, outfalls, inlets, micropools, outlet structures, and proprietary control measures. An access road must also be provided along the top of the embankment, all the way around the basin. Access roads must pass close enough to each structure needing maintenance so that the equipment used will be able to reach the full extent of the structure. For example, a backhoe must be able to reach the farthest point of each forebay or micropool invert without leaving the access road. Available maintenance equipment must be confirmed with the City prior to design. If the access road cannot pass close enough to the structure for the equipment to reach it, a 10' wide access ramp capable of supporting an HS-20 loading under saturated conditions shall be provided at a slope no steeper than 10:1 that leads from the access road to the structure. The ramp must be made of concrete or granular materials that will not wash away during storm events. Ramp material, bedding, and subgrade requirements shall be provided by the geotechnical engineer in the geotechnical report. Concrete ramps shall be scored for wet weather traction. Section 13.06 provides additional requirements.

B. Underground Facilities. Access roads located fully within an easement or outlot shall be provided from the right-of-way to each access port of all underground facilities. Underground facilities must not require confined space entry to complete maintenance activities. Careful design of access to vaults and use of a vacuum truck can eliminate confined space entry requirements.

C. Infiltration Facilities. Access roads located fully within an easement or outlot shall be provided from the right-of-way to each infiltration facility including grass swales, bioretention, sand filters, and permeable pavement systems. Access must be provided so that any filter material may be replaced without compacting the new material by driving on it. Easements for temporary stockpiling of filter material being removed may be required as well unless procedures specified in the O&M Plan specifically dictate that material to be removed will not be placed on the ground but shall be hauled away directly from the facility.

D. Storm Drain Pipes & Culverts. Access roads located fully within an easement or outlot shall be provided from the right-of-way to each manhole, junction box, or inlet along an enclosed storm drainage system and to the inlet or outlet of each culvert.

E. Open Channels & Swales. Access roads located fully within an easement or outlot shall be provided from the right-of-way to and along each open channel or swale so that maintenance staff can access all parts of the channel or swale.

13.06 OPERATION & MAINTENANCE PLAN

An Operation and Maintenance (O&M) Plan shall be created, approved by the Stormwater Division, and recorded for all detention and water quality facilities. An O&M Plan may be required for open channels, ditches, or swales as well, depending on their hydrology, risk, and function. The requirements of an O&M Plan are in this section. The O&M Plan will be an appendix to the OMC. The O&M Plan will specify the types of maintenance activities to be performed and the timing and frequency of those activities. It will also indicate the estimated equipment hours and man hours required to maintain the facility, delineate access requirements, and explain any special procedures required to maintain the facility to function according to the original design. It is possible that some maintenance information or requirements may change over time. Revisions should be noted on the O&M Plan as they occur.

Detention and water quality facilities not on public property or in the public right-of-way will be maintained by a private individual, business, or property owners' association. They will not be maintained by the City. See the Maintenance Enforcement subsection below.

An O&M Plan example is also included as an appendix. Because each facility is unique, each O&M Plan will be unique as well, and no single example can be comprehensive. Rather, the example O&M Plan includes many commonly required components. All O&M Plans shall generally conform to the example regarding the type of information provided; however, not all necessary content may be included in the O&M Plan example. Unique features may warrant the inclusion of additional information.

A. Format. Each O&M Plans shall be no more than two single-sided 11"x17" sheets with a CAD font height of at least 0.10. The O&M Plan may be printed double-sided for field use. If an item is not required, note that it is not required rather than omitting it from the O&M Plan. Each sheet must include a title block and text that includes:

   1. Development name (e.g., Highland Hills Phase 1), facility name (e.g., Detention Pond HHP1-B), type (e.g., full spectrum detention basin, swale), and address or parcel number.
   2. Land use case number.
   3. Month and year the facility was constructed.
   4. Party or parties responsible for maintenance.

B. First Page Content. The following items must be included on the front page of the O&M Plan with any dimensions or elevations representing as-built conditions. Additional information may be required based on the function and circumstances of each facility.

1. Location map. A large-scale location map shall cover enough area and include enough major roadways that the O&M Plan user can find the facility. The map shall include a north arrow and the location of the facility. Scale shall be 1"=1000' to 1"=5000'.

2. Detailed as-built plan view. A smaller scale detailed plan view of the facility location shall show all adjacent roadways; all access points, turn-arounds, and sediment/debris stockpile areas; at least one hard maintenance control point including elevation; right-of-way, property boundaries, ownership, and easements; areas to remain undisturbed by maintenance activities such as areas regulated by a 404 permit or any other sensitive areas; and areas to be mowed or to receive other weed control activities including weed spraying. Major features shall be identified such as forebays, micropool, inlets, outlet, structures, trickle channels, overflow path, etc. Include the 100-year floodplain if applicable. If a power source usable by maintenance staff is present at the site, it shall be shown in the detailed plan view. Any weight-restricted areas shall be shown. Detailed instructions do not need to be provided on the detailed plan view if they are included in the notes. Scale shall be 1"=20' to 1"=100'. The location of the main access point may need to be delineated by dimensions from roadway centerline, edge of pavement, or other hard, visible structure if it is below grade or otherwise may be difficult to find. For example, if the facility is a below-grade vault with manhole access, and there are multiple manholes in the vicinity, it will be necessary to indicate which specific manhole(s) access the facility.

3. Profile. While not required for every facility, if critical information cannot be sufficiently in sections and/or the plan view, a profile view of the main flow path through the facility may be added to show critical elevations and information. Such information may include variations in slope of the main channel invert or pipes and culverts, the extents and depth of filter media, and underdrains and other structures. The profile shall show permanent pool elevations, crossing utilities, flow direction, and any design water surface elevations used such as the elevation of the water quality capture volume (WQCV) or any specific design storm event. General maintenance notes may be included on the profile or reserved for the detailed notes on the back of the O&M Plan.

