City of Evans

Drainage Criteria Manual

December, 2016

MULLER ENGINEERING COMPANY

City of Evans, Colorado

DOLA CO COLORADO Department of Local Affairs

City of Evans

DRAINAGE CRITERIA MANUAL

Volume II

December 2016

Prepared for:

City of Evans
1100 37th Street
Evans, CO 80620

Muller Project Number: 15-041.01

MULLER
ENGINEERING COMPANY

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BFE	base flood elevation
BMP	best management practice
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
CMP	corrugated metal pipe
Criteria	City of Evans Storm Drainage Criteria Manual (this document)
CRS	Colorado Revised Statute(s)
CUHP	Colorado Urban Hydrograph Procedure
CWCB	Colorado Water Conservation Board
EGL	energy grade line
EPA	U.S. Environmental Protection Agency
EURV	excess urban runoff volume
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FPE	flood protection elevation
HGL	hydraulic grade line
H:V	horizontal to vertical ratio of a slope
MS4	municipal separated storm sewer system
NAVD	North American vertical datum
NGVD	National Geodetic vertical datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
RCP	reinforced concrete pipe
SWMM	EPA Stormwater Management Model
SWMP	stormwater management plan
SWUMP	City of Evans Stormwater Utility Management Plan
TSS	total suspended solids
UDFCD	Urban Drainage and Flood Control District
UDSWM	Urban Drainage Stormwater Management Model
USGS	U.S. Geological Survey
WCECC	Weld County Engineering and Construction Criteria
WQCV	water quality capture volume

COMMONLY USED UNITS

cfs	cubic feet per second
cfs/ft	cubic feet per second per foot
ft	foot
ft2	square feet
ft/sec	feet per second
ft/sec2	feet per second squared
hr	hour
in	inch
in/hr	inches per hour
in/hr/ac	inches per hour per acre
lbs	pounds
lbs/cy	pounds per cubic yard
lbs/ft2	pounds per square foot
lbs/ft3	pounds per cubic foot
lbs PLS/acre	pounds pure live seed per acre
min	minute
psi	pounds per square inch
psf	pounds per square foot

SECTION 1 GENERAL REQUIREMENTS

1.1 Purpose

The purpose of the "City of Evans Storm Drainage Criteria Manual" (Criteria) is to the provide minimum design and specification criteria for the analysis and design of future storm drainage facilities within the City of Evans and the areas within its Urban Growth Boundary. All residential, commercial, and industrial developments shall include adequate storm drainage system design. These facilities shall be designed to reduce flooding, improve water quality released into the river system and aid in the compliance of the National Pollutant Discharge Elimination System (NPDES) and the City's Colorado Discharge Permit System (CDPS) permit. All designs must meet the requirements set forth in the Criteria, which may be amended as new technology is developed or the need for revisions are proven.

1.2 Relationship to Other Criteria

The Criteria is to be used in conjunction with the Urban Storm Drainage Criteria Manual (USDCM). Policies and technical criteria not specifically addressed in this document shall be in accordance with the most recent version of the USDCM. If the government imposes stricter criteria or standards, the City's criteria shall be amended to reflect the most restrictive standards.

The Weld County Engineering and Construction Criteria (WCECC), Chapter 5 – Drainage Criteria was used as a guideline for the Criteria. The City of Greeley's Design Criteria and Construction Specifications, Storm Drainage Volume II was also referenced.

The planning of drainage facilities must be included in the urbanization process. City of Evan's Stormwater Utility Management Plan (SWUMP) proposes stormwater facilities, such as storm drains, ditches, detention ponds, and channels that both convey and store stormwater. The City also has completed the development of other regional drainage facilities. Direction laid out with these developments must be followed for future development.

1.3 Drainage Law and Policy

The City of Evans adheres to Colorado state laws. Refer to the drainage law chapter of the USDCM (Volume 1) and WCECC section 5.2 for more information on drainage law as it relates to stormwater runoff and floodplain management.

The principles of City of Evans storm drainage policy are summarized below.

- Stormwater facility design shall observe Colorado's water rights law.
- Storm drainage crosses boundaries between properties and governmental jurisdiction, therefore the regional flow paths and phenomenon must be considered. Safety and prevention of harm are paramount.
- Evan's storm drainage system is only a subsystem of the total natural water resource system.
- Planning and design of stormwater facilities shall not transfer the problems from one location to another.
- The functions and features of the natural drainage systems must be considered in the design and construction of stormwater facilities.
- Solutions and strategies to mitigate stormwater issues need to be a flexible, multi-objective, and a multi-means effort.
- Criteria, concepts and ideas presented in the SWUMP and other regional development plans must be followed.
- To the maximum extent practicable, stormwater facility design for new development should strive to prevent pollutant load and reduce stormwater runoff rates.

- Stormwater facility design for new development shall give full consideration to downstream impacts and safe conveyance of upstream off-site flows entering the system.
- Regular maintenance is required for stormwater management systems.
- Full consideration for water quality and erosion and sediment control must be given to all stormwater facility designs.
- Floodplain concerns, capacity needs, and regulations must be followed in accordance with FEMA and Colorado Water Conservation Board (CWCB), and provide adequate space for any necessary lateral stream channel movement in natural channels.
- Retention of stormwater shall be discouraged. All retention ponds must drain within 72 hours to be consistent with Colorado Water Law. Construction of retention ponds requires a variance, and retention ponds must be sized to accommodate 1.5 times the volume of the 100-year, 24-hour developed site runoff. To protect public health, retention ponds must not be allowed to become mosquito habitat.

1.4 Floodplain Management

The South Platte River and the Big Thompson River flow northwest past the City of Evans and Ashcroft Draw flows in and out of Arrowhead Reservoir. Both waterways are regulated by FEMA. All FEMA regulation apply in all floodplain areas and information can be found at http://msc.fema.gov. Chapter 4 of USDCM is also informative concerning floodplains.

Hydraulic modeling is required for the majority of Flood Hazard Development Permit applications. The modeling must conform to the standards outlined in FEMA's guidelines and specifications and must show compliance with the various floodplain regulations. In areas where there is a FEMA-approved model and changes are proposed, the necessary hydraulic modeling may include the current effective model, a duplicate effective model, a corrected effective model, and the proposed conditions model. In areas where there is not a FEMA-approved model, the hydraulic model must contain the existing condition model and proposed condition model. A 0.5-foot floodway model is required for all sites where a FEMA-approved floodway has not been established. All hydraulic modeling must be certified by a registered professional engineer licensed in the State of Colorado.

1.5 Irrigation Facilities

Evans Town Ditch

It is the policy of the City of Evans that stormwater flows will not be allowed to be discharged into the Evans Town Ditch. Use of the ditch as a stormwater conveyance system is prohibited. As development occurs in the Urban Growth Area, the drainage systems shall be developed or modified so that stormwater bypasses the ditch and is discharged per the SWUMP. Developments within the City shall make necessary modifications to ensure that excess stormwater does not discharge into the ditch.

1.6 Storm Drainage Fees

For the purpose of providing adequate stormwater conveyance systems, the fees shall be set by the Evans City Council. A list of applicable fees can be found at www.evanscolorado.gov

1.7 Required Permits

At a minimum, the following City permits may be necessary prior to the start of construction:

- ROW/Excavation permit
- Grading Permit

- Access Permit
- Floodplain Permit

All the permits are available on the City's website at www.evanscolorado.gov.

SECTION 2 SUBMITTAL REQUIREMENTS

2.1 Review and Acceptance

Drainage reports and plans, construction drawings, special provisions, and calculations submitted to the City of Evans for review must be prepared by or under the supervision of a Professional Engineer licensed in Colorado. The City's review will only be to determine if the submittals conform to the City's requirements. The City's approval does not relieve the design engineer or the contractor from responsibility or liability for the design or construction of a project.

Approval of the submittal information shall be valid for one year after the acceptance date. If construction of the project has not started within that period, the acceptance by the City will be invalid.

It is the responsibility of the Owner, or the Owners' selected Engineer, to request any variances from the City standard. Variances shall be requested in the early stages of the planning/designing process, and will be considered on a case-by-case basis.

2.2 Submittal Requirements

Drainage reports and plans, construction drawings, specifications, and as-built information shall be submitted to the City of Evans, Engineering Department for compliance with the Criteria. The applicant should consult with the City for a general information meeting in regards to the project and its prospective design and submittal process.

The following horizontal and vertical information shall be used for all mapping.

Horizontal: NAD 1983 HARN (High Accuracy Reference Network) State Plane Colorado North, US Foot
Vertical: NAVD 1988 (height) US Foot

The City of Evans will not accept any other datum nor will an adjustment from some other datum be acceptable.

All reports shall be typewritten on 8½" x 11" paper and bound with a cover letter, identifying the project and the type of information submitted (preliminary or final). All figures, tables, plans, and maps that are larger than 11x17 must be attached to the report. The report shall be prepared (or supervised), signed and stamped by a Professional Engineer licensed to practice in the State of Colorado, and possessing adequate experience in the fields of hydrology and hydraulics. The report shall contain the following statement, and appropriate signatures:

> "I hereby attest that this report for the (Preliminary or Final) drainage design of (Name of Development) was prepared by me, or under my direct supervision, in accordance with the provisions of the City of Evans Storm Drainage Design Criteria for the responsible parties thereof. I understand that the City of Evans does not and shall not assume liability for drainage facilities designed by others.
>
> ____
>
> Registered Professional Engineer
> State of Colorado No.________________ (Affix Seal)

Large size drawings, tables or exhibits shall be included in a pocket attached to the report. The information presented in technical appendices shall contain sufficient detail and clarity to allow replication of the results presented in the report. Any unacceptable conditions could warrant a requirement for re-submittal of the report, and subsequent delay of the project review.

2.3 Preliminary Drainage Report

The purpose of the preliminary drainage report is to identify and define conceptual solutions to existing or future drainage problems that result from the proposed development. The preliminary drainage report shall be reviewed and signed by a professional engineer licensed in Colorado.

The Preliminary Drainage Report will include all necessary project information and drainage design and a Site Drainage Plan. The Preliminary Drainage Report shall be submitted on 8 ½”x11” paper and bound. A final copy shall also be submitted in electronic form. The plans shall be on 11”x17” or 22"x34" paper. If submitting hard copies, two copies of the report and plan will be submitted to the City for review. One copy will be returned with comments for revision.

A checklist has been prepared to summarize the requirements for the Preliminary Drainage Report. See the checklist at the end of this section.

2.4 Final Drainage Report

The purpose of the final drainage report is to update the concepts and to present the design details for the drainage facilities presented in the preliminary drainage report. The final drainage report must address any changes to the preliminary design concept and any questions or comments made during the review of the preliminary submittal. The final drainage report shall be reviewed and signed by a professional engineer licensed in Colorado. The report shall be properly certified and signed by such engineer.

See the checklist included at the end of this section for all the requirements of the Final Drainage Report.

2.5 Construction Plans

When drainage improvements are to be constructed, final construction plans (11”x17” and 22"x34") shall be submitted with the final drainage report. Two copies of the report and plan will be submitted to the City for review. One copy will be returned with comments for revision. Once the revisions are made, four sets of construction plans shall be signed by a registered professional engineer and submitted to the City for final acceptance and approval; one 22x34 set of plans on reproducible Mylar, one 22x34 set of plan on bond paper and two 11x17 sets on bond paper. A signed copy will be returned to the originator. Issuance of the necessary construction permits is contingent on the approval of the construction plans by the City.

After approval of the final construction plans, any changes in plans or specifications must be approved by the City. These changes will be included on the as-built drawings.

The following list details the plan set requirements for stormwater review. Other departments within the City of Evans may require additional plans for approval.

A. General Details
   1. Title block.
   2. Scale and legend.
   3. Date and revisions block.
   4. Name of firm and professional engineer with the professional engineer's stamp.
   5. Approval block.

B. Site Plan/Grading Plan
   1. Existing and Proposed contours (with labels)

2. Proposed Site Details
3. Flow Arrows
4. North arrow and scale
5. Drainage Features (detention ponds, swales, permanent water quality, etc.)

C. Subdivision Plat

D. Master Utility Plan
1. Proposed storm drain lines.
2. Property lines.
3. Existing and proposed easements and right-of-ways.
4. Street and alley names.
5. Proposed utilities.
6. Existing utilities on and adjacent to the site.
7. Topographic features (houses, curbs, water courses, etc.).
8. North arrow and scale.

E. Construction plans and profiles
1. Key map.
2. Existing utilities.
3. Proposed and existing easements, right-of-ways, and property lines.
4. Diameter, type, and length of pipe of proposed storm drain lines.
5. Depth, elevation, slope, manhole invert, and rim elevations on proposed storm drain lines.
6. Horizontal and vertical relationship of the storm drain to the other proposed and existing utilities.
7. Existing and proposed ground profile.
8. Matchlines indicating references to next sheets of design.
9. Tie downs to the center of the street.
10. Detention Pond and swale grading.
11. Maintenance access
12. Survey stations.
13. North arrow and scale.
14. Horizontal and vertical scales.

F. Details Sheet
1. Critical connections.
2. Crossings.
3. Special fittings and appurtenances.

G. Erosion Control Plan
1. Hard surfaces
2. Flow direction arrows
3. Temporary and Permanent BMPs
4. Seeding and soil stabilization
5. Legend, north arrow and scale

2.6 Construction As-Built and Record Drawings

Record drawings for all projects are to be submitted on mylar to the City Engineer to receive Substantial Completion Certificate. Certification of the record drawings is required as follows:

A. The project responsible Design Engineer and/or Surveyor shall observe construction as required to be able to certify that the conditions and information recorded on the As-Built Record drawings is true and correct. The owner or responsible party of the General Contractor for the project shall sign each drawing sheet in the "As-Built" plan set.

B. A Professional Land Surveyor shall perform or directly supervise all field survey data collection to verify the As-Built conditions and shall stamp and seal each drawing sheet in the As-Built Record plan set.

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

D. The City shall compare the certified record drawing information with the construction drawings. A Certificate of Substantial Completion shall be issued only if:

1. The record drawing information demonstrates that the construction complies with the design intent.

2. The record drawings are certified by a Professional Land Surveyor, a Professional Engineer, and the Owner or responsible party of the General Contractor. Both the Professional Land Surveyor and the Professional Engineer shall be registered in the State of Colorado.

Checklist of Drainage Report Requirements

Project: ______________________ **Date:** ____________

Item No.	Description	Preliminary Report	Final Report	N/A
	COVER SHEET with title, date, applicant, preparer			
	TABLE OF CONTENTS			
	PE Certification and Seal			
	Names and addresses of all parties involved in the design			
	GENERAL LOCATION AND DESCRIPTION			
1	Map in sufficient detail to identify the project location			
2	Legal description of property location including Township, Range, Section, and 1/4 Section			
3	Location of the proposed development with respect to adjacent public and private roads			
4	Names of surrounding developments within 1/2 mile of the proposed development			
5	Area in acres			
6	Ground cover (trees, shrubs, etc.)			
7	General topography			
8	General soil conditions/types			
9	Major drainage facilities on the property			
10	Irrigation facilities and laterals within the property			
11	Proposed land use			
	DRAINAGE BASINS AND SUB-BASINS			
	Major Basin Description			
12	Reference previous drainage studies affecting the site			
13	Reference flood hazard delineation report and FEMA flood insurance study			
14	Include FEMA flood insurance map			
15	Identify presence of regulatory floodplains/floodways onsite. Discuss any proposed disturbance in the floodplain.			
16	Will a CLOMR or LOMR be required?			
17	Coordination with surrounding subdivision plans			
18	Discuss major basin drainage characteristics, including historical and planned land use and basin slope			
19	Describe any infringements on drainage easements			
20	Verify that offsite flows pass through a pond or are routed around the site			
	Site Sub-Basin Description			
21	Discuss historic drainage pattern of the proposed development			
22	Identify any major drainage systems on the site			
23	Discuss off-site basins and flow patterns and their potential impact on the proposed development			
24	Include off-site delineation map			
25	Discuss irrigation facilities and laterals that will affect or be affected by the local drainage			
	DRAINAGE DESIGN CRITERIA			
	Regulations			
26	Discuss compliance with the City's floodplain ordinance			
	Development Criteria Reference and Constraints			
27	Discuss previous drainage studies for the site			
28	Discuss changes from the previous study			
29	Discuss coordination with adjacent drainage studies			
30	Discuss site drainage constraints (such as streets, utilities, existing structures, etc.)			
	Hydrology Criteria			
31	Identify design rainfall event, frequency, and duration			
32	Identify runoff calculation method used			
33	Identify calculation method for detention storage requirement			
34	Identify calculation method for detention discharge			
35	Discuss and provide justification for criteria or methods not referenced by the Criteria			
	Hydraulic Criteria			
36	Identify street capacity references			
37	Identify other capacity references			
38	Identify detention pond outlet design method			
39	Identify check/ drop structure criteria used			
40	Discuss drainage facility design criteria not referenced by Criteria			
	Variance from Criteria			
41	Identify provision by section number for which a waiver or variance is requested			
42	Provide justification and discussion for each variance requested			
	DRAINAGE FACILITY DESIGN			
	General Concept			
43	Present existing and proposed hydrologic conditions, including flow rates entering and exiting the area			
44	Present approach to accommodate drainage impacts of existing or proposed improvements and facilities			
45	Present proposed drainage facilities with respect to alignment, material, structure type and size			
46	Discuss opportunities for integration of other services (recreational, natural resource, etc.)			
47	Land use assumptions regarding adjacent properties			
48	Minor and major storm runoff at specific design points			
49	Historic and fully developed runoff computations at specific design points			
50	Hydrographs at critical design points			

Checklist of Drainage Report Requirements

Project: ______________________ **Date:** ______________

Item No.	Description	Preliminary Report	Final Report	N/A
51	Discuss stormwater quality control concepts			
52	Discuss maintenance access aspects of the design			
53	Downstream system capacity of the Major Drainage system			
54	Discuss concept and proposed drainage patterns of the site			
55	Discuss off-site runoff impacting the site			
56	Discuss runoff impacting downstream properties			
57	Discuss tables, charts, figures, drawing, etc. presented in the appendix			
Specific Details				
58	Discuss drainage problems on the site			
59	Discuss specific solutions at design points			
60	Determine and discuss the street capacity at critical locations for both the major and minor design storms			
Discuss detention storage required for detention				
61	Provide labeled calculation for adequate storage volume requirements			
62	Provide labeled calculation that detention pond will accommodate volume required			
63	Provide labeled calculations for water surface elevations			
64	Provide labeled calculations for minimum of one foot freeboard requirement			
Discuss outlet requirements				
65	Demonstrate how water quality requirements are met			
66	Provide labeled calculations for water quality orifice plate geometry and perforation sizing.			
67	Provide labeled calculations for detention pond outlet staged release structure			
68	Provide labeled calculations for detention pond outlet pipe capacity			
69	Provide labeled calculations for sewer pipe outfall and design of riprap (including downstream flowpath)			
70	Provide labeled calculations for emergency overflow conditions			
Discuss storm sewer configuration				
71	Provide calculations for storm sewer capacity, type of flow, calculated pipe losses, and HGL calculations			
72	Provide labeled calculations for storm sewer inlet type and sizing calculations			
73	Provide labeled calculations for storm sewer outlet conditions			
74	Provide labeled calculations for conduit outlet protection design			
Discussion on channel design and soil erodibility within channel				
75	Provide labeled calculations for type of flow and velocity of flow			
76	Discuss proposed channel lining/bank protection			
77	Provide labeled calculations for freeboard requirement			
78	Provide labeled calculations for water surface elevations			
79	Provide labeled calculations for backwater analysis			
80	Provide labeled calculations for sizing of check structures			
81	Provide labeled calculations for sizing of drop structures			
82	Discuss easements and tracts dedicated for drainage & maintenance purposes			
83	Discuss maintenance and access aspects of the design			
ENVIRONMENTAL PROTECTION CRITERIA				
General				
84	Identify wetland areas, jurisdictional status, and other "Waters of the U.S."			
85	Identify potential impacts to T & E species and presence of Habitat Protection Areas and Stream Restoration Areas			
86	Discuss compliance with State and Federal environmental permitting regulations			
Construction BMP Plan				
87	Discuss Construction BMP requirements			
Permanent BMP Plan				
88	Discuss Permanent BMP requirements			
89	Provide labeled calculations for WQCV requirements			
90	Provide labeled calculations for storage volume requirements			
91	Provide labeled calculations for outlet structure design			
92	Provide labeled calculations for erosion protection at storm drain outlets			
93	Discuss landscaping considerations for Permanent BMP			
94	Discuss maintenance and access aspects of the design			
CONCLUSIONS				
Compliance with Standards:				
95	City Ordinances			
96	Evans Criteria Manual, SWUMP, and USDCM			
97	Floodplain regulations			
Drainage Concept				
98	Effectiveness of design to control storm runoff			
99	Discuss maintenance responsibility for public and private drainage facilities			
100	Discuss impact of proposed development on the SWUMP recommendations			
Sediment and Erosion Control Concept				
101	Discuss effectiveness of erosion control plan			
102	Discuss suitability of site soils for development			
103	Provide certification statement and PE seal and signature			