4. Sections. Enough sections shall be included to detail all tops of walls, inverts, rims, dimensions, and flowline elevations of all components including, but not limited to, forebays, inlets, micropools, outlets, open channels, storm sewers, underdrains, sumps, headwalls, wingwalls, overflow weirs, orifice plates, grates, screens, gates, trash racks, and filter media dimensions and specifications. Sections of proprietary structures may be as provided by the manufacturer. Nearby utilities shall be shown in the sections as applicable. A section showing the maintenance access roads shall also be included with the access road surfacing material and thickness, minimum width, maximum grade, and any weight limitations.

5. Grate Details. Details of all grates must be included with enough information that the party responsible for maintenance can reorder grates if they are stolen. This includes exterior dimensions, materials, and bar spacing in both directions.

6. First page notes. While the first page of the O&M Plan is generally reserved for plans, sections, profiles, and details, any notes of high importance may be added here in addition to the back page of the O&M Plan. Front page notes must include the same list

of approved dischargers to the facility that are included in the OMC. They may include detailed notes on critical items such as how to handle wetlands or weeds on site or unique access instructions. These notes shall also be included on the back page to provide redundancy.

Note that if an additional party not listed in the original O&M Plan or OMC wishes to discharge to an existing facility, the O&M Plan and OMC must both be updated and rerecorded, or a new one created if one was not previously recorded, to establish shared responsibility or specific maintenance requirements of each party.

7. Maintenance Procedures. Frequency, & Schedule. Maintenance procedures and their timing and frequency will be included on the O&M Plan in accordance with the recommendations presented later in the section for each type of structure.

C. Second Page Content. The following items must be included on the back page of the O&M Plan. Additional information may be required based on the function and circumstances of each facility.

1. Notes on general project information. The notes shall include the name of the receiving water; the property owner name(s), contact name, address, phone number, and contact email address if available; the name(s), contact name, address, phone number, and contact email address if available of the party or parties responsible for maintenance; the design engineer's name(s), contact name, address, phone number, PE license number, and contact email address if available. If the City is responsible for maintenance, the name of the Stormwater Manager shall be included.

2. Notes on the general facility description. The notes shall include a general facility description including the type of facility. Types of facilities allowed by the City are included in Sections 10 and 11. The notes shall also indicate how the facility functions (filtration, sedimentation, etc.) and the origin of the runoff it treats, including total tributary area. A brief note about the overall project under which the facility was constructed, if applicable, should be included as well. If the facility will not treat the 100-year storm event but will receive inflow exceeding its volumetric capacity, a note should be added on how those flows are safely conveyed through and beyond the facility. If flows are bypassed prior to reaching the facility, a note shall be included that details the function and location of the bypass structure.

3. Notes on the anticipated inspection and maintenance frequency and procedure. Initial inspection frequency shall be annually plus after storms producing more than 1” of rainfall per hour, at a minimum. Inspection frequency may be adjusted based on findings of inspections during the first year. Maintenance shall be annually at a minimum. Maintenance frequency may be increased based on findings of inspections during the first year and any requirements issued by the EPA or CDPHE. Examples of items to be inspected include pond forebays, low water crossings, riprap side slopes and inverts, grouted riprap, inlets, access ramps, storm sewer outfalls, incoming and outgoing pipes, pond outlet structure including interior of structure, canal gate (to be exercised), restrictor plate, micropool, trash rack, and well screen.

Inspection and maintenance frequency and procedures listed in the O&M Plan shall include those in Table 13.07.1 of this section as well as the following, at a minimum,

provided they are applicable: Traffic control plan; dewatering and water control requirements such that a dewatering permit is not required; longest reach distance from access road for sediment and debris removal; information on wetlands and other sensitive areas; any other maintenance required maintenance activities; items to be replaced; any materials testing requirements if sediment must be tested for contaminants prior to disposal; post-maintenance considerations such as restoring flow patterns, removing temporary dewatering and water control measures such as stop logs, or additional cleanup requirements.

4. Notes on required maintenance equipment, materials, staffing, and responsibility. Notes shall include all equipment, materials, and labor that is anticipated to be required to maintain the facility. Equipment may include, but not be limited to mowers, pumps, hoses, vac trucks (note reach required), air compressors, shovels, buckets, excavators (note reach required), inflatable coffer dams, weed killer, generators, and sprayers. The anticipated size of all equipment shall be included. Materials may include proprietary replacement products such as filter bags or media that need to be ordered in advance or more general filter media. Materials notes should include approximate quantities. Staffing notes shall include the minimum number of maintenance staff expected to be required to complete the maintenance activities. For example, if two employees are required to operate a pump or install a coffer dam, this should be noted in this section.

   These notes shall also include a description and details of any agreements regarding the properties allowed to discharge to the facility, the party(ies) responsible for maintenance of the facility, and which party is responsible for which aspects of maintenance, if applicable. The agreement description and details should include the dates and parties subject to the agreement and a general summary of the agreement, including what happens if one party does not fulfill its contractual obligations. This information is also required in the Operation and Maintenance Covenant (OMC).

   If an additional property not listed in the original O&M Plan and OMC wishes to discharge to an existing facility; if there are changes in ownership or use of any discharging property; or if a discharging property is subdivided, the O&M Plan, easement or outlot, and OMC must be updated and rerecorded, or a new one created if one was not previously recorded, to establish shared responsibility or specific maintenance requirements of each party.