Checklist of Drainage Report Requirements

Project: ______________________ **Date:** ______________

Item No.	Description	Preliminary Report	Final Report	N/A
REFERENCES				
104	Refer to all criteria and technical information used in support of the drainage facility design concept			
105	List all drainage reports and technical information used			
106	List all computer software used in analysis			
APPENDICIES				
Hydrologic Computations (Historic)				
107	Historic basin delineation, onsite and offsite			
108	Runoff coefficient determination, including composite "C" calculation			
109	Rational Method analysis for each basin, minor and major storm including urbanization check			
110	Rational method analysis for each design point (i.e., routed cumulative flow), minor and major storm			
111	Schematic figure illustrating routing for basins and design points			
112	CUHP/UDSWM input and output data			
113	Schematic figure illustrating routing of CUHP basins and SWMM elements			
Hydrologic Computations (Developed)				
114	Developed basin delineation, onsite and offsite			
115	Runoff coefficient determination, including composite "C" calculation			
116	Rational Method analysis for each basin, minor and major storm			
117	Rational method analysis for each design point (i.e., routed cumulative flow), minor and major storm			
118	Schematic figure illustrating routing for basins and design points			
119	CUHP/UDSWM input and output data			
120	Schematic figure illustrating routing of CUHP basins and UDSWM elements			
Hydraulic Computations (Extended Detention Basin)				
121	Volume of storage required (WQCV, EURV and 100-year event)			
122	Volume of designed detention pond (maximum volume)			
123	Does maximum water surface elevation allow for 1 foot freeboard depth			
124	Inflow(s) energy dissipater (see hydraulic computations for storm sewer)			
125	Overflow spillway sizing			
126	Forebay - volume and drain pipe/weir			
Hydraulic Computation (EDB Outlet Structure)				
127	Historic release rates based on UDFCD Volume 2, Storage Chapter			
128	Calculation of allowable 100-year release rate			
129	Water quality orifice plate geometry			
130	Water quality trash rack/screen geometry and open area			
131	Orifice or weir sizing for 100-year release rate (verify rate is equal to the historic flow)			
132	Orifice or weir placement for 100-year water surface elevation			
133	Trash Rack (overflow) sizing calculation			
134	Calculations for emergency overflow			
135	Capacity, velocity, and Froude number calculations for outlet structure storm sewer pipe			
136	Calculations for outlet protection for outlet structure pipe			
137	Invert locations, slope, diameter (18-inch minimum), material, and pipe classification for outlet structure			
138	Does the invert out of the outlet structure storm sewer pipe match grade and have a logical downstream flowpath			
139	Profile of outlet structure and outlet storm sewer pipe (may be included with profile of pond)			
Hydraulic Computation (Storm Sewer Configuration)				
140	Minimum pipe size 15-inch for laterals and 18-inch for main line			
141	Capacity calculations			
142	Pipe loss calculations			
143	Minor and major storm hydraulic grade line calculations (minor storm cannot surcharge storm sewer system)			
144	Inlet (or entrance condition) sizing and capacity calculations, including sump depths			
145	Velocity and Froude number calculation at pipe outlet			
146	Outlet protection design calculations			
147	Calculations for toe walls at storm drain outlets			
148	Discharge of a storm sewer onto streets is prohibited			
149	Ensure there is at least 1 foot cover between the top of all RCP storm pipes and the top of pavement			
Hydraulic Computation (Culverts)				
150	Calculations for flow through structure			
151	Calculations for controlling condition (entrance or outlet)			
152	Capacity calculations			
153	Velocity calculations (minimum of 3 fps during minor storm is recommended)			
154	Water surface or overtopping elevations calculated and compared to allowable overtopping			
Hydraulic Computation (Bridges)				
155	See UDFCD Volume 2, Hydraulic Structures Chapter			
Hydraulic Computation (Open Channels)				
156	Calculation of developed flow through the channel			
157	Determine the location of hydraulic jumps and seepage distances			
158	Investigation of erodibility of soils in channel is required			
159	Calculations to document 100-year discharge flow parameters			

Checklist of Drainage Report Requirements

Project: ______________________ **Date:** ______________

Item No.	Description	Preliminary Report	Final Report	N/A
160	Backwater calculations			
161	Check structure design calculations			
162	Drop structure design calculations			
163	Riprap design calculations			
164	Calculations for all other proposed channel lining			
165	Ensure there is appropriate freeboard, velocity, and Froude number			
Hydraulic Computation (Streets)				
166	Street classification			
167	Street capacity minor and major storm			
Permanent BMP Calculations				
168	Calculations for WQCV requirements			
169	Calculations for storage volume requirements			
170	Supporting labeled calculations for outlet structure design			
171	All other design calculations necessary for design of Permanent BMP			
HISTORIC CONDITIONS DRAINAGE DRAWING				
172	22"x 34" drawing(s) - scale of 1"=100' to 1"=400'			
173	General location or vicinity map			
174	North arrow and scale			
175	Legend to define map symbols			
176	Title block in lower right hand corner			
177	Existing contours at appropriate contour interval			
178	Delineation of onsite basins and offsite basins impacting site			
179	Drainage flow paths and design points for accumulated flow			
180	Table showing routing and accumulation of flow at design points for minor and major event			
181	Existing drainage facilities			
182	Existing 100-year floodplains			
DRAINAGE DRAWING CONTENTS				
183	22"x 34" drawing(s) - scale of 1"=20' to 1"=200'			
184	General location or vicinity map			
185	North arrow and scale			
186	Legend to define map symbols			
187	Title block in lower right hand corner			
188	Property lines and easements with purposes noted			
189	Overall drainage area boundary and sub-basin boundaries, names, areas and runoff coefficients (including off-site basins)			
190	Design point designations			
191	Existing and proposed contours at an interval not to exceed 2', extending 100' beyond property lines			
192	Location and elevations (if known) of 100-year floodplain limits and documented elevations			
193	Existing drainage facilities with all pertinent information such as material, size, shape, slope and locations			
194	Proposed site flow arrows delineating the direction of flows			
195	Proposed drainage facilities (e.g. manholes, storm pipes, inlets, open drainageways, riprap)			
196	Location and type of facilities relevant to the proposed development (ponds, streams, irrigation ditches, etc.)			
197	Location and elevation (if known) for all existing and proposed utilities affecting the drainage design			
198	Streets shown (with ROW width, flowline, sidewalk, etc.)			
199	Proposed type of street flow (detail if necessary)			
200	Detention pond with extent of pond delineated (shade 100-year water surface)			
201	Table of volumes and release rates for water quality/detention facilities			
202	Detail information on EDB outlet structure			
203	Profile of EDB outlet structure, including water surface elevations, outlet pipe, and discharge orifices			
204	Detail of water quality orifice plate showing size of perforations, number of rows, and spacing			
205	Detail information on permanent BMPs			
206	Profile of permanent BMP outlet structure, including water surface elevations, outlet pipe, water quality plate and discharge orifices			
207	Routing of off-site flows through the development (around detention basins, not through)			
208	Flow path leaving the development through downstream properties to a major drainageway			

SECTION 3 RAINFALL

3.1 Introduction

Presented in this section is the design rainfall data to be used with the Rational Method and the Colorado Urban Hydrograph Procedure (CUHP). The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 1 "Rainfall" Chapter, and all hydrologic analysis shall use the rainfall data presented herein for calculating storm runoff.

The design storms and intensity-duration-frequency curves for the City were developed using the rainfall data as presented in the NOAA Atlas for Colorado and the procedures presented in the Urban Storm Drainage Criteria Manual (USDCM).

3.2 Design Storms

Two design storms shall be investigated for each development: minor storm and a major storm. The minor storm occurs at fairly regular intervals. It is not typically the cause of excessive damage, but results in higher costs in maintenance, repair, and replacement of facilities if not handled adequately. Proper handling of the major storm can eliminate substantial property damage or loss of life.

The minor and major storm frequencies used for runoff analysis and the subsequent design of stormwater management facilities in the City of Evans are presented below:

Table 3.2.1 Design Storm Frequencies

LAND USE	MINOR STORM FREQUENCY	MAJOR STORM FREQUENCY
Residential	5-YEAR	100-YEAR
Open Space, Parks	5-YEAR	
Commercial, Public Buildings, Business, Industrial	10-YEAR	
Natural Drainageway	25-YEAR	

Please also see Table 5.2.1 Street Classifications for Drainage Purposes for additional details on allowable street encroachment.

3.3 Rainfall Intensity

A. Rainfall intensities to be used in the Rational Method computation of runoff shall be obtained from the City of Evans Intensity-Duration-Frequency Curves which are included in Figure 3.3.1. The corresponding tabulated values are included in Table 3.3.1 which show the values extended out to 24 hours.

TABLE 3.3.1 Extended Intensity-Duration-Frequency Table

STORM DURATION	STORM FREQUENCY					
	2-YEAR (IN/HR)	5-YEAR (IN/HR)	10-YEAR (IN/HR)	25-YEAR (IN/HR)	50-YEAR (IN/HR)	100-YEAR (IN/HR
5 MIN	3.62	5.19	6.12	7.31	8.73	9.67
10	2.81	4.02	4.75	5.67	6.78	7.51
15	2.37	3.40	4.01	4.79	5.72	6.34
20	2.00	2.86	3.38	4.03	4.81	5.34
25	1.77	2.54	3.00	3.58	4.28	4.74
30	1.64	2.35	2.78	3.22	3.97	4.39
40	1.34	1.92	2.27	2.70	3.23	3.59
50	1.16	1.66	1.96	2.34	2.80	3.10
60 (1HR)	1.04	1.49	1.76	2.10	2.51	2.78
80	0.80	1.14	1.47	1.61	1.91	2.16
100	0.67	0.94	1.20	1.30	1.58	1.79
120 (2HR)	0.58	0.80	0.96	1.14	1.30	1.50
150	0.49	0.66	0.78	0.93	1.10	1.23
180 (3HR)	0.42	0.56	0.67	0.80	0.92	1.05
4 HR	0.33	0.44	0.53	0.62	0.72	0.81
5	0.27	0.36	0.43	0.50	0.57	0.66
6	0.23	0.30	0.37	0.43	0.49	0.57
8	0.20	0.24	0.29	0.34	0.39	0.44
10	0.15	0.20	0.24	0.29	0.32	0.36
12	0.13	0.17	0.20	0.25	0.28	0.31
14	0.11	0.15	0.18	0.23	0.24	0.27
16	0.10	0.13	0.16	0.20	0.22	0.24
18	0.09	0.12	0.14	0.18	0.19	0.21
20	0.08	0.11	0.13	0.17	0.18	0.19
22	0.07	0.10	0.12	0.16	0.16	0.17
24	0.07	0.09	0.11	0.14	0.15	0.16

B. One-hour point rainfall values to be used with the CUHP method of analysis shall be the City of Evans One-Hour Point Rainfall values shown below:

Table 3.3.2 One Hour Point Rainfall Data

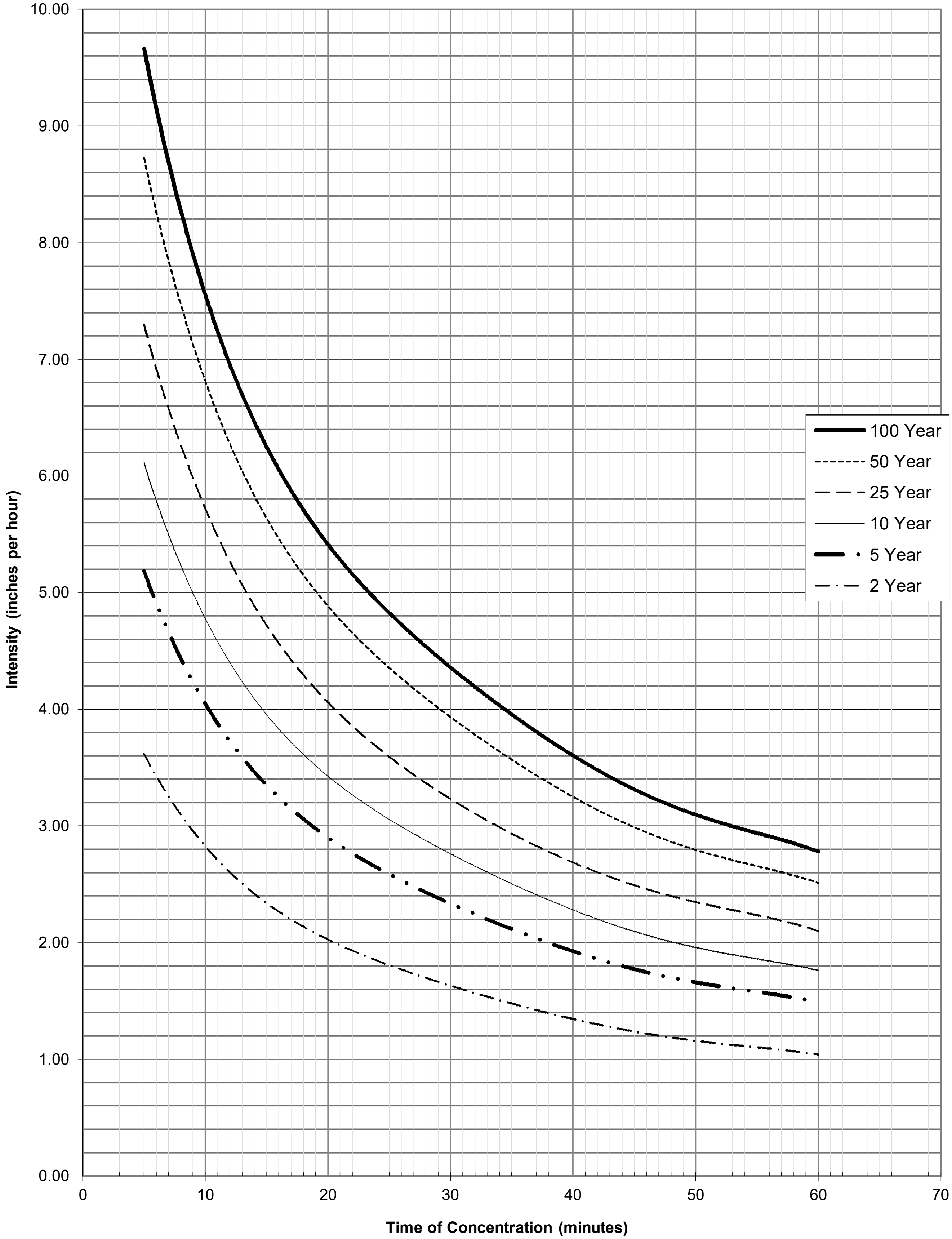
ONE-HOUR POINT RAINFALL (IN)				
2-year	**5-year**	**10-year**	**50-year**	**100-year**
1.04	1.49	1.76	2.51	2.78

C. For analysis of watersheds greater than 5 square miles, the design storm duration and rainfall values must be adjusted to account for the averaging effects of larger watersheds. The incremental rainfall distribution for all basin areas up to 20 square miles shall be based on the City of Evans values and are included in Table 3.3.3.

Table 3.3.3 Design Storms for Evans

INCREMENTAL RAINFALL DEPTH/RETURN PERIOD															
	BASINS LESS THAN 5 SQ. MILES					**BASINS BETWEEN 5 AND 10 SQ. MILES**					**BASINS BETWEEN 10 AND 20 SQ. MILES**				
TIME	**2-YR**	**5-YR**	**10-YR**	**50-YR**	**100-YR**	**2-YR**	**5-YR**	**10-YR**	**50-YR**	**100-YR**	**2-YR**	**5-YR**	**10-YR**	**50-YR**	**100-YR**
(MIN)	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**
5	0.02	0.03	0.04	0.03	0.03	0.02	0.03	0.04	0.03	0.03	0.02	0.03	0.04	0.03	0.03
10	0.04	0.06	0.07	0.09	0.08	0.04	0.06	0.07	0.09	0.08	0.04	0.06	0.07	0.09	0.08
15	0.09	0.13	0.14	0.13	0.13	0.09	0.13	0.14	0.13	0.13	0.09	0.13	0.14	0.13	0.13
20	0.17	0.23	0.26	0.20	0.22	0.16	0.22	0.25	0.20	0.22	0.15	0.21	0.24	0.20	0.22
25	0.26	0.37	0.44	0.38	0.39	0.25	0.36	0.42	0.36	0.37	0.23	0.34	0.40	0.34	0.35
30	0.15	0.19	0.21	0.63	0.70	0.14	0.19	0.20	0.60	0.67	0.13	0.17	0.19	0.57	0.63
35	0.07	0.09	0.10	0.30	0.39	0.07	0.09	0.10	0.29	0.37	0.07	0.09	0.10	0.27	0.35
40	0.05	0.07	0.08	0.20	0.22	0.05	0.07	0.08	0.20	0.22	0.05	0.07	0.08	0.20	0.22
45	0.03	0.05	0.07	0.13	0.17	0.03	0.05	0.07	0.13	0.17	0.03	0.05	0.07	0.13	0.17
50	0.03	0.05	0.06	0.08	0.14	0.03	0.05	0.06	0.08	0.14	0.03	0.05	0.06	0.08	0.14
55	0.03	0.05	0.06	0.08	0.11	0.03	0.05	0.06	0.08	0.11	0.03	0.05	0.06	0.08	0.11
60	0.03	0.05	0.06	0.08	0.11	0.03	0.05	0.06	0.08	0.11	0.03	0.05	0.06	0.08	0.11
65	0.03	0.05	0.06	0.06	0.11	0.03	0.05	0.06	0.06	0.11	0.03	0.05	0.06	0.06	0.11
70	0.02	0.05	0.06	0.06	0.06	0.02	0.05	0.06	0.06	0.06	0.02	0.05	0.06	0.06	0.06
75	0.02	0.04	0.06	0.05	0.06	0.02	0.04	0.06	0.05	0.06	0.02	0.04	0.06	0.05	0.06
80	0.02	0.03	0.04	0.05	0.03	0.02	0.03	0.04	0.05	0.03	0.02	0.03	0.04	0.05	0.03
85	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03
90	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03
95	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.03
100	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03
105	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03
110	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.03
115	0.01	0.02	0.03	0.04	0.03	0.01	0.02	0.03	0.04	0.03	0.01	0.02	0.03	0.04	0.03
120	0.01	0.02	0.02	0.04	0.03	0.01	0.02	0.02	0.04	0.03	0.01	0.02	0.02	0.04	0.03
125											0.01	0.01	0.02	0.02	0.02
130											0.01	0.01	0.01	0.02	0.02
135											0.01	0.01	0.01	0.01	0.02
140											0.01	0.01	0.01	0.01	0.01
145											0.01	0.01	0.01	0.01	0.01
150											0.01	0.01	0.01	0.01	0.01
155											0.01	0.01	0.01	0.01	0.01
160											0.01	0.01	0.01	0.01	0.01
165											0.01	0.01	0.01	0.01	0.01
170											0.00	0.00	0.01	0.00	0.01
175											0.00	0.00	0.00	0.00	0.01
180											0.00	0.00	0.00	0.00	0.01
TOTAL	1.20	1.72	2.04	2.81	3.21	1.18	1.69	2.00	2.76	3.15	1.24	1.73	2.05	2.79	3.22
	Reference:		Miller, J.F., and Tracey, R.J. Precipitation-Frequency Analysis of the Western United States (NOAA Atlas) Volume III - Colorado 1973												

Figure 3.3.1
Intensity Duration Frequency Curves
City of Evans, Colorado



SECTION 4 RUNOFF

4.1 Introduction

This section presents the methodology and criteria for determining the storm runoff design peaks and volumes to be used in the City of Evans in the preparation of stormwater facility design. The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 1 "Runoff" Chapter. Software from the UDFCD can be found at http://udfcd.org/software.