5. Notes on ROW, adjacent ownership, and access. Include a general description of the right-of-way shown in the detailed plan view, the adjacent property ownership, and locations and dimensions of maintenance access. These notes shall include property access requirements such as whether locked gates might be encountered, locations of keys, access codes, and vehicular weight limitations. The notes shall also include additional specific instructions (e.g., must approach access drive from the south). Any changes to this information shall be noted on the O&M Plan.

6. Notes on vegetation management. The notes are specific to seed mixes, irrigation, mowing, and weed control. There may be some redundancy with the notes on the anticipated inspection and maintenance procedure and frequency. These notes are intended to be more detailed. The notes shall include all seed mixes (dryland/upland and/or wetland mixes) and any trees or shrubs that have been planted at the site. Seed

mixes shall include all genus, species, variety, and pounds pure live seed per acre of each type of seed that was planted as well as the location (e.g., above elevation XXXX.XX, on the low flow channel side slopes, etc.). If an irrigation system is used, the notes must include seasonal maintenance and testing requirements.

These notes shall also indicate the total area to be mowed, in acres, and any notes on mowing including mowing height, frequency, and any variations required based on vegetation type.

How weed control is to be accomplished (e.g., mowing, spraying, etc.) shall also be included in the notes. Different areas may require different methods, and these shall be noted. These notes shall also include criteria on replacement of seed or other vegetation.

7. Notes on hydraulic design. The notes shall include all flow rates used in the hydraulic design including base flow and the 5- and 100-year peak inflow and outflow at a minimum. The notes shall include other calculated flow rates as applicable, the WQCV and associated water surface elevation, the excess urban runoff volume (EURV) and associated water surface elevation, if applicable, the 100-year volume and associated water surface elevation if applicable, and the volumes of major structures that can accumulate sediment including forebays, micropools, and sumps. Depths of major structures shall be noted. The WQCV drain time and EURV drain time shall be noted if applicable.

8. Notes on sensitive areas, wetlands, and permits. The notes shall include descriptions of any environmentally sensitive areas, wetlands to remain undisturbed, and areas covered by a 404 permit or other environmental permit and how maintenance activities are different for these areas, if applicable. The notes shall include any monitoring or inspections required by 404 or other environmental permits. The notes shall also include information on any current or retired groundwater monitoring wells, any hazardous materials that were or could reasonably be anticipated to be encountered on site, and any known unmitigated hazards. Permits that may be required include a floodplain development permit if the facility is within the 100-year floodplain and CDPHE permits such as construction dewatering, stormwater discharge, groundwater, etc.

9. Notes on snow and ice control. Notes shall include descriptions of locations where the party responsible for maintenance is responsible for snow and ice control if necessary for sidewalks and/or roadways within the facility and the methods by which these are to be controlled. If snow storage is required, notes shall include possible snow storage locations and any areas where snow may not be stored.

10. Notes on miscellaneous information. Notes shall include any other items or details that are important for understanding the inspection and maintenance requirements of the site or for general informational purposes. One required item is the approximate survey date, horizontal and vertical datum, and coordinate system information.

11. Notes on homeless encampments. The note included on the O&M Plan example shall be included on all O&M Plans. The contact person for all facilities maintained by the City shall be the Stormwater Manager. For facilities maintained by others, contact the party responsible for maintenance.

13.07 REQUIRED OPERATION & MAINTENANCE

Table 13.07.1 lists the minimum required inspection and maintenance schedule and typical maintenance activities and operational protocols for various types of water quality treatment and detention facilities. Based on site conditions, the design engineer may require additional maintenance measures, a more frequent schedule, or unique protocols for a site. Volume 3 of the USDCM should be consulted when determining the maintenance schedule, activities, and protocols to be included on the O&M Plan.

An O&M Plan must be developed, submitted, and approved as part of the Drainage Report and then also included as an attachment to the OMC. An executed OMC may be required prior to facility approval and project close out. The City will have the right to access the property to maintain the treatment or detention facility and invoice the owner for the cost of such work if the parties to the OMC fail to maintain the facility. An example O&M Plan, including typical O&M Plan text are included as an appendix. City staff are available for consultation during the water quality treatment or detention facility selection and design process to ensure the design meets the requirements of these Standards. The minimum required components for maintenance are presented in Table 13.07.1 below.

City staff will routinely inspect open channel conveyances and detention and water quality facilities or respond to complaints that one may not be performing properly. Parties to the OMC should expect notification of inspections and subsequent findings to be communicated by inspection personnel.

Table 13.07.1. Required Inspection and Maintenance Schedule

Open Channels Including Swales and Ditches	
Activity	Required Frequency
Inspection for debris, accumulated sediment, and damage to side slopes or inverts; maintain or repair as necessary.	Twice annually
Removal of sediment, trash, debris, and large vegetation including trees and woody shrubs	Annually
Mowing and weeding	As needed to maintain 6” height and control weeds
Measurement of channel dimensions including bottom width and depth at 100-foot intervals to confirm cross sectional capacity is maintained in accordance with O&M Plan	Every 5 years

Detention Basins	
Activity	Required Frequency
Inspection for debris at outlet, sediment in the forebay, and damage to structures or embankments; maintain or repair as necessary.	Twice annually
Removal of sediment, trash, and debris from forebay, trickle channel(s), and micropool; aeration of vegetated areas	Annually
Mowing and weeding	As needed to maintain 6" height and control weeds
Removal of large vegetation including trees and woody shrubs near all inlets, forebays, trickle channels, and outlets	Annually
Irrigation and application of fertilizer, herbicide, and pesticide	As needed to maintain vegetative health

Notes: Maintenance frequency is highly dependent on construction activity within the tributary area, associated erosion control measures, and the design of the facility. More frequent removal of accumulated sediment may be required, but detention basins are generally low maintenance CMs.

Proprietary Structures	
Activity	Required Frequency
Inspection for debris that may cause bypass of design treatment flow rate; maintain as necessary.	Quarterly for first 2 years, as indicated based on first 2 years after that
Filter cartridge inspection; replace as necessary.	Twice annually
Removal of sediment, trash, and debris; filter cartridge replacement; and vacuuming	As recommended by the manufacturer

Sand Filter Basins, Bioretention, Grass Swales, and Permeable Pavement	
Activity	Required Frequency
Visual inspection to confirm infiltration after rainfall; maintain as necessary. Debris and litter removal.	Twice annually
Mowing, weeding, plant care, irrigation, and application of fertilizer, herbicide, and pesticide (for bioretention only)	As needed to maintain vegetative health
Mulch replacement (for bioretention only)	As needed to maintain 3" depth
Inspection of underdrain	When ponding lasts longer than 24 hours
Removal of sediment, trash, and debris, and replacement of media	When ponding lasts longer than 24 hours and underdrain is not clogged

13.08 MAINTENANCE ENFORCEMENT

If a stormwater facility in an outlot or easement on private property is not properly maintained, the City may, at its discretion, hire a private contractor to maintain the facility, invoice the property owner for the cost of the maintenance, and place a lien on the property until the invoice is paid (see City Code Sec. 20-636 and 20-637). This work will not include replacing surfacing such as sidewalk or asphalt or landscaping within the outlot or easement after the maintenance, repair, or replacement is completed.

STORMWATER FACILITY OPERATION AND MAINTENANCE COVENANT
{Unique name and type of Stormwater Facility (Detention Pond, Detention and Water Quality Pond, Water Quality Pond, Culvert, Swale, etc.)}

This Stormwater Facility Operation and Maintenance Covenant ("OMC") is made this _____ day of _____, 20__, by and among the City of Greeley, Colorado, a Colorado home rule municipality, whose address is 1000 10th Street, Greeley, CO 80631 ("City"), {Name of entity responsible for maintaining the stormwater facility}, a {Entity type}, whose address is {complete legal address} ("Owner"), and {Name of entity using the stormwater facility if different from Owner}, a {Entity type}, whose address is {complete legal address} ("User #1") {Repeat the information for each additional User who discharges stormwater runoff into the Stormwater Facility; #2, #3, etcetera}.

WHEREAS, an Operation and Maintenance Plan ("O&M Plan"), attached hereto and incorporated herein as Exhibit 1, has been approved by the City for the Stormwater Facility;

WHEREAS, the City requires that the Stormwater Facility be maintained by Owner (who may also be a developer) in a manner that allows the Stormwater Facility to function in accordance with the City's Design Criteria and Construction Specifications, Volume II, Storm Drainage ("SDDC"), the design shown in the O&M Plan, and other applicable legal requirements, including the City's municipal separate storm sewer system ("MS4") permit; and

WHEREAS, {User #1, User #2, and User #3} (together "Users") each discharge into the Stormwater Facility.

NOW THEREFORE, for consideration, the receipt and sufficiency or which are hereby acknowledged, the parties agree as follows:

AGREEMENT

1. Owner shall inspect the Stormwater Facility in accordance with the requirements in the O&M Plan and report all identified maintenance needs to Users within fourteen (14) business days.

2. Owner shall, at no cost to the City, maintain the Stormwater Facility in accordance with the SDDC, the O&M Plan, and Table 1, below, to ensure it remains in proper working condition.

Table 1: Maintenance Action by Responsible Party

Maintenance Action Description	Responsible Party

3. The City may inspect the Stormwater Facility to determine compliance with paragraphs 1 and 2, above.

a. If the City finds noncompliance, the City will provide written notice to Owner and Users of any deficiencies. If the noncompliance continues thirty (30) days after delivery of the written notice, the City may enter the Stormwater Facility and take action to maintain or repair the Stormwater Facility and invoice Owner and Users for reimbursement of funds reasonably necessary for the maintenance or repair of the Stormwater Facility, including labor, equipment, and materials.

b. If the City finds noncompliance that could cause damage to property, loss of life, or a violation of its MS4 permit, without notice to Owner or Users, the City may, but is not obligated to enter and take immediate action it deems necessary to maintain or repair the Stormwater Facility and invoice Owner and Users for reimbursement of funds.

c. If reimbursement is not received by the City at least thirty (30) days after delivery of invoice to Owner and Users, interest shall accrue on the unpaid amount at the rate of 1½% per month until paid in full.

4. Owner and Users shall indemnify and hold harmless the City for any and all damages, accidents, casualties, occurrences, or claims which might arise or be asserted against the City arising out of the existence, maintenance, repair, or use of the Stormwater Facility.

5. Owner shall notify the City if it desires to convey its interest in the Stormwater Facility or any portion thereof and provide a copy to the City of the conveyance documents. Owner may not dedicate the Stormwater Facility to the public, to public use, or to the City without the City's prior written consent.

6. This OMC shall be recorded by Owner. The responsibilities and obligations of Owner and Users included in this OMC shall constitute a covenant running with the land and shall be binding upon an inure to the benefit of all subsequent owners or users.