4.2 Design Criteria

A. Runoff shall follow the quantities, methods and flow paths laid out in the SWUMP, and take into consideration the existing drainage paths, ponds, and facilities for the City area.

B. The runoff analysis for a site shall be based on the land use for that area. The analysis shall include contributing runoff from upstream areas. The contributing runoff shall be based on:
   1. Ultimate developed land use of the area.
   2. Topographic characteristics of those areas.

C. Natural topographic features shall be used as the basis for locating drainage facilities and runoff calculations. Average land slopes may be utilized in runoff computations (see the USDCM for detailed methods of computing runoff).

E. Soils groups must be determined for the area being analyzed. The NRCS soil group classification is factored into the calculations for runoff, and this information can be found at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

4.3 Rational Method

The Rational Method of runoff analysis may be used for basins less than 160 acres in size. Procedures and spreadsheets for the Rational Method and applicable runoff coefficients are presented in the USDCM Volume I. In addition, a sample has been created for the City of Evans which is available on the City's website. See Section 3 of this report for the required rainfall values. Refer to the USDCM and Table 4.3.1 for the recommended impervious values.

The Rational Method is based on the formula:

$$Q=CIA$$

Where: Q = the maximum rate of runoff (cfs),
C = Runoff coefficient–a non-dimensional coefficient equal to the ratio of runoff volume to rainfall volume.
I = average intensity of rainfall for a duration equal to the time of concentration, tc (inches/hour)
A = tributary area (acres)

The general procedure for using the Rational Method for basins is as follows.

1. Delineate the catchment boundary and determine its area.
2. Define the flow path from the upper-most portion of the catchment to the design point. This flow path should be divided into reaches of similar flow type (e.g., overland flow, shallow swale flow, gutter flow, etc.). Determine the length and slope of each reach.
3. Determine the time of concentration, tc, for the selected waterway.

4. Find the rainfall intensity, I, for the design storm using the calculated tc and the rainfall intensity-duration-frequency curve (see Rainfall chapter).
5. Determine the runoff coefficient, C in Table 4.3.2
6. Calculate the peak flow rate, Q, from the catchment using Rational Method equation.

TABLE 4.3.1 Recommended Percentage Imperviousness Values

LAND USE OR SURFACE CHARACTERISTICS	PERCENTAGE IMPERVIOUS
Business:	
Commercial areas	95
Neighborhood area	75
Residential:	
Single-family	See USDCM
Multi-family (detached)	60
Multi-family (attached)	75
Half-acre lot or larger	See USDCM
Apartments	75
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	10
Playgrounds	25
Schools	55
Railroad yard areas	20
Undeveloped areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel	40
Recycled asphalt	75
Drives and walks	90
Roofs	90

Obtained from the runoff chapter of the UDFCD Manual (Volume 1), Table RO-3. http://udfcd.org/volume-one

4.4 Colorado Urban Hydrograph Procedure (CUHP)

For basins greater than 160 acres the Colorado Urban Hydrograph Procedure (CUHP) method of runoff analysis is required. The CUHP method is recommended for basins greater than 90 acres, but is not required. Detailed explanation of the CUHP procedures is presented in the USDCM Volume 1. The computerized modeling software to create hydrographs may be obtained from the UDFCD website (www.udfcd.org). The design storms to be used with CUHP are presented in Section 3.2 of this report.

When routing procedures are necessary, computer programs, such as the EPA Stormwater Management Model (SWMM), are recommended but not required. Channel routing methodology is explained in the USDCM Volume 1.

4.5 On-Site and Off-Site

Following guidelines set in the SWUMP, the design engineer shall use the proposed fully developed land use to determine runoff coefficients for analyzing the peak flows and volumes.

On-Site flows are those flows generated within the project limits. For an undeveloped lot, historic flows are calculated based on the undeveloped condition. If the project is a re-development, the developed flow leaving the site shall be no worse than the previous usage of the site (i.e. current condition). With the guidance of the SWUMP, the on-site developed flows generally cannot exceed those of the historic on-site flows and detention may be required to accomplish this.

Off-site flows are those flows generated outside the project limits and flow to, around, or through the project site. These flows need to safely pass through the site in their historic or current path without adversely impacting downstream development. If the tributary area upstream of the project site is undeveloped, the off-site flows will be calculated with consideration of any anticipated or planned development, or current zoning.

4.6 Channel Routing

Natural drainageways are to be used whenever feasible. Past experience has shown that stormwater drainage systems perform better and have fewer problems when they follow the existing natural drainageways. Alteration to natural drainage patterns will be considered if investigation and analysis can show no hazard or environmental degradation will result from the proposed construction.

Drainage systems shall not be designed to transfer the excess stormwater from one location to another. System design must not create a more hazardous condition downstream of the site. Each design shall include provisions for the 100-year storm to pass through the site at historic discharge levels.

Streets shall not be used as a primary flow conveyance for storm runoff and without exception storm flows are not permitted to flow into the Evans Town Ditch.

Table 4.3.2 Runoff Coefficients, c

Total or Effective % Imperviousness	**NRCS Hydrologic Soil Group A**					
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
2%	0.02	0.02	0.02	0.02	0.02	0.17
5%	0.04	0.05	0.05	0.05	0.05	0.19
10%	0.09	0.09	0.09	0.09	0.10	0.23
15%	0.13	0.14	0.14	0.14	0.14	0.28
20%	0.18	0.19	0.19	0.19	0.19	0.32
25%	0.22	0.23	0.24	0.24	0.24	0.36
30%	0.27	0.28	0.28	0.28	0.29	0.40
35%	0.31	0.33	0.33	0.33	0.33	0.44
40%	0.36	0.37	0.39	0.38	0.38	0.48
45%	0.40	0.42	0.42	0.42	0.43	0.52
50%	0.45	0.47	0.47	0.47	0.48	0.56
55%	0.49	0.51	0.52	0.52	0.52	0.60
60%	0.53	0.56	0.56	0.57	0.57	0.64
65%	0.58	0.60	0.61	0.61	0.62	0.68
70%	0.62	0.65	0.66	0.66	0.67	0.72
75%	0.67	0.70	0.71	0.71	0.71	0.76
80%	0.71	0.74	0.75	0.76	0.76	0.80
85%	0.76	0.79	0.80	0.80	0.81	0.84
90%	0.80	0.84	0.85	0.85	0.86	0.88
95%	0.85	0.88	0.89	0.90	0.90	0.92
100%	0.89	0.93	0.94	0.94	0.95	0.96
Total or Effective % Imperviousness	**NRCS Hydrologic Soil Group B**					
2%	0.02	0.02	0.14	0.24	0.38	0.46
5%	0.04	0.05	0.17	0.27	0.39	0.48
10%	0.09	0.09	0.21	0.30	0.42	0.50
15%	0.13	0.14	0.25	0.34	0.45	0.53
20%	0.18	0.19	0.29	0.37	0.48	0.55
25%	0.22	0.23	0.33	0.41	0.51	0.58
30%	0.27	0.28	0.37	0.44	0.54	0.60
35%	0.31	0.33	0.41	0.48	0.57	0.63
40%	0.36	0.37	0.45	0.51	0.60	0.65
45%	0.40	0.42	0.49	0.55	0.63	0.67
50%	0.45	0.47	0.53	0.58	0.66	0.70
55%	0.49	0.51	0.57	0.62	0.69	0.72
60%	0.53	0.56	0.61	0.65	0.72	0.75
65%	0.58	0.60	0.65	0.69	0.75	0.77
70%	0.62	0.65	0.69	0.72	0.78	0.80
75%	0.67	0.70	0.73	0.76	0.81	0.82
80%	0.71	0.74	0.77	0.79	0.84	0.85
85%	0.76	0.79	0.81	0.83	0.87	0.87
90%	0.80	0.84	0.85	0.86	0.89	0.90
95%	0.85	0.88	0.89	0.90	0.92	0.92
100%	0.89	0.93	0.94	0.94	0.95	0.94

Table 4.3.2 Runoff Coefficients, c (continued)

Total or Effective % Imperviousness	**NRCS Hydrologic Soil Group C and D**					
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
2%	0.02	0.07	0.22	0.32	0.43	0.52
5%	0.04	0.10	0.24	0.34	0.45	0.53
10%	0.09	0.14	0.27	0.37	0.47	0.55
15%	0.13	0.18	0.31	0.41	0.50	0.58
20%	0.18	0.23	0.35	0.44	0.53	0.60
25%	0.22	0.27	0.39	0.47	0.55	0.62
30%	0.27	0.31	0.42	0.50	0.58	0.64
35%	0.31	0.36	0.46	0.53	0.61	0.67
40%	0.36	0.40	0.50	0.57	0.63	0.69
45%	0.40	0.44	0.53	0.60	0.66	0.71
50%	0.45	0.49	0.57	0.63	0.69	0.73
55%	0.49	0.53	0.61	0.66	0.72	0.76
60%	0.53	0.57	0.64	0.69	0.74	0.78
65%	0.58	0.62	0.68	0.73	0.77	0.80
70%	0.62	0.66	0.72	0.76	0.80	0.82
75%	0.67	0.70	0.76	0.79	0.82	0.85
80%	0.71	0.75	0.79	0.82	0.85	0.87
85%	0.76	0.79	0.83	0.85	0.88	0.89
90%	0.80	0.83	0.87	0.89	0.90	0.91
95%	0.85	0.88	0.90	0.92	0.93	0.94
100%	0.89	0.92	0.94	0.95	0.96	0.96

SECTION 5 STREETS

5.1 Introduction

This section presents criteria for the evaluation of the allowable drainage encroachment within public streets and is in addition to the requirements and recommendations set forth in the USDCM Volume 1 "Streets" chapter. The review of all reports shall be based on the criteria herein.

5.2 Functions of Streets

Stormwater that collects in the streets will flow down the gutter. It will encroach on the roadway and hinder traffic, possibly becoming a hazard. The object of the drainage design is to keep that encroachment of stormwater on the streets to an acceptable limit for any given storm event. Refer to Table 5.2.1 for criteria for each street classification.

Ideally, streets are symmetric and follow the standard cross sections as shown in the City of Evans Street Specifications. In many cases, each street is unique and does not conform to the standard. For example, streets that have non-symmetrical curb elevations can have more water running down one side than the other. The longitudinal slope of one side of the road may not be the same as the other. The right-of-way and property beyond the edge of road can vary greatly in elevations, slopes, surface material, landscaping, etc. For any given design configuration, each side of the roadway must be designed to conform to the criteria listed in Table 5.2.1.

TABLE 5.2.1 Street Classifications for Drainage Purposes

<table>
<tr><th>STREET CLASSIFICATION</th><th>FUNCTION</th><th>MINOR STORM
MAXIMUM ENCROACHMENT AND INUNDATION</th><th>MAJOR STORM

MAXIMUM DEPTH AND INUNDATED AREA</th></tr>
<tr><td>Local</td><td>Provides access to residential and industrial areas</td><td>No curb overtopping. Flow may spread to crown of street.</td><td rowspan="2">Residential dwellings, public, commercial and industrial buildings should be no less than 12 inches above the 100-year flood at the ground line or lowest water entry of the building. The depth of water at the gutter flow line should not exceed 12 inches. Verify site conditions allow containment up to 12 inches.</td></tr>
<tr><td>Collector</td><td>Collects and convey traffic between local and arterial streets</td><td>No curb overtopping. Flow spread must leave at least one lane free of water.</td></tr>
<tr><td>Arterial</td><td>Delivers traffic between urban centers and from collectors to freeways</td><td>No curb overtopping. Flow spread must leave at least one lane free of water in each direction, and should not flood more than two lanes in each direction.</td><td rowspan="2">Residential dwellings, public, commercial, and industrial buildings should be no less than 12 inches above the 100-year flood at the ground line or lowest water entry of the building. The depth of water should not exceed the street crown to allow operation of emergency vehicles. The depth of water at the gutter flow line should not exceed 12 inches. Verify site conditions allow containment up to 12 inches.</td></tr>
<tr><td>Freeway</td><td>Provides rapid and efficient transport over long distances</td><td>No encroachment is allowed onto any traffic lanes</td></tr>
</table>

Refer to Figure 5.2.1 for examples of the 3 types of street sections mentioned.

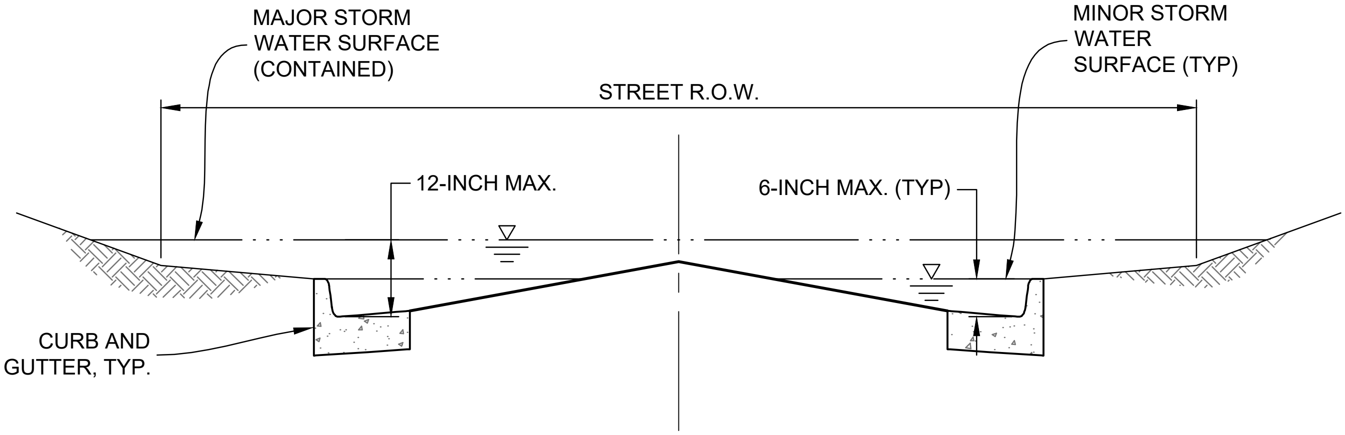
Converging street intersections will normally have cross street flow. The flow must be caught in a cross pan (where allowed) or possibly cross the crown of the perpendicular street. The restrictions for flow depth at intersections are set forth in Table 5.2.2.

TABLE 5.2.2 Allowable Street Cross-flow

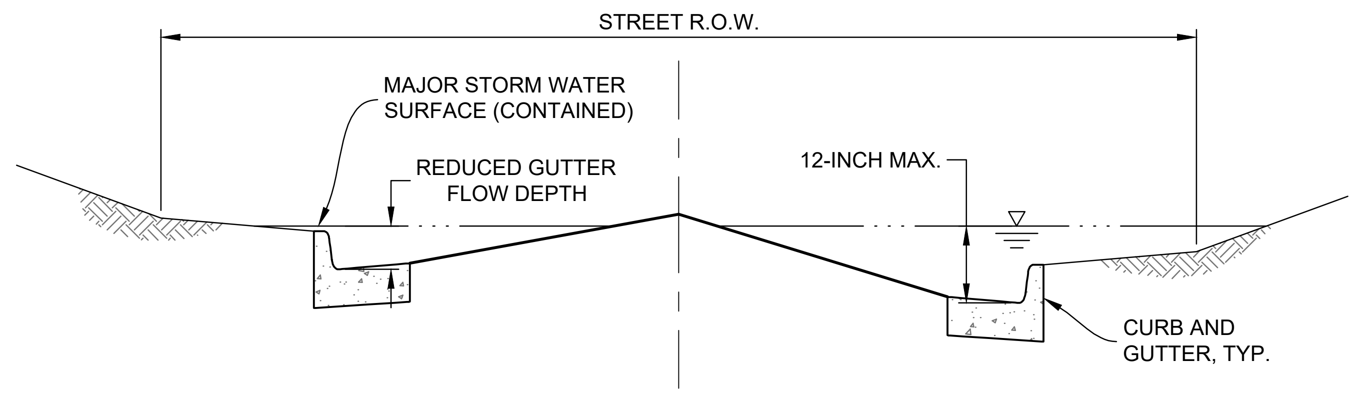
STREET CLASSIFICATION	**MINOR STORM FLOW**	**MAJOR (100-YEAR) STORM FLOW**
Local	6 inches of depth in crosspan	12 inches of depth above gutter flow line
Collector	Where crosspans allowed, depth of flown should not exceed 6 inches	12 inches of depth above gutter flow line
Arterial/Freeway	None	No cross-flow. Maximum depth at upstream gutter on road edge of 12 inches

5.3 Calculations and Examples

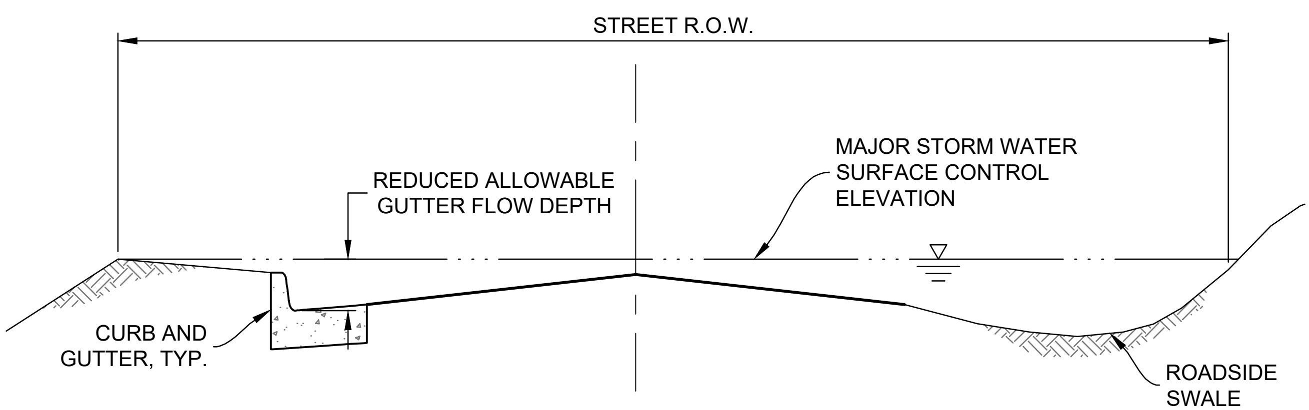
Hydraulic capacities for street sections and the allowable gutter capacity must be calculated to determine the inlet size, location and flows to designated design points. The appropriate reduction factor must be applied. The procedures and requirements for storm drainage design for streets is explained in USDCM Volume 1, chapter 7 with an example to follow. UD-inlet can be downloaded from the UDFCD website and used to complete the necessary calculations. A sample calculation is also included in Appendix A at the back of this document.