7. Users shall limit discharges to the Stormwater Facility to those listed in Table 2, below.

Table 2: Discharge Allocations by User

USER #	Water Quality Event Peak Discharge (cfs)	Minor Storm Event Peak Discharge (cfs)	Major Storm Event Peak Discharge (cfs)

[Signature Pages Follow]

OWNER
PROPERTY ADDRESS
COMPANY
ENTITY TYPE

By: _____ Date: _____

Printed Name: _____ Title: _____

STATE OF _____)
) ss.
COUNTY OF _____)

Acknowledged before me on this _____ day of _____, 20__, by _____ as _____, as Owner.

WITNESS MY HAND AND MY SEAL
MY COMMISSION EXPIRES _____

_____
Notary Public

USER #1 {add additional users as applicable}
PROPERTY ADDRESS
COMPANY
ENTITY TYPE

By: _____ Date: _____

Printed Name: _____ Title: _____

STATE OF _____)
) ss.
COUNTY OF _____)

Acknowledged before me on this _____ day of _____, 20__, by _____ as _____, as User #1.

WITNESS MY HAND AND MY SEAL
MY COMMISSION EXPIRES _____

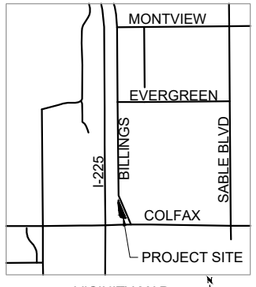
_____
Notary Public

CITY OF GREELEY, COLORADO

By: _____ Date: _____

_____, Real Estate Manager

[NAME AND TYPE OF STORM FACILITY] / LAND USE CASE NO. XXXXXXX
OPERATION AND MAINTENANCE PLAN
[PARTY OR PARTIES RESPONSIBLE] IS RESPONSIBLE FOR MAINTENANCE
ADDRESS, CONSTRUCTED IN [MONTH, YEAR]



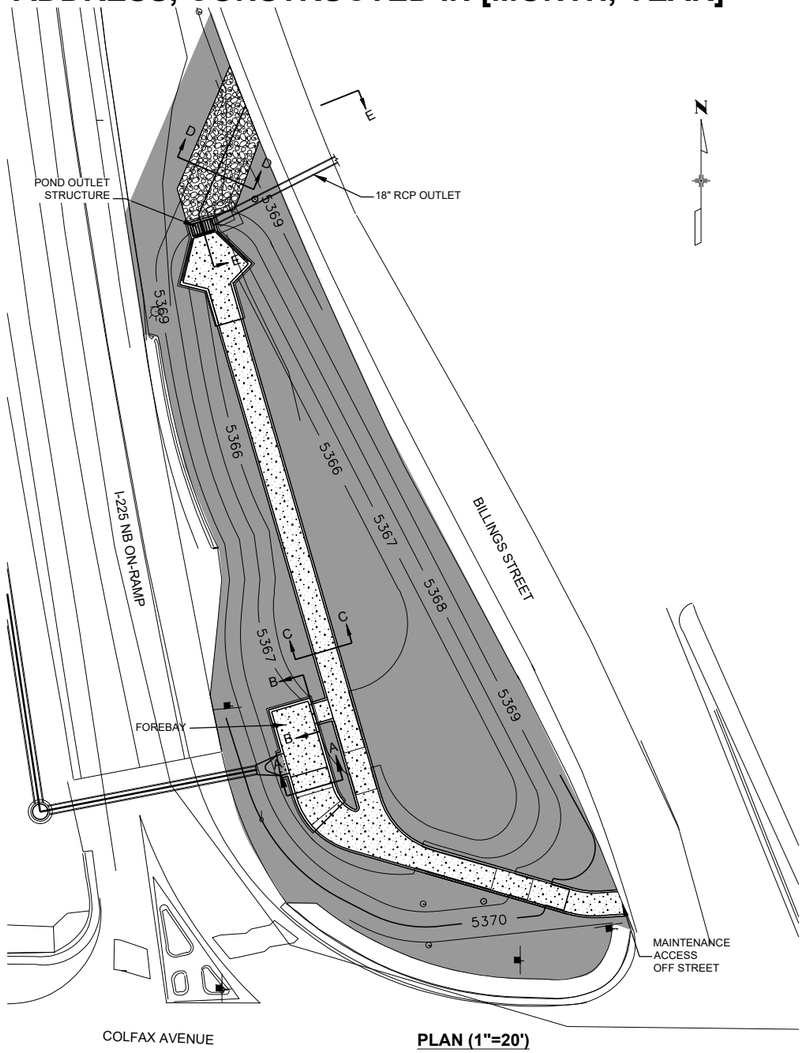
VICINITY MAP
SCALE: 1" = 1000'

NOTES:

1. FOR ADDITIONAL DESIGN INFORMATION, PLEASE REFER TO THE CONSTRUCTION DRAWINGS FOR THIS PROJECT.
2. PARCELS OR LOTS APPROVED TO DISCHARGE TO THIS FACILITY INCLUDE: [LIST OF APPROVED LOTS, THEIR WQCV, AND THEIR PEAK 100 YR DISCHARGE]
3. DISTURBANCE OF WETLAND AREAS SHALL BE AVOIDED DURING MAINTENANCE OPERATIONS.
4. SEE DETAILED NOTES ON BACK OF THIS SHEET FOR ALL MAINTENANCE REQUIREMENTS.