SYMMETRICAL STREET SECTION



NON-SYMMETRICAL STREET SECTION I



NON-SYMMETRICAL STREET SECTION II

NOTE:
CRITERIA REQUIRES MAJOR STORM WATER SURFACE TO BE 12-INCHES BELOW GROUND LINE OR LOWEST WATER ENTRY OF BUILDINGS

City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

STREET CAPACITY - MAJOR AND MINOR STORMS

FIGURE 5.2.1

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NAME: Q:\2015 PROJECTS\15-041.01 EVANS STORMWATER MANAGEMENT PLAN - EVANS\CAD\DRAWINGS\15-041.01_CRITERIA MANUAL FIGURES.DWG

SECTION 6 INLETS

6.1 Introduction

This section presents criteria and methodology for design and analysis of stormwater inlets. Three types of inlets (curb opening, grated, and combination inlets) are designed to collect flow and funnel it into the underground drainage system. Inlets are further classified as being on a "continuous grade" or in a “sump” condition. A “sump” condition exists when the all slopes coming toward the inlet creating the low point at the inlet. For a “continuous grade” the inlet is positioned where the road grade will drop to the inlet then continue to drop away beyond. The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume l "Storm Inlets" chapter.

6.2 Standard Inlets

Standard inlets permitted for use in the City are shown below.

Table 6.2.1 Permitted Types of Inlets

INLET TYPE	DETAIL	PERMITTED USE
Curb Opening Inlet, Type R	Figure 6.2.1	All street types
Grated Inlet Type C	Figure 6.2.2	All streets with roadside or median ditch
Grated Inlet Type 13	Figure 6.2.3	Alleys or private drives with a valley gutter
Combination Inlet Type 13 (Denver Type 16)	Figure 6.2.4	All street types
Note: Other combination inlet types may be requested as a variance and used with City approval.		

Please note that the Figures included may not be the most recent version of the detail. Newer versions of any of these details should be used instead of the details included at the end of this chapter.

Inlets shall be located to collect flows in the gutter or ditch. Inlets and inlet transitions are prohibited in curb returns, driveways, and street/curb transitions.

Optimum inlet spacing will depend on traffic requirements, land use, street slope, and distance to the outfall system. The recommended sizing and spacing of the inlets is based upon the interception rate of 70 to 80 percent. However, due to variable street flow capacities, optimum street flow cannot always be achieved.

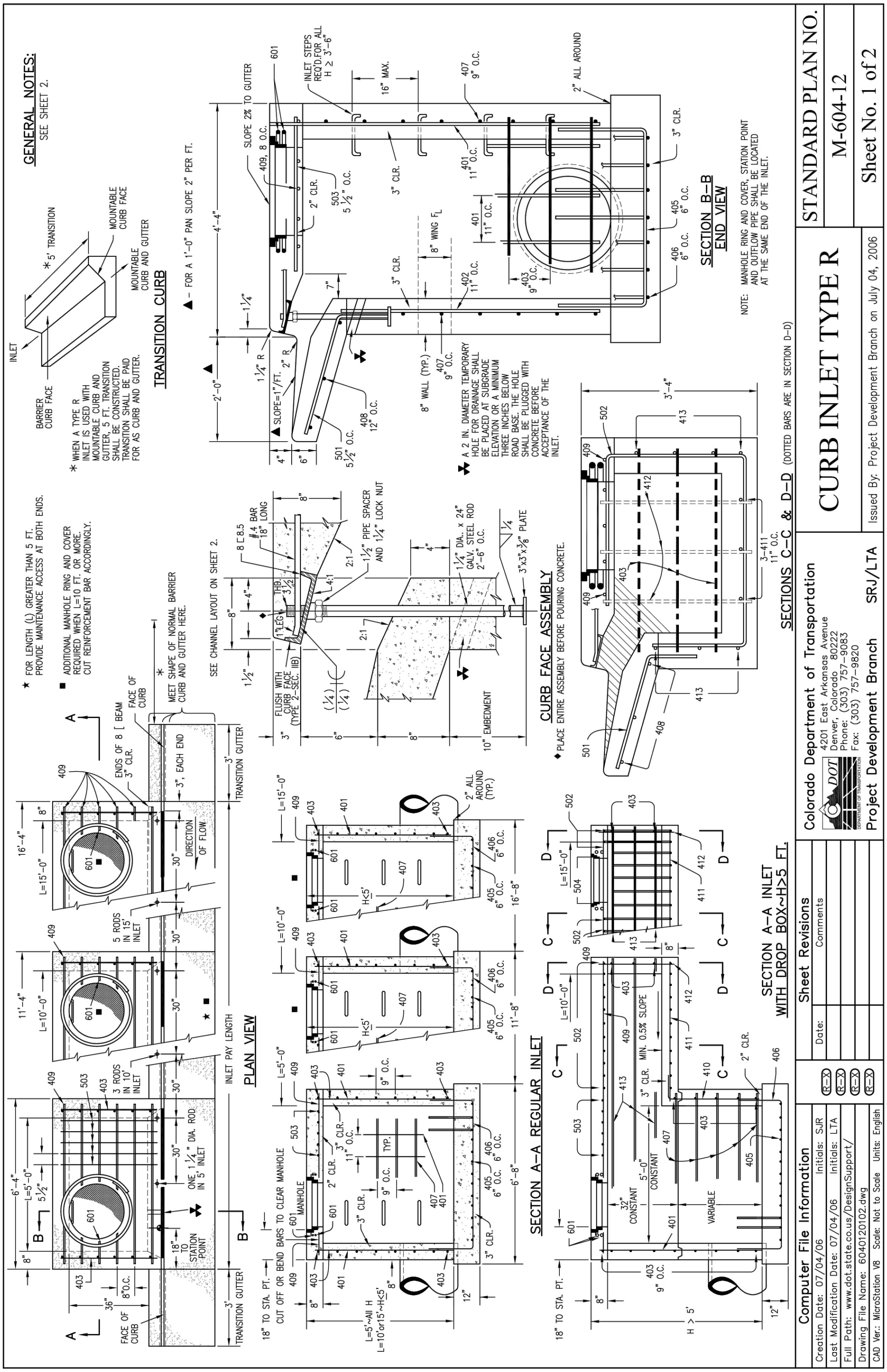
6.3 Inlet Hydraulics

The chapter on "Street/Inlets/Storm Sewers" in Volume 1 of the USDCM instructs how to design inlets. The UD-Inlet spreadsheet should be used to calculate the street capacity, curb flow, inlet capacity and inlet hydraulics. This spreadsheet is available for download from the UDFCD website.

Calculations for inlet capacity and hydraulics must consider the decreased capacity on the various types of inlets due to flow depth, debris, pavement overlaying, and other design assumptions. These reduction factors are already incorporated into the UD-Inlet spreadsheet.

Inlets set on continuous grade may not capture all the flow coming to it. Some of that flow will bypasses the inlet. In the design, layout and calculations of the stormwater drainage system the bypass flow must be analyzed. See the design example in Appendix A of this document.

Inlets in a sump do not have bypass flow, although ponding depths and the spread of the ponding has to be considered in the design. The City of Evans required not more than 12 inches of ponding at a sump inlet in a road. If an inlet is used in a swale (i.e. a Type C inlet), the maximum allowable ponding depth is 24 inches. Figure 6.3.1 show the inlet capacity for standard Type C inlets. All calculations for inlets in a sump shall conform to the procedures, variables, and coefficients provided in the USDCM.



CITY OF EVANS DRAINAGE CRITERIA MANUAL

CDOT TYPE R INLET (SHEET 1 OF 2)

FIGURE 6.2.1

City of Evans, Colorado

MARK	BAR # OR SIZE	O.C. SPACING	TYPE	ALL INLETS L = 5 FT. NO. REQ'D.	ALL INLETS L = 5 FT. LENGTH	INLETS: H ≤ 5 FT. L = 10 FT. NO. REQ'D.	INLETS: H ≤ 5 FT. L = 10 FT. LENGTH	INLETS: H ≤ 5 FT. L = 15 FT. NO. REQ'D.	INLETS: H ≤ 5 FT. L = 15 FT. LENGTH	INLETS: H > 5 FT. L = 10 FT. NO. REQ'D.	INLETS: H > 5 FT. L = 10 FT. LENGTH	INLETS: H > 5 FT. L = 15 FT. NO. REQ'D.	INLETS: H > 5 FT. L = 15 FT. LENGTH
401	4	11"	II	15	*	21	*	26	*	11	*	11	*
402	4	11"	II	7	*	13	*	18	*	7	*	7	*
403	4	9"	II	*	4'–0"	*	4'–0"	*	4'–0"	*	4'–0"	*	4'–0"
405	4	6"	VI	11	6'–10"	21	6'–10"	31	6'–10"	11	6'–10"	11	6'–10"
406	4	6"	VIII	7	8'–10"	7	13'–10"	7	18'–10"	7	8'–10"	7	8'–10"
407	4	9"	II	*	5'–10"	*	10'–10"	*	15'–10"	*	5'–10"	*	5'–10"
408	4	12"	II	3	6'–10"	3	11'–10"	3	16'–0"	3	11'–10"	3	16'–0"
409	4	8"	II	6	5'–10"	6	10'–10"	6	15'–10"	6	10'–10"	6	15'–10"
410	4	11"	VII							3	*	3	*
411	4	11"	II							3	5'–2"	3	10–2"
412	4	11"	II							3	2'–9"	3	2'–9"
413	4	9"	II							7	10'–10"	7	15'–10"
501	5	5½"	IV	11	3'–4"	22	3'–4"	33	3'–4"	22	3'–4"	33	3'–4"
502	5	5½"	III							11	11'–5"	17	11'–5"
503	5	5½"	II	5	3'–6"	16	3'–6"	27	3'–6"	6	3'–6"	6	3'–6"
504	5	5½"	IX									5	8'–4"
601	6	2½"	V	2	8'–10"	2	8'–10"	2	8'–10"	2	8'–10"	4	8'–10"
■8[8.5				1	5'–10"	1	10'–10"	1	15'–10"	1	10'–10"	1	15'–10"
				2 BARS, 1 RODS	——	4 BARS, 3 RODS	——	8 BARS, 5 RODS	——	4 BARS, 3 RODS	——	8 BARS, 5 RODS	——

REGULAR INLETS (L = 10 FT. and L = 15 FT., H ≤ 5 FT.) — DROP BOX INLETS (H > 5 FT.)

* VARIABLE REFER TO TABLE TWO.

■ INCLUDE #4, 18 IN. BARS (SEE CHANNEL LAYOUT).

TABLE ONE ~ BAR LIST FOR CURB INLETS, TYPE "R"

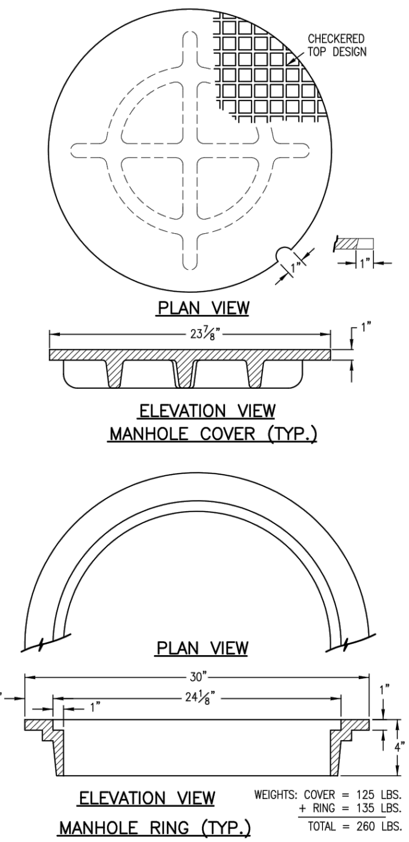
"H"	LENGTH 401	LENGTH 402	LENGTH 410	NO. REQ'D. REGULAR 403	NO. REQ'D. REGULAR 407	NO. REQ'D. DROP BOX 403	NO. REQ'D. DROP BOX 407	L = 5 FT. CONC. CU. YDS.	L = 5 FT. STEEL LBS.	L = 10 FT. CONC. CU. YDS.	L = 10 FT. STEEL LBS.	L = 15 FT. CONC. CU. YDS.	L = 15 FT. STEEL LBS.
3'–0"	2'–8"	1'–8"		10	7			3.2	285	5.3	497	7.4	706
3'–6"	3'–2"	2'–2"		10	7			3.4	305	5.7	528	7.9	747
4'–0"	3'–8"	2'–8"		12	9			3.7	326	6.0	559	8.4	786
4'–6"	4'–2"	3'–2"		12	9			3.9	334	6.4	571	8.8	803
5'–0"	4'–8"	3'–8"		14	11			4.1	354	6.7	602	9.3	844
5'–6"	5'–2"	4'–2"	3'–5"	16	13	15	6	4.4	375	6.0	607	7.4	850
6'–0"	5'–8"	4'–8"	3'–11"	16	13	16	6	4.6	382	6.2	616	7.6	860
6'–6"	6'–2"	5'–2"	4'–5"	18	15	18	8	4.8	402	6.4	637	7.8	880
7'–0"	6'–8"	5'–8"	4'–11"	20	17	19	10	5.0	423	6.6	654	8.0	897
7'–6"	7'–2"	6–2"	5'–5"	20	17	20	10	5.3	430	6.9	664	8.3	907
8'–0"	7'–8"	6'–8"	5'–11"	22	19	22	12	5.5	451	7.1	684	8.5	927
8'–6"	8'–2"	7'–2"	6'–5"	24	21	23	14	5.7	471	7.3	702	8.7	944
9'–0"	8'–8"	7'–8"	6'–11"	24	21	24	14	6.0	479	7.6	711	9.0	954
9'–6"	9'–2"	8'–2"	7'–5"	26	23	26	16	6.2	499	7.8	732	9.2	974
10'–0"	9'–8"	8'–8"	7'–11"	28	25	27	18	6.4	520	8.0	749	9.4	992
10'–6"	10'–2"	9'–2"	8'–5"	28	25	28	18	6.7	527	8.3	759	9.7	1001
11'–0"	10'–8"	9'–8"	8'–11"	30	27	30	20	6.9	547	8.5	779	9.9	1022

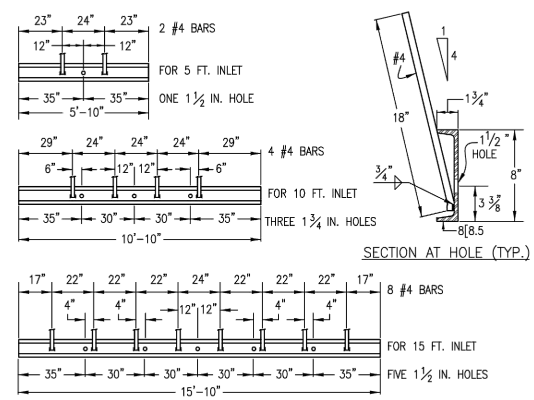
NOTES: FOR L=5 FT., L=10 FT., AND L=15 FT.
REGULAR INLETS: TOTAL QUANTITIES NEEDED ARE OUTSIDE THE HEAVY BLACK LINE.
DROP BOX INLETS: TOTAL QUANTITIES NEEDED ARE INSIDE THE HEAVY BLACK LINE.
STEEL WEIGHTS DO NOT INCLUDE STRUCTURAL STEEL CHANNEL.

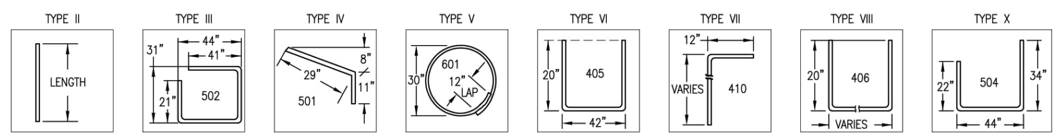
TABLE TWO ~ BARS AND QUANTITIES VARIABLE WITH "H"

GENERAL NOTES

1. CONCRETE SHALL BE CLASS B. INLET MAY BE CAST–IN–PLACE OR PRECAST.
2. CONCRETE WALLS SHALL BE FORMED ON BOTH SIDES AND SHALL BE 8 IN. THICK.
3. INLET STEPS SHALL BE IN CONFORMANCE WITH AASHTO M 199.
4. CURB FACE ASSEMBLY SHALL BE GALVANIZED AFTER WELDING.
5. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED 3/4 IN. CURB AND GUTTER CORNERS SHALL BE FINISHED TO MATCH THE EXISTING CURB AND GUTTER BEYOND THE TRANSITION GUTTER.
6. REINFORCING BARS SHALL BE DEFORMED AND SHALL HAVE A 2 IN. MINIMUM CLEARANCE. ALL REINFORCING BARS SHALL BE EPOXY COATED.
7. DIMENSIONS AND WEIGHTS OF TYPICAL MANHOLE RING AND COVER ARE NOMINAL.
8. MATERIAL FOR MANHOLE RINGS AND COVERS SHALL BE GRAY OR DUCTILE CAST IRON IN ACCORDANCE WITH SUBSECTION 712.06.
9. SINCE PIPE ENTRIES INTO THE INLET ARE VARIABLE, THE DIMENSIONS SHOWN ARE TYPICAL. ACTUAL DIMENSIONS AND QUANTITIES FOR CONCRETE AND REINFORCEMENT SHALL BE AS REQUIRED IN THE WORK. QUANTITIES INCLUDE VOLUMES OCCUPIED BY PIPES.
10. STRUCTURAL STEEL SHALL BE GALVANIZED AND SHALL BE IN ACCORDANCE WITH SUBSECTION 712.06.







BAR BENDING DIAGRAMS ~ (DIMENSIONS ARE OUT–TO–OUT OF BAR)

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R–X	

Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222
Phone: (303) 757–9083
Fax: (303) 757–9820
Project Development Branch SRJ/LTA

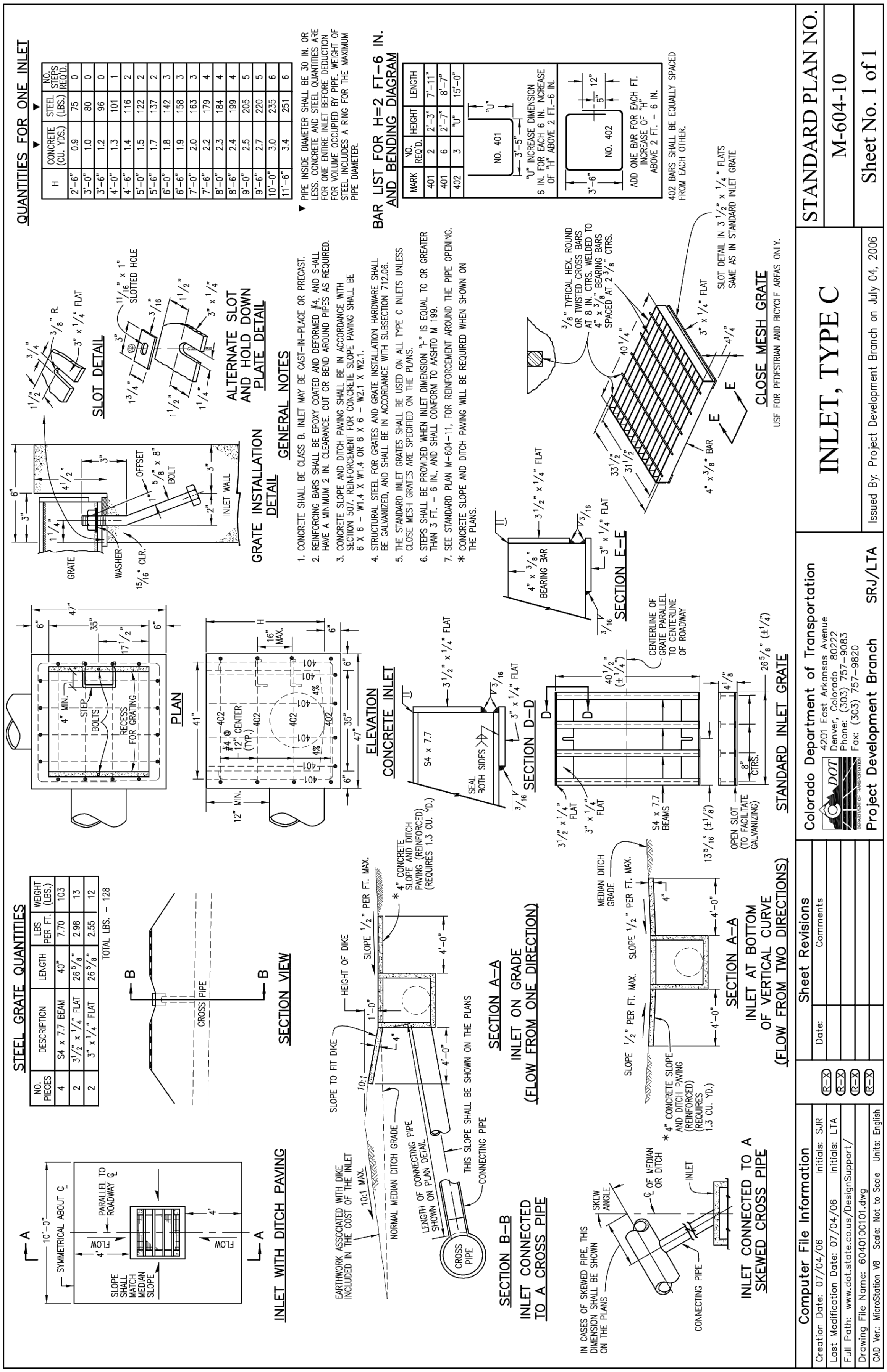
CURB INLET TYPE R

Issued By: Project Development Branch on July 04, 2006

STANDARD PLAN NO.
M-604-12
Sheet No. 2 of 2

CDOT TYPE R INLET (SHEET 2 OF 2)

FIGURE 6.2.1

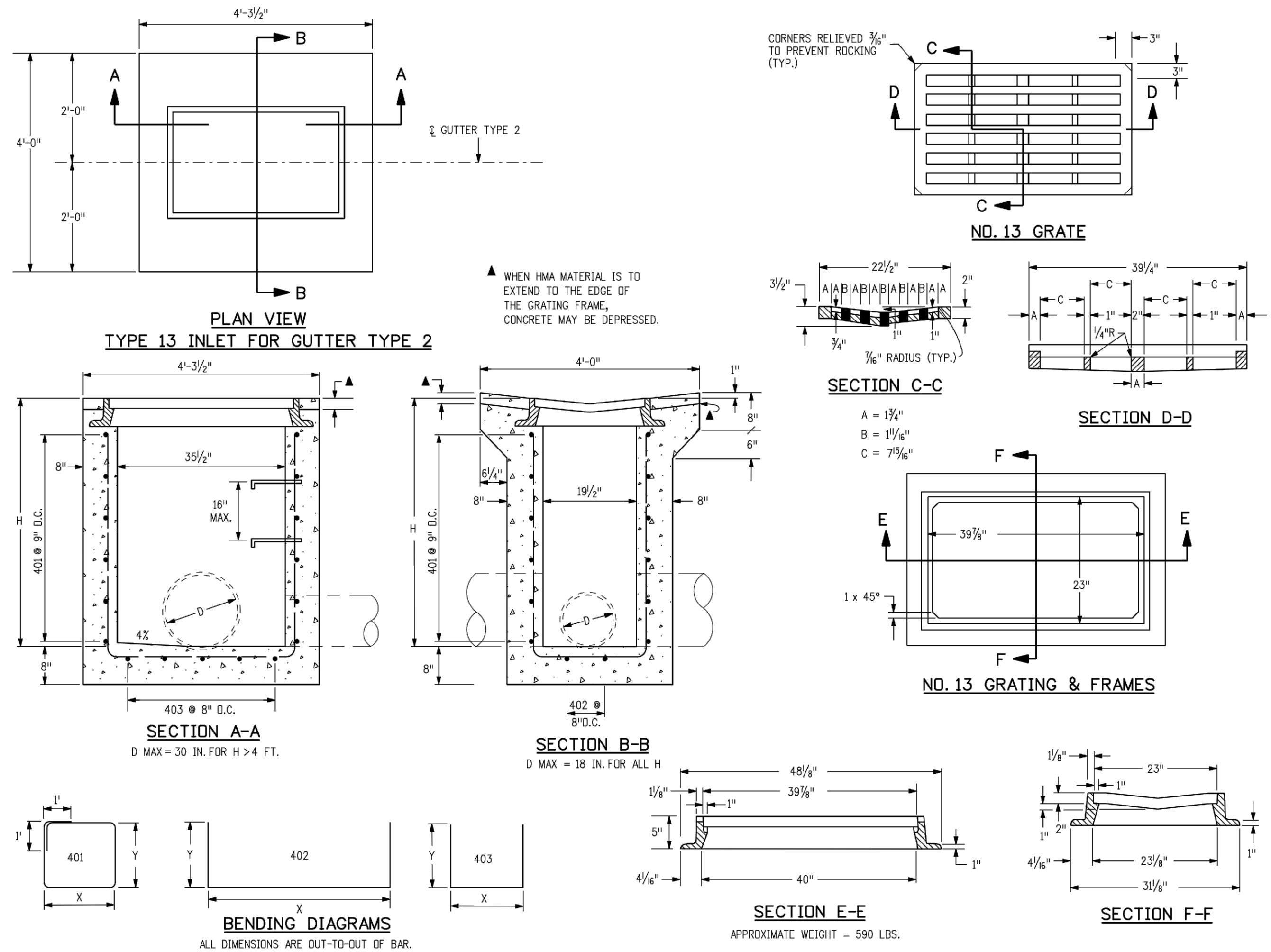


City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

CDOT TYPE C INLET

FIGURE 6.2.2



GENERAL NOTES

1. CONCRETE SHALL BE CLASS B. INLET MAY BE CAST-IN-PLACE OR PRECAST.
2. CAST-IN-PLACE CONCRETE WALLS SHALL BE FORMED ON BOTH SIDES.
3. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED 3/4 IN.
4. REINFORCING BARS SHALL BE DEFORMED #4 AND SHALL HAVE A 2 IN. MINIMUM CLEARANCE. ALL REINFORCING BARS SHALL BE EPOXY COATED.
5. STEPS SHALL BE PROVIDED WHEN INLET DIMENSION "H" IS EQUAL TO OR GREATER THAN 3 FT.-6 IN. AND SHALL CONFORM TO AASHTO M 199.
6. ALL GRATES AND FRAMES SHALL BE GRAY OR DUCTILE CAST IRON IN ACCORDANCE WITH SUBSECTION 712.06. GRATES AND FRAMES SHALL BE DESIGNED TO WITHSTAND HS 20 LOADING.
7. STATION POINT IS AT THE CENTER OF THE INLET.

H	CONCRETE	REINFORCING STEEL	NO. OF 401 BARS REQ'D.	MAXIMUM PIPE I.D. SEC. A-A	MAXIMUM PIPE I.D. SEC. B-B
	CU. YDS.	θ LB.		IN.	IN.
3'-0"	1.3	72	4	18	18
3'-6"	1.5	76	4	24	18
4'-0"	1.6	90	5	30	18
4'-6"	1.8	104	6	30	18
5'-0"	1.9	109	6	30	18
5'-6"	2.1	122	7	30	18
6'-0"	2.2	136	8	30	18
6'-6"	2.4	141	8	30	18
7'-0"	2.5	154	9	30	18
7'-6"	2.7	168	10	30	18
8'-0"	2.8	173	10	30	18
8'-6"	3.0	187	11	30	18
9'-0"	3.1	200	12	30	18
9'-6"	3.3	205	12	30	18
10'-0"	3.4	219	13	30	18

θ INCLUDES 1% FOR OVERRUN.
NOTE: CONCRETE QUANTITIES INCLUDE VOLUME OCCUPIED BY PIPE.

QUANTITIES FOR ONE INLET

MARK	NO. REQ'D.	DIMENSIONS X	DIMENSIONS Y	LENGTH
401	4	3'-6"	2'-2"	13'-4"
402	2	3'-4 1/2"	* 2'-6 1/2"	8'-5 1/2"
403	5	2'-1/2"	* 2'-7"	7'-2 1/2"

* ADD 6 IN. TO THIS DIMENSION FOR EACH 6 IN. INCREASE OF "H" OVER 3 FT.-0 IN.

BAR LIST FOR H = 3 FT.-0 IN.

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R-X	
R-X	

Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222
Phone: (303) 757-9083
Fax: (303) 757-9820
Project Development Branch SRJ/LTA

CONCRETE INLET TYPE 13

Issued By: Project Development Branch July 04, 2006

STANDARD PLAN NO.
M-604-13
Sheet No. 1 of 1

City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

CDOT TYPE 13 INLET

FIGURE 6.2.3

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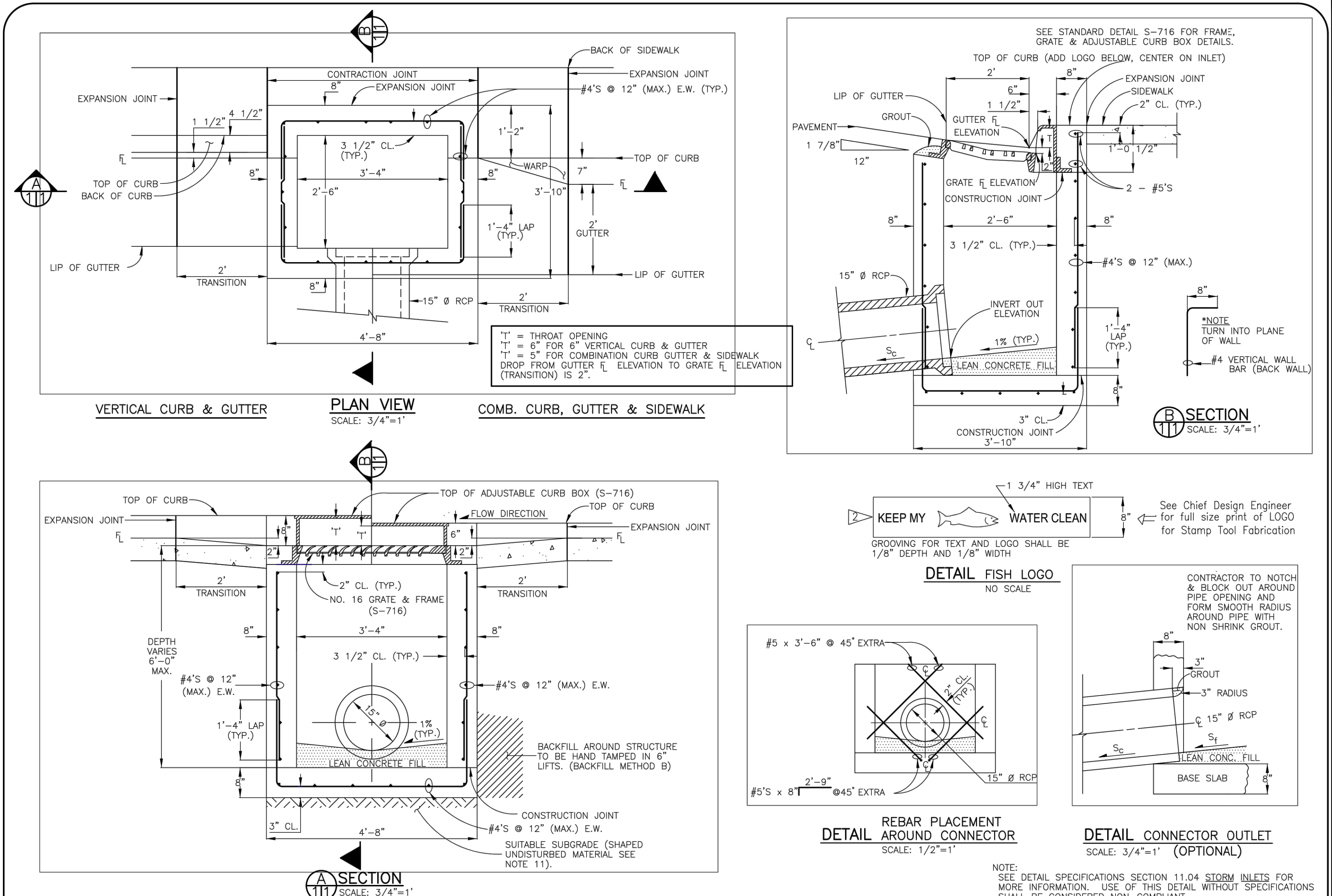


NOTES:

1. FOR PAYMENT PURPOSES, INLET STRUCTURES SHALL ALSO INCLUDE 2'-0" CURB & GUTTER TRANSITION SECTION AT EACH END OF INLET PLUS SIDEWALK SECTIONS WHERE REQUIRED BEHIND INLET STRUCTURE AND TRANSITION SECTIONS.
2. FLOOR SLOPE MAY BE POURED MONOLITHIC WITH BASE.
3. S_C = SLOPE OF CONNECTOR = 1% MIN.
4. UNLESS OTHERWISE SPECIFIED ON THE DRAWINGS OR OTHERWISE APPROVED, ALL #16 INLETS SHALL BE CONSTRUCTED WITH AN ADJUSTABLE C.I. CURB BOX (S-716).
5. DESIGN CONDITIONS FOR INLET ALLOWS DEPTHS OF 6' (MAX.). FOR INLETS MORE THAN 6 FEET IN DEPTH, SHOP DRAWINGS AND DESIGN ANALYSIS SHALL BE SUBMITTED FOR APPROVAL.
6. ALL REINFORCING STEEL SHALL BE ASTM, A-615, GRADE 60 DEFORMED BARS. DIAMETER OF BEND MEASURED ON THE INSIDE OF THE BAR SHALL BE A MINIMUM OF 6 BAR DIAMETER.
7. ALL WORK SHALL CONFORM TO AASHTO "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES", FIFTEENTH EDITION, 1992.
8. CONCRETE SHALL HAVE A 28 DAY COMPRESSIVE STRENGTH OF 4000 PSI.
9. SUB-GRADE SHALL BE A GRADATION EQUAL TO CLASS B BEDDING COMPACTED TO 95% MAXIMUM DRY DENSITY. AASHTO DESIGNATION T-180.
10. NO FORMWORK SHALL REMAIN INSIDE STRUCTURE WHEN COMPLETE.
11. SUB-GRADE SHALL BE SHAPED UNDISTURBED MATERIAL OR OVEREXCAVATED AND BACKFILLED WITH CLASS B BEDDING MATERIAL, COMPACTED PER WMD SPECIFICATIONS.
12. SPLICING OF REINFORCING STEEL SHALL BE PERMITTED ONLY WHERE DETAILED IN DRAWINGS.
13. INLET WALLS SHALL BE FORMED BOTH INSIDE AND OUTSIDE. CASTING OF SIDEWALLS AGAINST EARTH IS NOT PERMITTED.
14. LEAN CONCRETE FILL TO BE f'_c = 2000 PSI.

REVISED	BY	DATE
1	E.M.K.	4/10/96
2	I.J.	3/29/99

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS
WASTEWATER MANAGEMENT DIVISION

STANDARD DETAILS
SINGLE NO. 16 OPEN THROAT INLET
ADJUSTABLE CURB BOX

ISSUE DATE 6/94 | DRAWN BY E.M.K. | CHECKED BY I.J. | SHEET NO. 1 OF 1 SHEETS | DRAWING NO. S-616.1

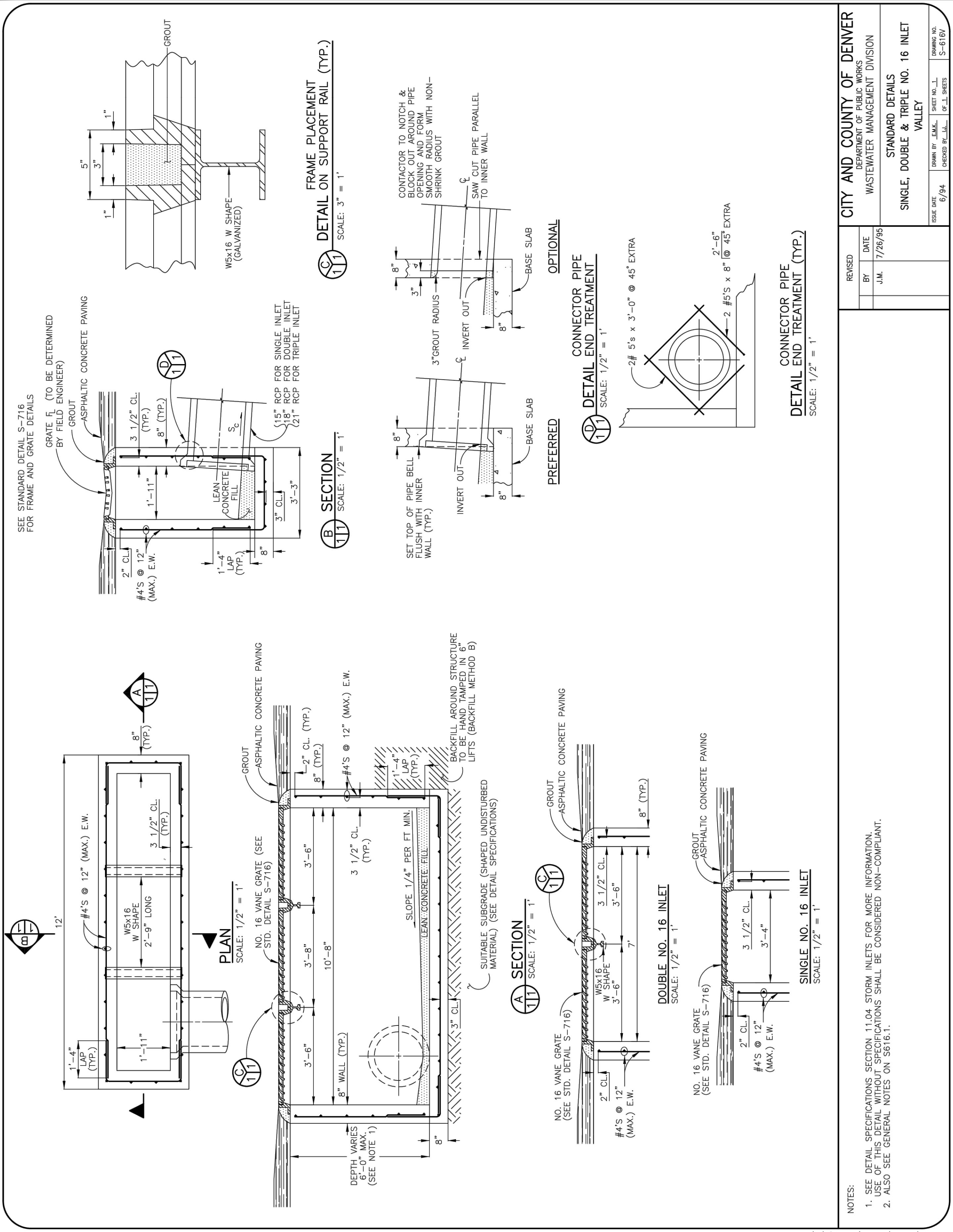
FILENAME: C:\DRAWINGS\WMDSTAND\S616-1.DWG, 4/11/96

City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

DENVER COMBINATION TYPE 16 INLET (SHEET 1 OF 2)