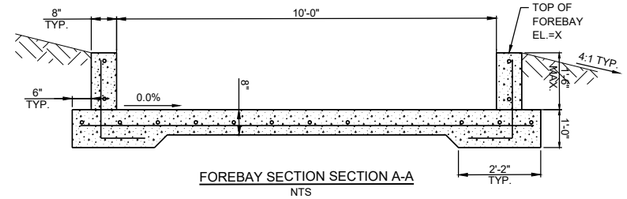
LEGEND:

AREA TO BE MOWED
(SEE NOTE 6 NEXT SHEET)

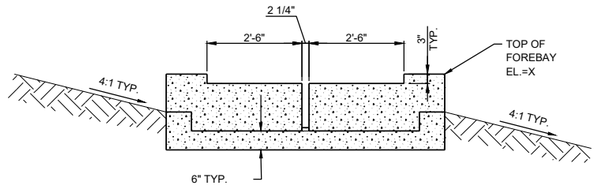


COLFAX AVENUE

PLAN (1"=20')



FOREBAY SECTION SECTION A-A
NTS



FOREBAY OUTLET SECTION B-B
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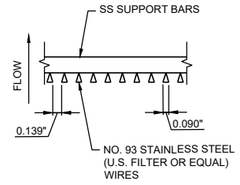
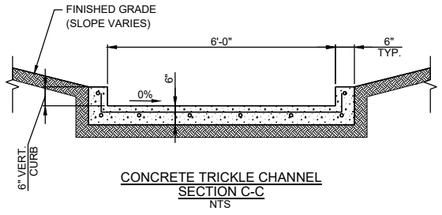
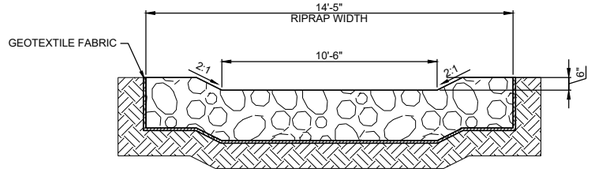


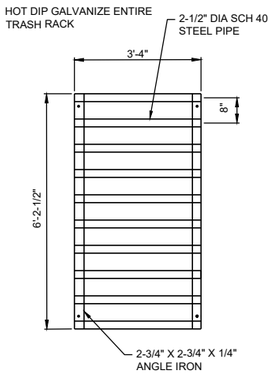
WATER QUALITY TRASH RACK
NTS



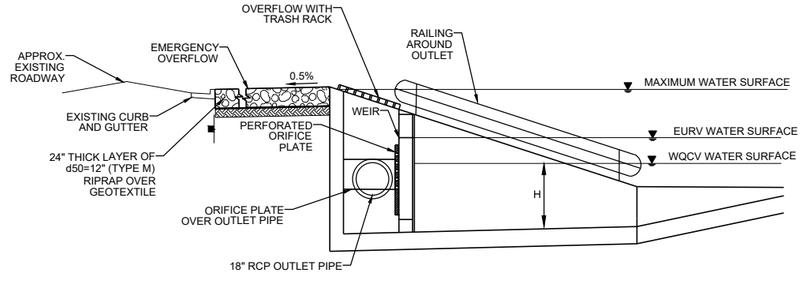
CONCRETE TRICKLE CHANNEL
SECTION C-C
NTS



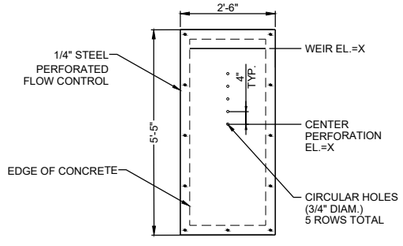
EMERGENCY OVERFLOW
SECTION D-D
NTS



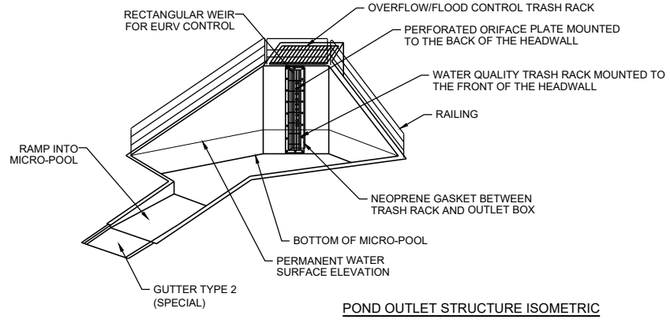
OVERFLOW TRASH RACK
NTS



EMERGENCY OVERFLOW
SECTION E-E
NTS



PERFORATED ORIFICE PLATE
NTS



POND OUTLET STRUCTURE ISOMETRIC
NTS

REVISION

DESIGNED
DRAWN
CHECKED
DATE

Know what's below. Call before you dig.

LAND USE CASE NUMBER

DEVELOPMENT NAME
ADDRESS

EXAMPLE OPERATION AND MAINTENANCE PLAN

DRAWING NUMBER:

SHEET

[NAME AND TYPE OF STORM FACILITY] / LAND USE CASE NO. XXXXXXX

OPERATION AND MAINTENANCE PLAN

[PARTY OR PARTIES RESPONSIBLE] IS RESPONSIBLE FOR MAINTENANCE

ADDRESS, CONSTRUCTED IN [MONTH, YEAR]