FIGURE 6.2.4



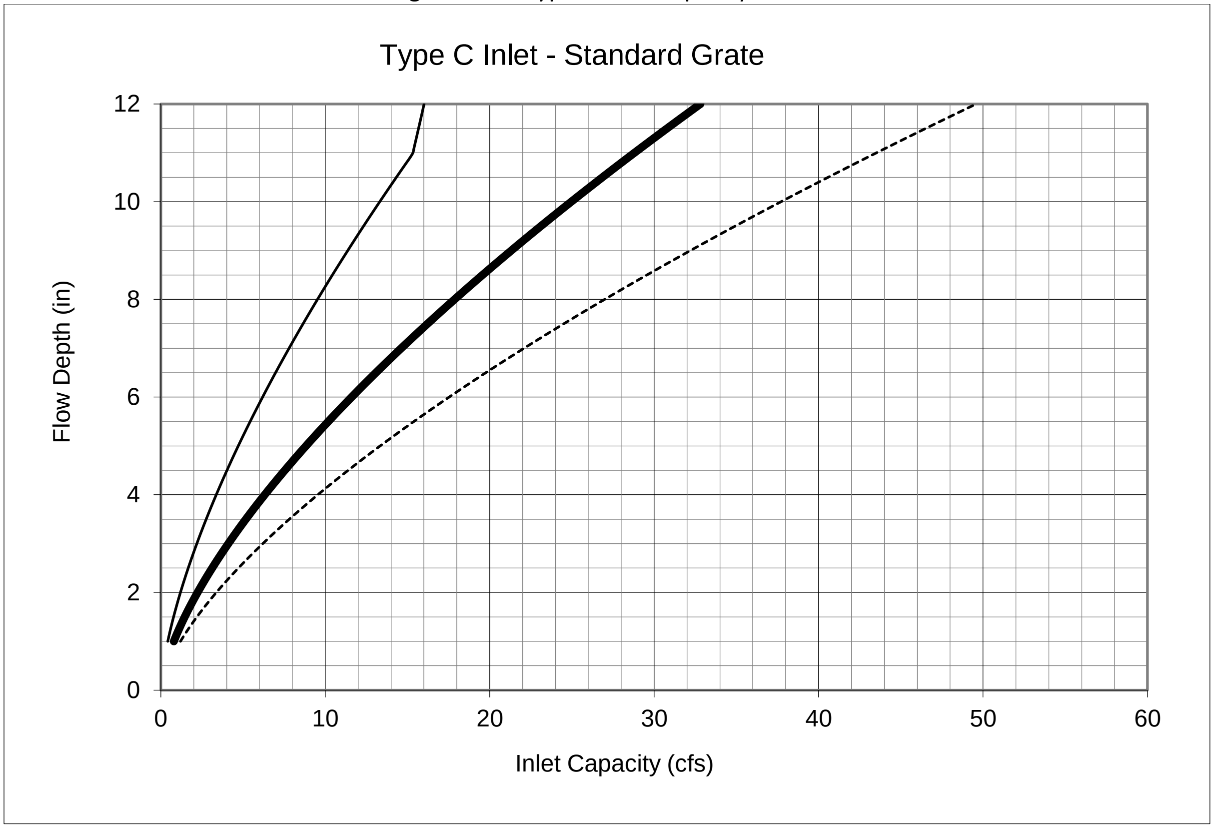
City of Evans, Colorado

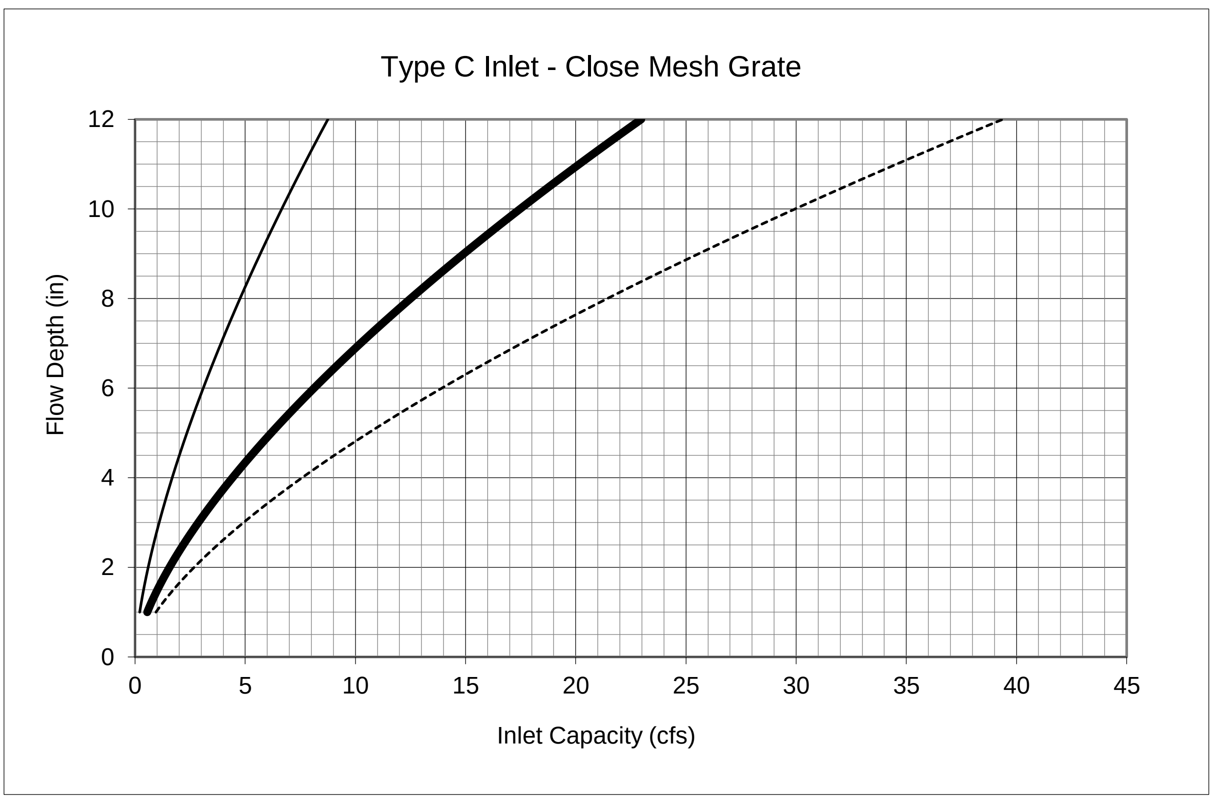
CITY OF EVANS DRAINAGE CRITERIA MANUAL

DENVER COMBINATION TYPE 16 INLET (SHEET 2 OF 2)

FIGURE 6.2.4

Figure 6.3.1 Type C Inlet Capacity Charts





SECTION 7 STORM DRAINS

7.1 Introduction

Storm drains are required when other parts of the drainage system, such as curb and gutter and roadside ditches, no longer have capacity to hold the runoff within the limits set by the criteria. The following design criteria are in additions to and clarifications of the requirements and recommendations set forth in the USDCM Volume 1 "Storm Sewers" chapter.

All storm drains within the City of Evans shall conform to the City of Evans construction specifications. Chosen materials may also require approval from CDOT. Elliptical and arched pipe should be used only when conditions prevent the use of circular pipes.

7.2 Hydraulic Design

Storm sewers shall be designed to convey the minor storm peaks. All hydraulic losses shall be considered in the computations. Computer programs such as FlowMaster, StormCAD, UD-Sewer, or HY8, can be utilized to complete the hydraulic calculations for the storm drain system.

For the final design report, the hydraulic grade line (HGL) and energy grade line (EGL) shall be calculated for each storm sewer system with supporting information included in the final drainage report. The design flow HGL and EGL shall be profiled on the final construction drawings. The energy grade line (EGL) for the design flow shall be a minimum of 6 inches below the final finished elevation of the manhole rims and inlet flowlines to prevent surcharging.

7.2.1 Manning "N"

The Manning's "n" values to be used in the calculations of storm sewer capacity are presented in the table 7.3.1 below.

TABLE 7.2.1 Pipe Material Manning's Roughness Coefficient "n"

PIPE MATERIAL	ROUGHNESS COEFFICIENT
Cast-iron, new	0.012
Concrete Pipe	0.013
Corrugated metal	0.024
Ductile iron	0.012
Polyethylene PE - Corrugated with smooth inner walls	0.009-0.015
Polyethylene PE - Corrugated with corrugated inner walls	0.018-0.025
Polyvinyl Chloride (PVC) - with smooth inner walls	0.009-0.011
Steel - smooth	0.012
Steel - Riveted	0.016
Clay - vitrified	0.014

7.2.2 Pipe Losses

The design guidelines, equations, and examples provided in the "Streets, Inlets, and Storm Sewers" chapters of Volume 1, USDCM should be used when calculating losses in pipes. In addition, the typical loss coefficients due to expansion and contraction can be found in Figure 7.2.1. The typical loss coefficients due to bends can be found in Figure 7.2.2.

7.3 Pipe Sizing and Clearance Criteria

The following Criteria is in addition to the City of Evans Construction specifications. Any variance of this criteria or the specifications must be approved by the City of Evans Public Works Engineering Department. The minimum allowable size for a storm sewer or culvert within a public right-of-way or public drainage easement are listed in Table 7.4.1. The minimum size of the lateral shall also be based on the water surface inside the inlet (the EGL shall be 6 inches below the invert flowline).

Table 7.3.1 Minimum Pipe Size

TYPE	MINIMUM (EQUIVALENT) PIPE SIZE	MINIMUM CROSS-SECTIONAL AREA
Lateral	15-Inch	1.22 SQ-FT
Main Trunk	18-Inch	1.44 SQ-FT

All minimum storm sewer depths shall be as defined by the pipe manufacturer to follow AASHTO HS-20 loading requirements. Cover shall be no less than 12 inches at any point along the pipe, unless additional structural measures are taken to protect the pipe.

The clearance between storm sewer and water main shall be greater than 12 inches. If clearance of less than 12 inches is necessary, a concrete encasement of the water line will be required. The minimum clearance between storm sewer and sanitary sewer shall be 18 inches. If less than 18 inches is necessary, the design shall be approved by the Director of Public Works. When a sanitary sewer lies above the storm sewer or within 18 inches below the storm sewer, the sanitary sewer shall have an impervious encasement or be constructed of structural sewer pipe for a minimum of 10 feet on each side of where the storm sewer crosses. Designer shall refer to the most recent version of the City of Evans Water and Sewer System specifications for additional details.

7.4 Manholes

Manholes or maintenance access ports shall be required at changes in size, direction, elevation, grade, or where there is a junction of two or more sewers. The maximum spacing between manholes and the required manhole diameter is outlined in Table 7.4.1.

Table 7.4.1 Manhole Size and Geometry

STORM DRAIN SIZE	MANHOLE DIAMETER	ALLOWABLE DISTANCE BETWEEN MANHOLES, (OR INLETS OR CLEANOUTS)	MINIMUM RADIUS OF PIPE CURVATURE*
15” to 18”	4	400 feet	-
21” to 36”	5	400 feet	-
42”	5	500 feet	-
48” to 54”	6	500 feet	28.5 feet
57” to 72”	CDOT Standard M-604-20 and -21	500 feet	32.0 feet
72” to 108”	CDOT Standard M-604-20 and -21	500 feet	38.0 feet

* Short radius bends shall not be used on sewer 42” Diameter or less

There are also losses due to flow through a manhole. Losses occur based on the angle of the pipes coming into and out of the manhole. See Figure 7.4.1 for additional details. Also, if there are multiple pipes coming into a manhole there will be additional losses. See Figure 7.4.2 for additional details.

7.5 Maintenance and Access

Maintenance and access easement widths shall be as follows:

Table 7.5.1 Required Easement Widths

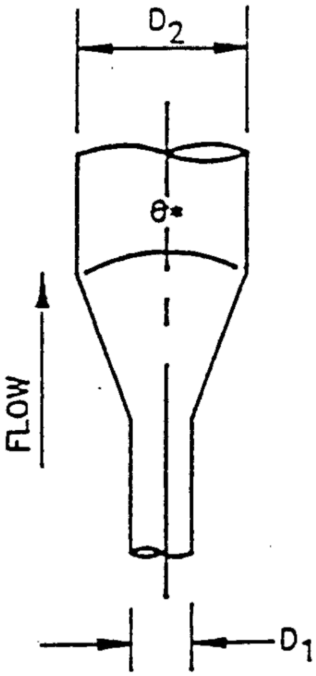
REQUIRED STORM SEWER MAINTENANCE AND ACCESS EASEMENTS	
STORM SEWER DIAMETER	**EASEMENT WIDTH**
Less than 36”	20 feet
Equal to or greater than 36”	25 feet (with sewer at the 1/3 point in the easement)

EXPANSION/CONTRACTION

(a) EXPANSION (K_e)

θ*	$\frac{D_2}{D_1}=3$	$\frac{D_2}{D_1}=1.5$
10	0.17	0.17
20	0.40	0.40
45	0.86	1.06
60	1.02	1.21
90	1.06	1.14
120	1.04	1.07
180	1.00	1.00

* THE ANGLE θ IS THE ANGLE IN DEGREES BETWEEN THE SIDES OF THE TAPERING SECTION



(b) PIPE ENTRANCE FROM RESERVOIR

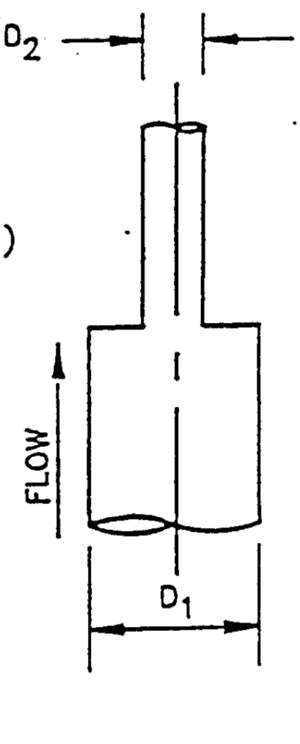
BELL-MOUTH $H_L=0.04\ \frac{V2}{2g}$

SQUARE EDGE $H_L=0.5\ \frac{V2}{2g}$

GROOVE END U/S FOR CONCRETE PIPE $H_L=0.2\ \frac{V2}{2g}$

(c) CONTRACTION (K_c)

$\frac{D_2}{D_1}$	K_c
0	0.5
0.4	0.4
0.6	0.3
0.8	0.1
1.0	0



City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

EXPANSION AND CONTRACTION PIPE LOSSES

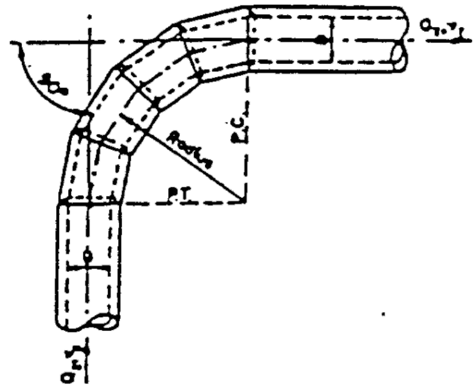
FIGURE 7.2.1

STORM SEWER ENERGY LOSS COEFFICIENT

(BENDS)

CASE I
CONDUIT ON 90° CURVES

NOTE: Head loss applied at P.C. for length

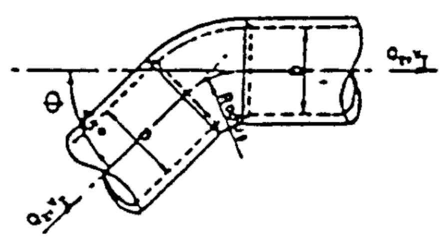


$$K_b = 0.25\sqrt{\frac{\theta}{90}}$$

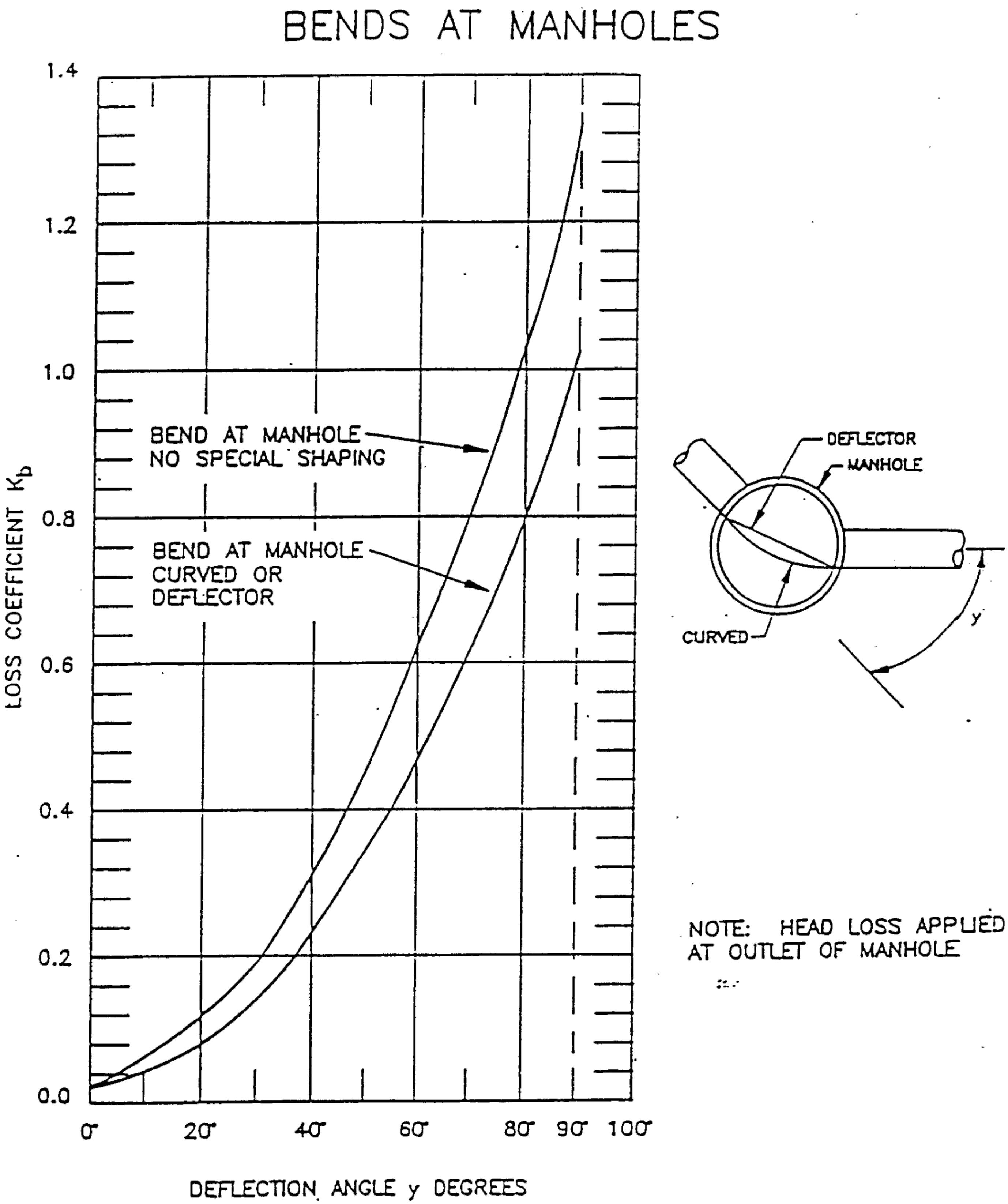
θ	K_b
90	0.25
60	0.20
45	0.18
30	0.14

CASE II
BENDS WHERE RADIUS IS EQUAL TO DIAMETER OF PIPE

NOTE: Head loss applied at begining of bend



θ° BEND	K_b
90	0.50
60	0.43
45	0.35
22-1/2	0.20

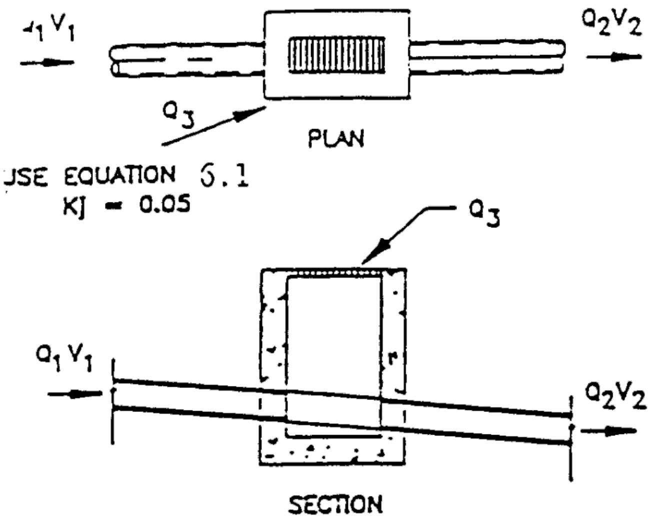


City of Evans, Colorado

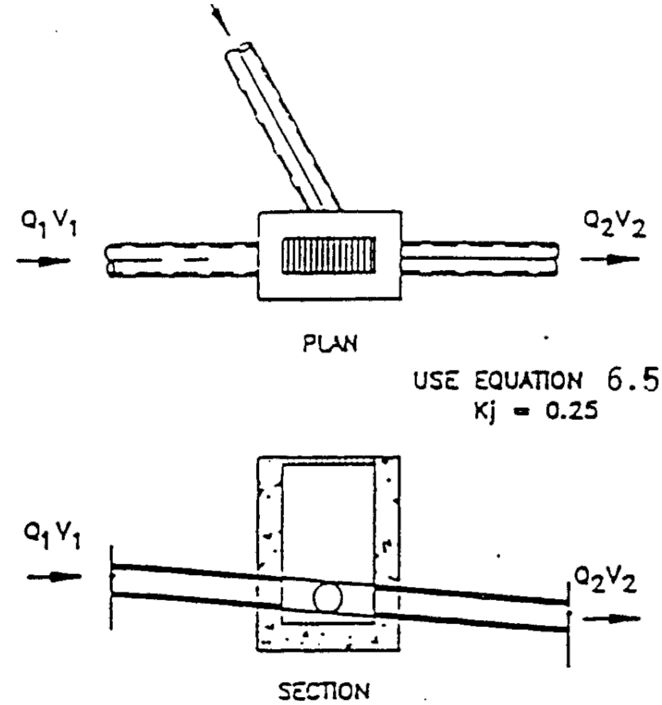
CITY OF EVANS DRAINAGE CRITERIA MANUAL

MANHOLE LOSSES DUE TO BENDS

FIGURE 7.4.1



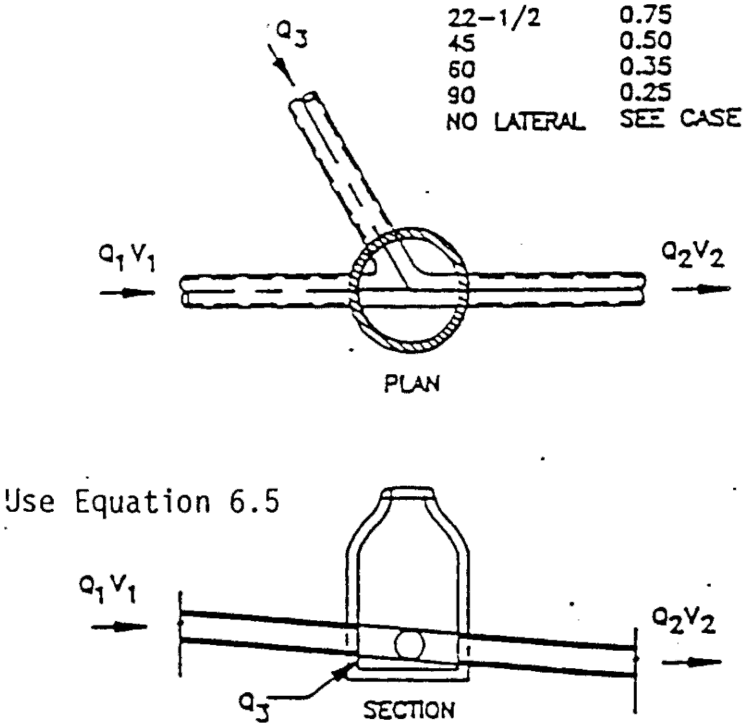
CASE I
INLET OR STRAIGHT THROUGH
MANHOLE ON MAIN LINE



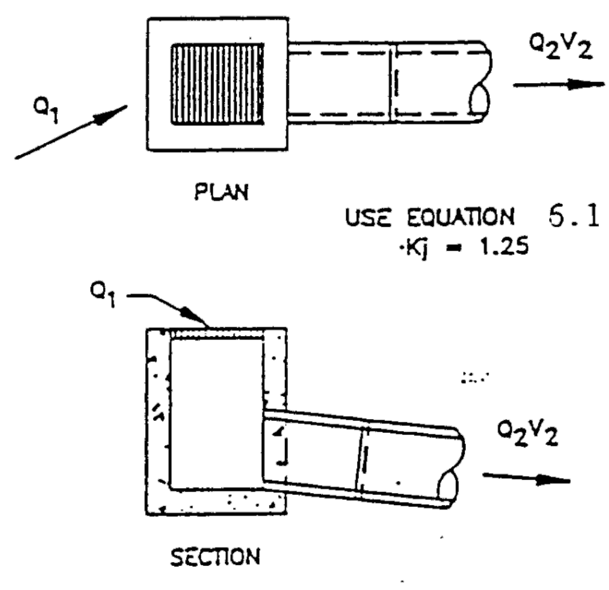
CASE II
INLET ON MAIN LINE
WITH BRANCH LATERAL

CASE III

Ø	Kj
22-1/2	0.75
45	0.50
60	0.35
90	0.25
NO LATERAL	SEE CASE I



CASE III
MANHOLE ON MAIN LINE
WITH Ø BRANCH LATERAL



CASE IV
INLET OR MANHOLE AT
BEGINNING OF LINE

City of Evans, Colorado

CITY OF EVANS DRAINAGE CRITERIA MANUAL

MANHOLE LOSSES DUE TO MULTIPLE PIPES

FIGURE 7.4.2

SECTION 8 OPEN CHANNELS

8.1 Introduction and Definitions

The information presented herein shall be considered a minimum criteria for the hydraulic analysis and design of open channels. Following are some of the pertinent definitions that apply to channel design.

Major Drainageway – a channel with a flow rate greater than 20 cfs
Minor Drainageway – a channel with a flow rate less than 20 cfs
Thalweg - a line drawn to join the lowest points along the length of a channel bottom or streambed.

The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 1 "Open Channels" chapter.

8.2 Hydraulic Modeling

Computer modeling with the use of programs such as HEC-RAS is recommended for the hydraulic analysis of channels. The "Open Channels" chapter in USDCM presents guidelines to calculating channel hydraulics and further describes Manning's equation. The Manning's "n" values to be used in the calculations of open channels are presented in Table 8.2.1 below.

TABLE 8.2.1 Manning's "n" for Open Channels

SURFACE MATERIAL	MANNING'S ROUGHNESS COEFFICIENT "N"
Concrete - steel forms	0.011
Concrete (Cement) – trowel finished	0.012
Concrete (Cement) – broom finished	0.016
Concrete - wooden forms	0.015
Earth, rough	0.035
Earth channel - clean	0.022
Earth channel – gravelly	0.025
Earth channel - weedy	0.030
Earth channel - stony, cobbles	0.035
Floodplains - pasture, farmland	0.035
Floodplains - light brush	0.050
Floodplains - heavy brush	0.075
Floodplains - trees	0.100
Gravel, firm	0.023
Gravel, riprap 1"	0.033
Natural streams - clean and straight	0.030
Natural streams - major rivers	0.035
Natural streams - sluggish with deep pools	0.040
Natural streams - stony	0.050
Natural streams - weedy	0.045
Natural channels - very poor condition	0.060
Straw with net	0.033
Synthetic mat	0.025

8.3 Channel Design Criteria

All major drainageways shall be designed to contain the 100-year storm. All minor drainageways shall analyze the 100-year storm and if unable to contain it, show that other criteria such as street flow are met. Table 8.3.1 lists the design storm criteria necessary to design minor drainageways through specific parcels for the different land use.

TABLE 8.3.1 Minor Channel Storm Frequencies

LAND USE	DESIGN STORM FREQUENCY	CHECK STORM FREQUENCY
Residential	5-year	100-year shall be contained or controlled through property following all other criteria with this manual.
Open space	5-year	
Commercial	10-year	
Public buildings	10-year	
Industrial	10-year	
Natural drainages	25-year	

Table 8.3.2 summarizes some of the general design guidelines for channel lining. Please refer to the USDCM for additional channel sizing information.

TABLE 8.3.2 Channel Lining Criteria

DESIGN ITEM	CRITERIA FOR VARIOUS TYPES OF CHANNEL LINING			
	NATURAL CHANNEL	GRASS[6]	RIPRAP[9]	CONCRETE[7, 8]
Maximum 100-year velocity	6.0 ft/sec	5.0 -7.0 ft/sec[1]	16.0 ft/sec	18.0 ft/sec
Minimum Manning's n – stability check	0.030	0.020	0.03	0.011
Minimum Manning's n – capacity check	0.060	0.035	0.04	0.013
Maximum Froude number	0.8	0.5 / 0.8 [1]	0.8	N/A
Maximum depth outside low-flow zone	5.0 ft	5.0 ft	N/A	N/A
Maximum channel longitudinal slope	0.6%	0.6%	varies	N/A
Maximum side slope[5]	4H:1V	4H:1V	2.5H:1V	1.5H:1V
Minimum centerline radius for a bend	2 x top width			
Minimum freeboard[2]	1.0 ft [3,4]	1.0 ft [3,4]	2.0 ft [3]	2.0 ft [3]

Portions of this table were obtained from USDCM Volume 1, Table 8-1 & Table 8-2

1. Maximum Froude number for erosive soils is 0.5 and for erosion resistant soils it is 0.8. Maximum velocity for erosive soils is 5.0 fps and for erosion resistant soils is 7.0 fps.
2. Add super-elevation to the normal water surface to set freeboard at bends.
3. Suggested freeboard is 2.0 feet to the lowest adjacent habitable structure's lowest floor.
4. Natural and Grass-lined open channels conveying less than 50 cfs may reduce the minimum 1.0-foot freeboard requirement to the freeboard required to convey 1.33 times the 100-year design flow. The reduced freeboard may only occur if a 1.0-foot minimum freeboard is not physically possible and a variance request is submitted.
5. Side slopes may be steeper if designed as a structurally reinforced wall to withstand soil and groundwater forces. Maintenance accessibility must be considered on any slope steeper than 3H:1V. The design engineer should address how the channels will be maintained since it may not be safe to mow on slopes that are greater than 4H:1V.
6. Requirements vary based on the type of soil. Refer to the UDFCD criteria for additional details.
7. The use of concrete and grouted riprap channels is discouraged due to maintenance concerns, minimum flood storage in the channel and other issues. The City's goal is to improve the flood storage, promote infiltration and provide water quality.
8. The requirements for grouted riprap are very similar to concrete.
9. See additional details in the USDCM, Volume 1 Chapter 8 for sizing of riprap in channels.

Spreadsheets and programs provided by UDFCD will be the standard to which channel design will be held. The designer is encouraged to use these programs and can download them from the UDFCD website under the download tab.

8.4 Channel Types

8.4.1 Natural Channels

Natural channels for the native high prairies of Colorado are grass-lined with stands of cottonwood trees, willows, and other native brush. Within the City limits natural channels are rare, but can be replicated in areas to regain the natural look of the high prairies.

Additional criteria for natural channels are as follows:

A. If a natural channel is found to have supercritical flows, a drop structures or other appropriate energy dissipation structures must be designed to create a stabilized channel.

B. Segments which have a calculated Froude number greater than 0.8 for the 100-year storm runoff shall be protected from erosion.

C. A channel stability analysis shall be completed to determine the impact of urbanization on the bank stabilization.

8.4.2 Grass Lined Channels

Grass lined channels within the City of Evans are usually, but not limited to, grassy ditches along streets. These pleasant urban drainageways convey storm flows through properties and most often are dry or have a very small low flow Descriptions, examples and cross sections can be found in USDCM Volume 1 “Open Channels” chapter.

Additional criteria for grass lined channels are as follows:

A. The City of Evans and its Urban Growth Area have predominantly sandy soils. The minimum velocity shall be 2.0 fps for the minor storm runoff.

8.4.3 Riprap Lined Channels

Riprap lined channels are not encouraged due to the difficulty to maintain them. Although newer designs of soil riprap and buried riprap channels are acceptable. If a channel configuration does not allow for a grass-lined channel to be built steeper more protected riprap channel can be designed. Reinforcing the low flow area with riprap in advised for those channels that have the potential to erode.

Additional criteria for riprap lined channels are as follow:

A. If the project constraints dictate the use of riprap lining for a major drainage way, then the Design Engineer shall present the concept, with justification, to the City for consideration of a variance from these Criteria. The design of rock-lined channels shall be in accordance with the most current revision of the USDCM, Volume 1, Chapter, "Open Channels”.
B. The riprap shall be designed and constructed in accordance with Chapter 8 “Open Channels” of USDCM.

8.4.4 Concrete Lined Channels

Concrete lined channels have a very urban look and shall be used only as needed in locations that have been approved by the City. Concrete lining of low flow channel bottoms and short steep run downs can be a desirable design application.

Additional criteria for concrete lined channels are as follow:

A. The surface of the concrete lining shall be a wood float finish. Excessive working or wetting of the finish shall be avoided.

8.4.5 Other Lining Types

In areas of existing development where the constraints prohibit grass lined channels, the use of synthetic fabrics and slope revetment mats may be used with approval by the City.

Design criteria shall follow grass-lined channels except as specified below:

A. A turf reinforcement mat (TRM), or similar material, in combination with grass lining may be acceptable in some situations. A permanent irrigation system must be included to help maintain the vegetation.
B. An articulated block may also be an acceptable option. All manufacturers requirements must be followed.
C. The Froude Number shall be less than 0.8.
D. The centerline curvature shall have a minimum radius twice the top width of the design flow but not less than 100 feet.
E. A Manning's "n" value range shall be determined using the manufacturer's data. The high value shall be used to determine depth/capacity requirements. The low value shall be used to determine the Froude Number and velocity restrictions.
F. Other alternatives may be used with approval from the Director of Public Works.

8.5 Wetlands

The selection of a particular channel can be based on many factors, one of which may involve protection or mitigation of wetlands. Section 404 requirements for the Clean Water Act may have stipulations on a channel section due to wetlands. The design engineer should contact the Corps of Engineers for additional information. Designing a channel with the presence of wetlands should follow the latest revision of the USDCM.

8.6 Roadside Ditches

The criteria for the design of roadside ditches are similar to the criteria for grass-lined channels with modification for the special purpose of minor storm drainage. Refer to Figure 8.6.1:

Additional criteria for roadside ditches are as follows:

A. Roadside ditches shall have adequate capacity for the minor storm runoff peaks. During the minor storm runoff event, encroachment shall not extend beyond the street right-of-way. Where the storm runoff exceeds the capacity of the ditch, a storm drain system shall be required.

B. The maximum velocity for the minor storm flood peak shall not exceed 5.0 feet per second.

C. The slope shall be limited by the average velocity of the minor storm flood peaks. Check drops may be required where street slopes are in excess of 2%. Maximum permissible slope is 5%.

D. Freeboard shall be equal to the velocity head, or a minimum of six inches.

E. Roadside ditches usually run parallel to the road and can follow the curve of a roadway with a minimum radius of curvature shall be 25 feet. If a variance is required, the Director of Public Works will need to provide approval. It is up to the Engineer to show why the 25-foot radius of curvature cannot be met.

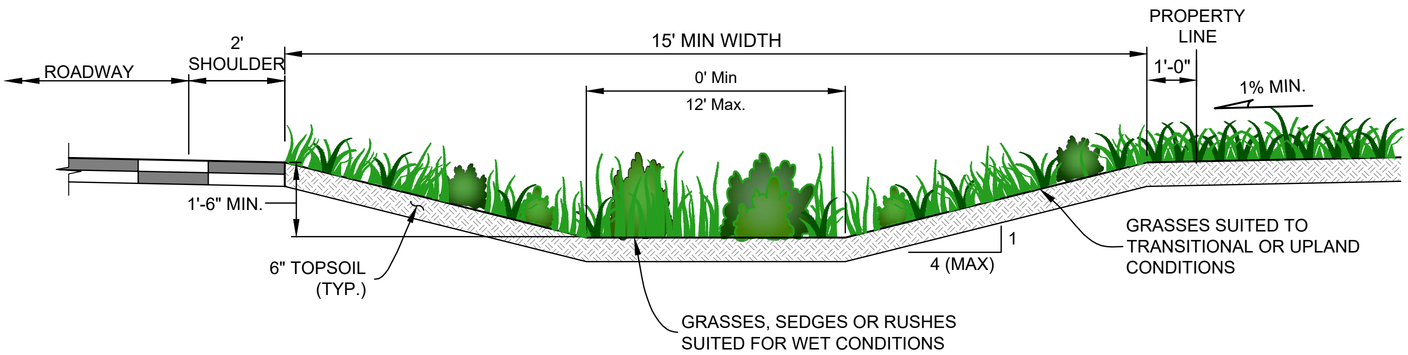
F. The capacity of roadside ditches for major drainage flow is restricted by the maximum flow depth allowed at the street gutter or edge of pavement. The flow spread should not inundate the ground line of residential dwellings, or public, commercial, or industrial buildings. Criteria in Table 5.2.1 for street capacities during major storms shall be followed.

8.7 Maintenance and Access Easements

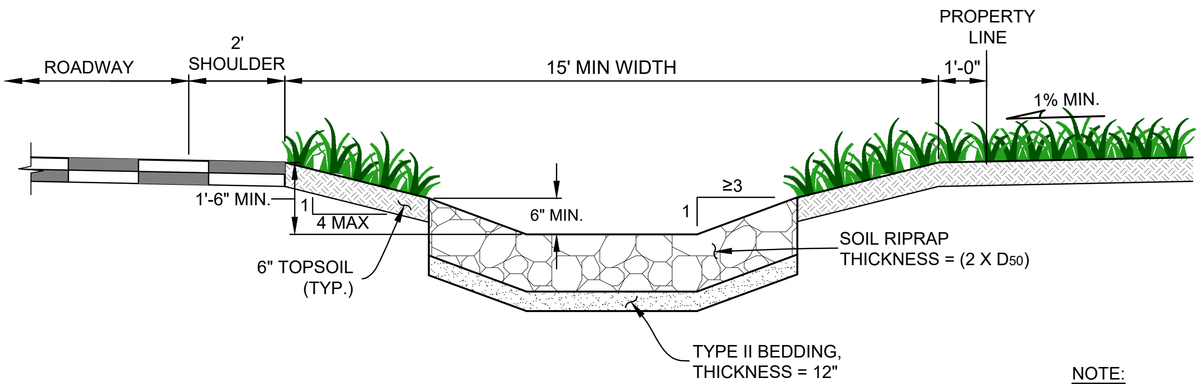
Minimum maintenance and access easements widths are shown in the following table:

Table 8.7.1 Minimum Channel Easement Widths

MINIMUM CHANNEL EASEMENT WIDTHS	
CHANNEL SIZE	**TOTAL ROW OR EASEMENT WIDTH**
Q (100) < 20 cfs	15 feet
Q (100) < 100 cfs	25 feet
Q (100) < 100 cfs	Freeboard+ 12-foot-wide access road(s) Access may be required on both sides of the channel.