1. GENERAL PROJECT INFORMATION

A. PARCEL NUMBER:

B. RECEIVING WATER:

C. DESIGN ENGINEER NAME, PHONE NUMBER, & EMAIL:

D. PROPERTY OWNER(S) NAME, CONTACT NAME, ADDRESS, PHONE NUMBER, & EMAIL:

E. MAINTAINING AGENCY NAME, CONTACT NAME, ADDRESS, PHONE NUMBER, & EMAIL:

F. DESIGN ENGINEER, CONTACT NAME, ADDRESS, PHONE NUMBER, EMAIL, & PE LICENCE NUMBER:

G. CITY STORMWATER MANAGER (IF CITY IS RESPONSIBLE FOR MAINTENANCE):

2. GENERAL FACILITY DESCRIPTION

THIS FACILITY IS AN [INSERT FACILITY TYPE] THAT WILL [DESCRIBE DETAINING MECHANISM]. EVENTS IN EXCESS OF THE WATER QUALITY EVENT WILL [DESCRIBE WHAT HAPPENS]. THE FACILITY HAS BEEN ADOPTED AND APPROVED BY X AS PART OF THE X PROJECT. IT WILL RECEIVE RUNOFF FROM X.XX ACRES AND WILL OCCUPY A PARCEL OR EASEMNET[EASEMENT TYPE] OF X.XX ACRES THAT WILL BE USED TO [INSERT TREATMENT, HYDRAULIC FUNCTION, MAINTENANCE, AND ACCESS OPERATIONAL ACTIVITIES]. THIS FACILITY [WILL][WILL NOT] DETAIN THE 100 YEAR STORM EVENT. [IF NOT DETAINING THE 100 YEAR STORM, INSERT NOTE ON HOW FLOWS WILL BE CONVEYED]. [IF FLOWS ARE BYPASSED PRIOR TO FACILITY, INSERT NOTE ON DETAILS OF BYPASS STRUCTURE].

3. INSPECTION & MAINTENANCE FREQUENCY & PROCEDURE

THE FOLLOWING ITEMS SHOULD BE INSPECTED ANNUALLY PLUS AFTER STORMS PRODUCING MORE THAN 1" OF RAINFALL PER HOUR, AT MINIMUM : [INSERT ITEMS TO BE INSPECTED.] ITEMS SHOULD BE MAINTAINED, REPAIRED, OR REPLACED AS NEEDED. AN INSPECTION FORM SHALL BE COMPLETED AFTER EACH INSPECTION.

A. REVISIONS TO MAINTENANCE FREQUENCY:
MAINTENANCE FREQUENCY MAY BE INCREASED BASED ON FINDINGS OF INSPECTIONS DURING THE FIRST YEAR AND ANY REQUIREMENTS ISSUED BY THE EPA OR CDPHE.

B. TRAFFIC CONTROL SHALL [INCLUDE REQUIREMENTS OF TRAFFIC CONTROL INCLUDING WHO IS RESPONSIBLE IF NOT MAINTAINING AGENCY]. CONTACT CITY OF GREELEY TRAFFIC IF YOU NEED TO STAGE MAINTENANCE ACTIVITIES ALONG THE STREET.

C. THE FACILITY [DOES][DOES NOT] REQUIRE CONFINED SPACE ENTRY PROCEDURES. [ADD DETAILS AS NECESSARY].

D. DEWATERING AND WATER CONTROL
CLEANING THE [INSERT COMPONENTS] MAY REQUIRE DEWATERING. [INSERT EQUIPMENT] WILL BE REQUIRED. [INSERT DEWATERING AND WATER CONTROL PROCEDURES SO THAT A PERMIT IS NOT REQUIRED]. IF DEWATERING IS CONDUCTED IN ACCORDANCE WITH THE PROCEDURES SPECIFIED HEREIN, A DEWATERING PERMIT SHOULD NOT BE REQUIRED.

E. SEDIMENT, DEBRIS, & TRASH REMOVAL & DISPOSAL
REMOVAL SHALL BE CONDUCTED [INSERT FREQUENCY, ANNUALLY AT A MINIMUM] OR WHEN SEDIMENT REACHES [INSERT DEPTH] IN [INSERT STRUCTURES]. REMOVAL SHALL BE CONDUCTED AS NEEDED, BUT ESPECIALLY WHEN ANY DEBRIS BLOCKS FLOW AT [INSERT FACILITIES, OUTLET AT A MINIMUM]. SEDIMENT AND DEBRIS SHALL BE [DESCRIBE REMOVAL PROCEDURE] AND DISPOSED OF AT [INSERT LOCATION]. THE LONGEST DISTANCE BETWEEN THE EDGE OF AN ACCESS ROAD AND THE FAR CORNER OF A STRUCTURE REQUIRING SEDIMENT REMOVAL IS X FEET.

F. VEGETATION MANAGEMENT
SEE SECTION 6.0 OF THE NOTES ON THIS SHEET.

G. WETLAND AREAS [ARE NOT ANTICIPATED ON SITE][ARE AS INDICATED ON THE DETAILED SITE PLAN AND SHALL REMAIN UNDISTURBED]. SEE SECTION 8.0 OF THE NOTES ON THIS SHEET.

H. [DESCRIBE ADDITIONAL REQUIRED MAINTENANCE PROCEDURES AND FREQUENCIES.]

I. [DESCRIBE ITEMS TO BE REPLACED, QUANTITIES, LOCATIONS, AND FREQUENCIES.]

J. MATERIALS TESTING OF SEDIMENT REMOVED FROM SITE [IS][IS NOT] REQUIRED. [ADD DETAILS AS NECESSARY.]

K. [DESCRIBE POST-MAINTENANCE ACTIVITIES INCLUDING REMOVAL OF TEMPORARY MEASURES.]

4. REQUIRED EQUIPMENT, MATERIALS, STAFFING, & RESPONSIBILITY

A. EQUIPMENT REQUIRED:
[INSERT EQUIPMENT REQUIRED AND INTENDED PURPOSE]

B. REPLACEMENT MATERIALS:
[INSERT REPLACEMENT MATERIALS REQUIRED INCLUDING QUANTITIES.]

C. STAFFING:
[INSERT NUMBER OF STAFF REQUIRED TO MAINTAIN PWQ CM.]

D. APPLICABLE IGA(S):
[DESCRIBE IGA(S).]

E. MAINTENANCE RESPONSIBILITY DETAILS:
[INSERT RESPONSIBLE PARTIES.]

5. ACCESS DETAILS

ACCESS INFORMATION AND DETAILS:

6. VEGETATION MANAGEMENT

SEED: [X] SEED MIXES [HAVE,HAVE NOT] BEEN PLANTED AT THE SITE. THE [NAME OF SEED MIX, TYPICALLY UPLAND, RIPARIAN, WETLAND, ETC.] SEED MIX HAS BEEN PLANTED [DESCRIBE LOCATION]. [REPEAT AS NECESSARY TO DESCRIBE ALL MIXES.] [THE INVERT OF THE LOW FLOW CHANNEL SHALL REMAIN UNDISTURBED.] SEED MIXES ARE AS FOLLOWS:

BOTANICAL NAME	COMMON NAME	LBS PURE LIVE SEED/AC
[SEED MIX NAME]:		
Xxxxx xxxxxxxxxxx	Xxxxxx Xxxxxx	X.*X*
[REPEAT AS NECESSARY TO INCLUDE ALL MIX SPECIES]		

[REPEAT AS NECESSARY TO INCLUDE ALL MIXES]

[DESCRIBE HOW TO REPLACE SEED AND OTHER VEGETATION IF NECESSARY.]

MOWING: THE [DESCRIBE AREAS TO BE MOWED] SHALL BE MOWED TO A HEIGHT OF X INCHES. [IF DIFFERENT AREAS SHOULD BE MOWED TO DIFFERENT HEIGHTS, DESCRIBE HERE.] AT COMPLETION OF CONSTRUCTION, REQUIRED MOW AREA WAS ESTIMATED TO BE X.X ACRES. SEE CITY OF GREELEY NO MOW LIST.

WEEDS & UNDESIRABLE VEGETATION: [WEEDS SHALL BE MOWED.][NO WEED KILLER SHALL BE USED ON THE SITE.]NOXIOUS WEEDS AND OTHER UNDESIRABLE VEGETATION SHALL BE REMOVED BY [HAND TOOLS][MOWING][WEED WHACKING][TRIMMERS][CHAIN SAW].

7. HYDRAULIC DESIGN

FLOW RATES (CFS):

	INFLOW	OUTFLOW
2-YEAR:	X CFS	X CFS
5-YEAR:	X CFS	X CFS
100-YEAR:	X CFS	X CFS

[VOLUMES, DEPTHS, & WSEL ARE NOT APPLICABLE][VOLUMES, DEPTHS, & WSELS:]

ITEM	VOLUME	WSEL	DEPTH	INVERT
[INSERT STRUCTURE]	XXX CF	XXXX.XX	XX"	XXXX.XX
[REPEAT AS NECESSARY]				
[OVERFLOW CREST]	[XX.X AF]	[XXXX.XX]		XXXX.XX
[WQCV]	X.X AF	XXXX.XX		

[INSERT OTHER VOLUMES SUCH AS EURV, 2-YEAR, 100-YEAR, AS APPLICABLE]

[WQCV DRAIN TIME = XX HOURS][IF APPLICABLE][NOT TO EXCEED 120 HOURS]
[EURV DRAIN TIME = XX HOURS][IF APPLICABLE][NOT TO EXCEED 120 HOURS]

8. SENSITIVE AREAS, WETLANDS, & PERMITS

THE SITE [HAS NO WETLANDS][INCLUDES X.XX ACRES OF WETLANDS LOCATED [DESCRIBE LOCATION]. [DESCRIBE THE 404 PERMIT INCLUDING INSPECTION AND DOCUMENTATION REQUIREMENTS.] [DESCRIBE ANY PERMITS ANTICIPATED TO BE REQUIRED FOR MAINTENANCE SUCH AS A FLOODPLAIN PERMIT OR CDPHE PERMITS].

9. SNOW AND ICE CONTROL

[SNOW AND ICE CONTROL ARE/ ARE NOT REQUIRED.][DESCRIBE LOCATIONS AND EXTENT OF AREAS THAT SHALL BE MAINTAINED FREE OF ICE AND SNOW.] [DESCRIBE SNOW AND ICE CONTROL MEASURES AND FREQUENCY AND RESPONSIBLE PARTY.]

10. MISCELLANEOUS INFORMATION

PROJECT SURVEY:
EXISTING CONDITIONS TOPOGRAPHIC SURVEY WAS PREPARED BY [PLS OR SURVEY COMPANY NAME] BASED ON INFORMATION GATHERED [INSERT DATES]. PROJECT BENCHMARKS IS [INCLUDE NAME, LOCATION, ELEVATION, AND DATUM]. THE COORDINATE SYSTEM IS [INCLUDE COORDINATE SYSTEM, ZONE, DATUM, AND COMBINED SCALE FACTOR.]

[ADDITIONAL INFORMATION]

11. HOMELESS ENCAMPMENTS

IF A HOMELESS ENCAMPMENT IS OBSERVED ON SITE, CONTACT THE [MAINTENANCE SECTION SUPERINTENDENT][INSERT LOCAL AGENCY CONTACT IF MAINTAINED BY A LOCAL AGENCY] IMMEDIATELY. DO NOT COMMENCE OR CONTINUE MAINTENANCE ACTIVITIES.

REVISION

DESIGNED
DRAWN
CHECKED
DATE

811 Know what's below. Call before you dig.

LAND USE CASE NUMBER

DEVELOPMENT NAME
ADDRESS

EXAMPLE OPERATION AND MAINTENANCE PLAN

DRAWING NUMBER:

SHEET