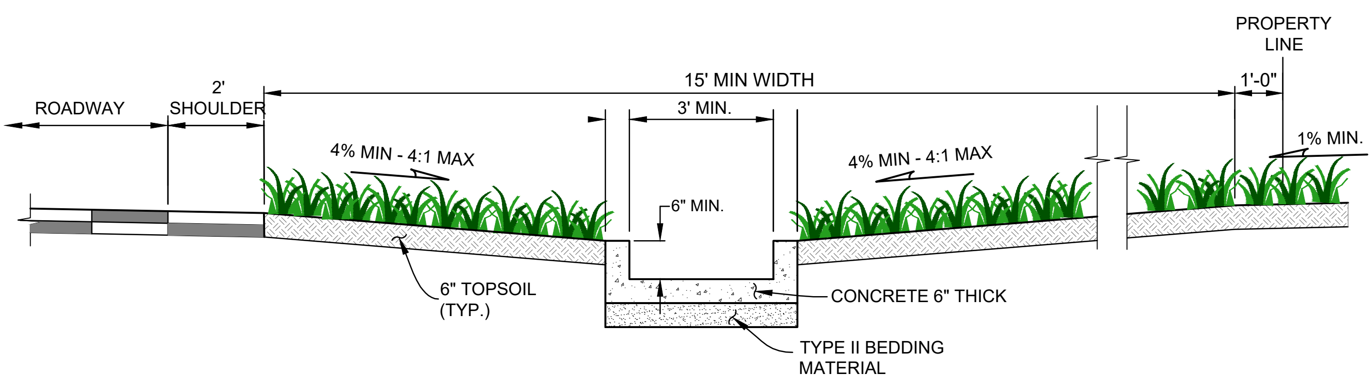


GRASS LINED



NOTE:
SOIL RIPRAP SHALL BE SIZED BY ENGINEER BASED ON ACTUAL HYDRAULIC CONDITIONS.

RIPRAP LINED



CONCRETE LINED

NOTES:
1. DITCH TYPE MUST BE APPROVED BY THE CITY PRIOR TO USE.
2. FOR STEEP LONGITUDINAL SLOPES, CHECK STRUCTURES (2' MAX HEIGHT) MAY BE REQUIRED.
3. STREET CROSS SECTION MAY INCLUDE CURB AND GUTTER OR OTHER SHOULDER WORK. SEE ROAD CROSS SECTION STANDARDS.

City of Evans, Colorado

ROADSIDE DITCH SECTIONS

FIGURE 8.6.1

SECTION 9 HYDRAULIC STRUCTURES

9.1 Introduction

Hydraulic structures control the energy of water and minimize damage it may cause. These structures are grade control structures, rock riprap revetment, energy dissipators, bridges, and irrigation ditch crossings. The energy associated with flowing water has the potential to erode and create damage to infrastructure. The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 2 "Hydraulic Structures" chapter.

9.2 Grade Control Structures

Reducing the channel invert slope is a common method to reduce the flow velocity in an open channel. Designing a grade control structure along a channel can achieve the grade change necessary while still maintaining a non-erosive channel slope.

Grade control structures are commonly classified as either drop structures or check structures. Drop structures may be designed and constructed to span the full 100-year channel or can be constructed with a more limited extent by only protecting the low flow portion of the drainageway. Check structures typically consist of a vertical concrete wall that traverses the entire waterway and are designed to protect the drainageway from future degradation. Check structures are frequently used in natural drainageway settings, where the intent is to protect and preserve the natural appearance of the drainageway while providing some protection against future degradation with minimal disturbance. Design criteria for grade control structures shall be in accordance with the USDCM, Volume 2, "Hydraulic Structures."

9.3 Pipe Outlet Protection

Pipe outlets represent a persistent erosion problem. Concentrated discharge and uncontrolled turbulence can erode a channel if there is not a proper transition to the open channel. Appropriate pipe end treatment and downstream erosion protection at pipe outfalls is critical to protect the structural integrity of the pipe and to maintain the stability of the adjacent slope. The design of energy dissipators and outlet protection shall follow the USDCM, Volume 2, "Hydraulic Structure" section on Pipe Outfalls and Rundowns.

Energy dissipation can be addressed with the following outlet treatments:

A. Riprap aprons
B. Low tailwater basin
C. Boulder rundowns – grouted or non-grouted
D. Impact basins

For reference, a standard detail for the low tailwater basin is included at the end of this section in Figure 9.3.1.

9.4 Channelized Rundowns

A channel rundown is used to convey storm runoff from the top of an embankment, culvert outlet, street or parking lot to the bottom of a channel or storage facility. The purpose of the structure is to minimize channelized erosion from concentrated flows, although they can easily fail and become a maintenance burden. The use of a level spreader such as a grass buffer (discussed in USDCM Volume 3, "Treatment BMPs") is an alternative that can distribute flows and convey it down the slope to the open channel. In the case when a rundown is the only viable option, then the following design criteria should be used.

9.4.1 Design Flow

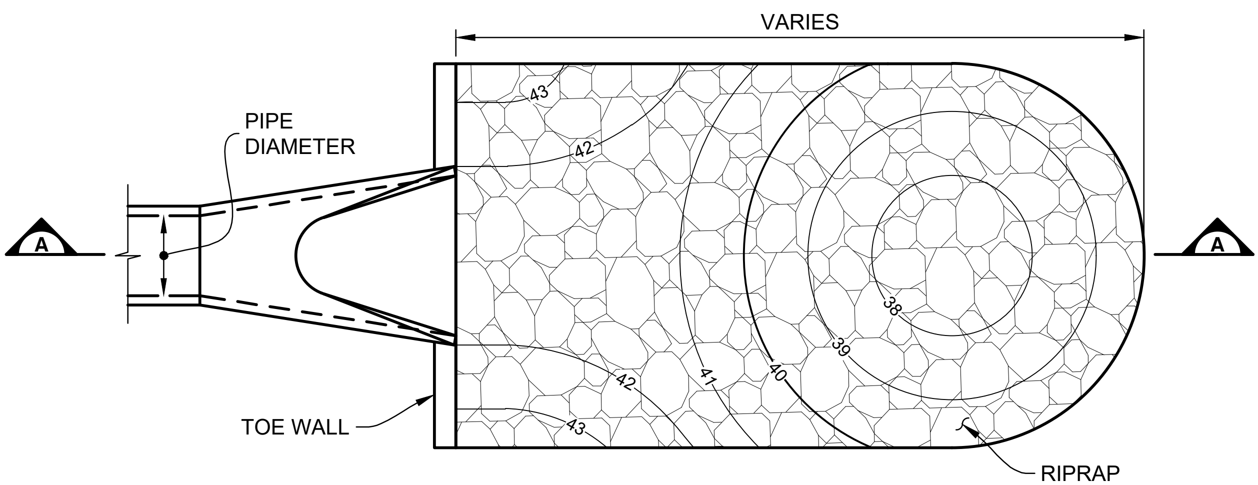
The rundown should be designed to carry the full design flow of the tributary area upstream (see Volume 1, "Runoff" chapter), or 1 cfs (assuming critical depth) with freeboard, whichever is greater.

9.4.2 Cross Section

The rundown should be constructed with a concrete (grout) invert with grouted boulder edge treatment. A minimum of 1 foot of freeboard should be provided from the calculated design flow depth to the top of the grouted boulders. Riprap and soil riprap rundowns frequently fail and are highly discouraged.

9.5 Irrigation Ditch Crossings

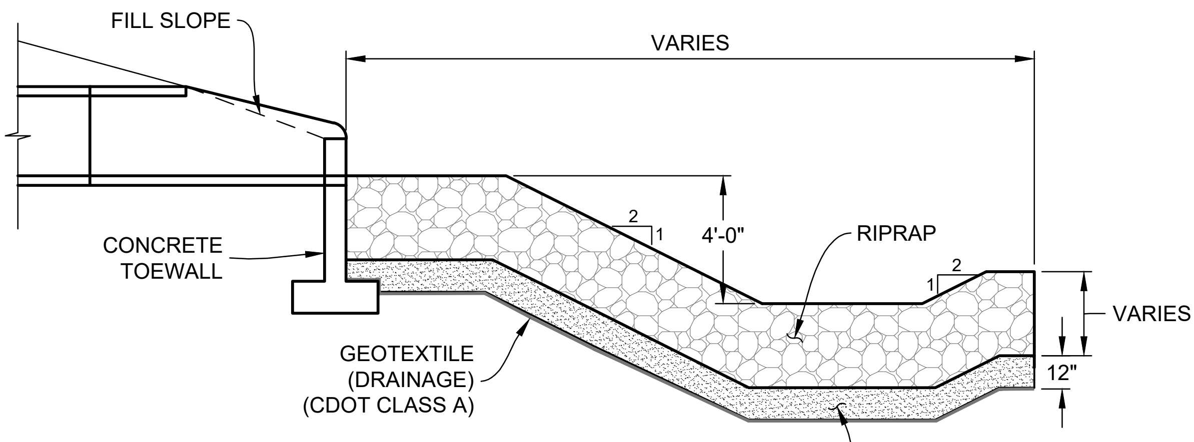
Any drainage plan in which surface drainage is in the vicinity of or crosses irrigation facilities shall have the plans approved by the controlling ditch company prior to acceptance by the City.



LOW TAILWATER RIPRAP BASIN

SCALE: 1" = 3'-0"

NOTE:
SEE URBAN DRAINAGE CRITERIA FOR ADDITIONAL INFORMATION ON SIZING.



SECTION A

SCALE: 1" = 3'-0"

CITY OF EVANS DRAINAGE CRITERIA MANUAL

LOW TAILWATER BASIN

FIGURE 9.3.1

SECTION 10 CULVERTS

10.1 Introduction

A culvert is a conduit for the stormwater to pass under a roadway, railroad, canal, or other embankment. They are usually round pipe or square concrete boxes, but can be a variety of shapes and sizes. The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 2 "Culverts and Bridges" chapter.

10.2 Culvert Hydraulics

The basic procedures and requirements to be used for the hydraulic evaluation of culverts shall be in accordance with USDCM Volume 2, Chapter 11, "Culverts and Bridges", in addition to the following criteria:

A. Manning's "n" roughness coefficients can be found on Table 7.3.1 in this document or Table 11-1 in USDCM.
B. Entrance Loss coefficients can be found on Table 11-2 in USDCM.
C. Headwater to Depth ratio shall not exceed the values in Table 10.2.1, but may be limited by the roadway or embankment elevation.
D. A minimum outlet velocity of 3 feet per second is required.
E. A maximum outlet velocity of 12 feet per second is recommended with erosion protection. Refer to Section 9.3 for protection requirements at culvert outlets.

Table 10.2.1 Headwater to Depth Ratio

RANGE OF DIAMETER OR HEIGHT OR RISE, INCHES	MAXIMUM HW/D
Less than 36 in.	2.0
36 in. to 60 in.	1.7
Larger than 60 in. but less than 84 in.	1.5
84 in. to less than 120 in.	1.2
120 in. or larger	1.0

10.3 Culvert Sizing and Design

When designing a culvert, the designer not only has to consider the hydraulic convenience of the culvert but also criteria associated with the roadway. Sizing of a culvert is dependent upon the street classification (local, collector, arterial, etc.) and the allowed street overtopping.

The designer is encouraged to use the nomographs, spreadsheets and programs provided by the UDFCD to assist in designing culverts. As an alternative, the industry standard software may be used. The City reserves the right to verify designs using the UDFCD programs and spreadsheets. The most current version of the UDFCD spreadsheets can be downloaded from the UDFCD website.

Some graphs are used which can assist the designer in calculating the hydraulic properties of circular and horizontal elliptical pipes. These are included in Figures 10.3.1 and 10.3.2 respectively. In addition, the designer shall consider inlet and outlet control of the pipes being designed.

10.3.1 Overtopping

A. The allowable street overtopping is set forth in Section 5.
B. No street overtopping shall occur for any street classification at a minimum 10-year frequency design storm event.
C. The 100-year runoff for future developed conditions must be used.
D. The culvert must be sized to convey the flow which decreases the roadway overtopping to allow the overtopping criteria to be met. This may require a culvert size bigger than the 10-year storm event, but shall not be less than the required size for the 10-year event.

10.3.2 Flooding

The culvert design shall not adversely impact a current 100-year floodplain, and the City may require the culvert design to improve the current floodplain limits.

10.3.3 Safety Grates

The USDCM recommends that safety grated be added to all culverts when any of the following conditions are or will not be true:

- It is not possible to “see daylight” from one end of the culvert or the other,
- The culvert is less than 42 inches in diameter, or
- Conditions within in the culvert (bends, obstructions, vertical drops) or at the outlet are likely to trap or injure a person

Several fatalities have been attributed to the lack of a safety grate on small diameter and long culverts. During the design process, it is important to identify the safety hazards and then take reasonable steps to minimize them while providing adequate flow capacity. See the USDCM, Volume 2, Chapter 11, Section 5.3 for additional considerations.

10.3.4 Inlet and Outlet Protection

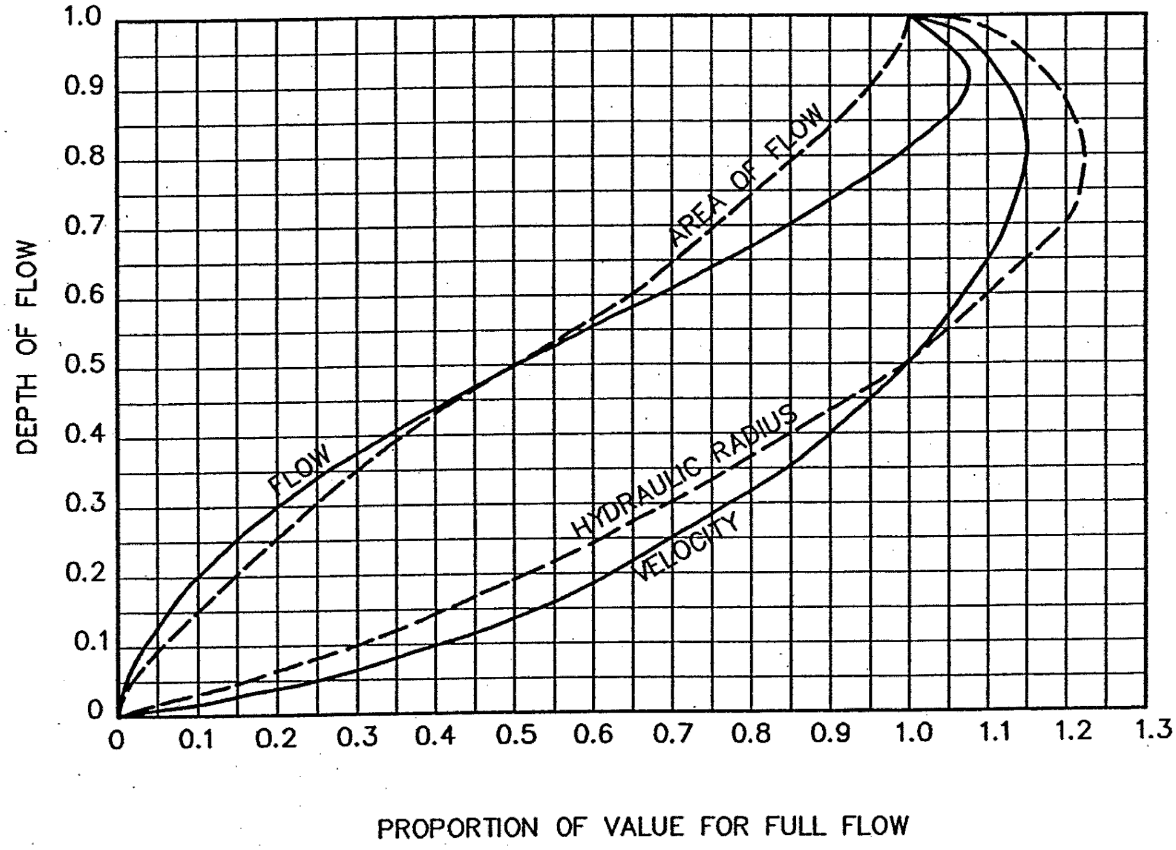
A. Culverts shall be designed with headwalls and wingwalls or with flared-end sections.
B. Approved outlet protection is required to prevent erosion and scour as specified in Section 9 of this document. Inlet protection may also be required if velocities are erosive.
C. If debris or safety is a concern, inlet protection and/or trash racks may be required by the City. The USDCM discusses design consideration in Section 5.2 of Volume 2, Chapter 11.

10.3.5 Structural Design

A. All culverts must be installed with a minimum of 1-foot of cover, unless special design for structural integrity is presented and approved by the City.
B. As a minimum loading, all culverts shall be designed to withstand an HS-20 loading (unless designated otherwise by the City) in accordance with the design procedures of AASHTO, "Standard Specifications for Highway Bridges," and with the pipe manufacturers' recommendations.

10.4 Bridges

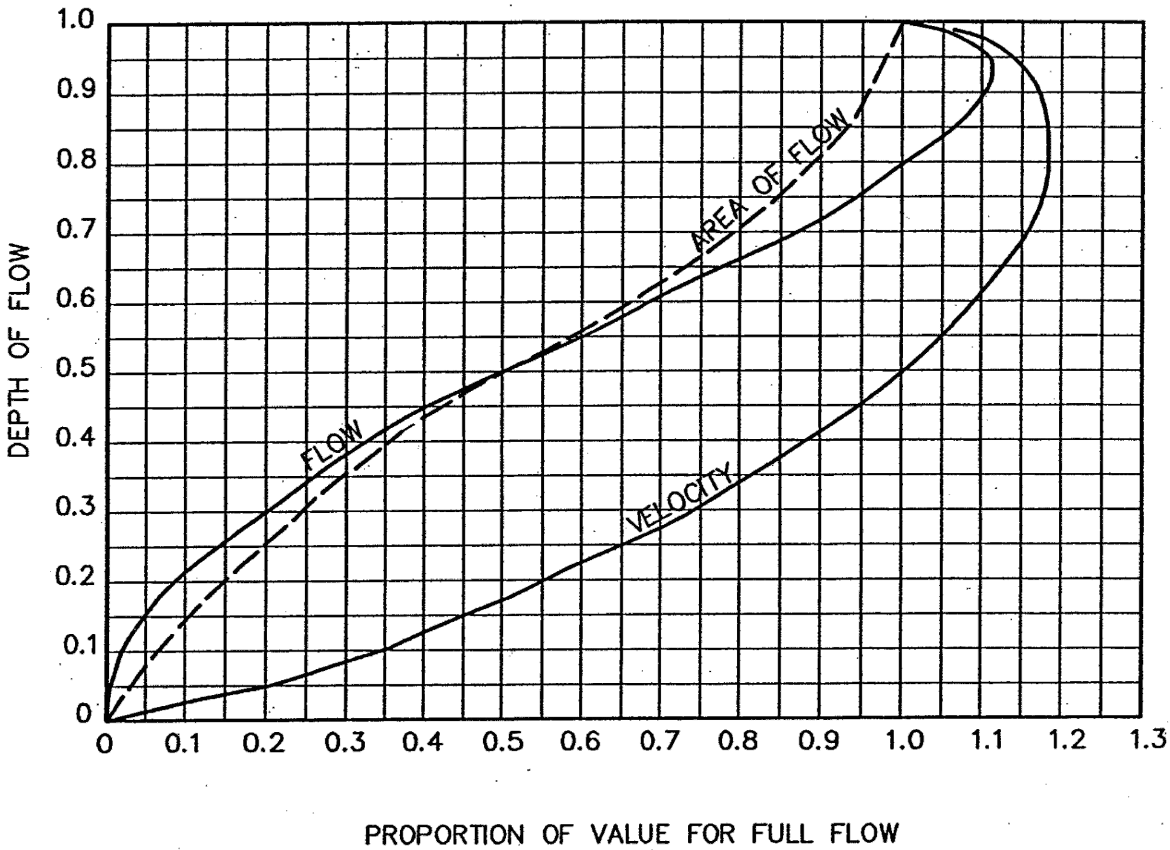
Design of bridges within the City shall be in accordance with the USDCM, Volume 2, "Culverts and Bridges." The design capacity of the bridge shall be follow the methods presented in this section of the USDCM for culverts. Overtopping of a bridge during the 100-year storm event is not allowed.
Figure 10.3.1 Hydraulic Properties of Circular Pipes



City of Evans, Colorado

HYDRAULIC PROPERTIES OF CIRCULAR PIPES

FIGURE 10.3.1



City of Evans, Colorado

HYDRAULIC PROPERTIES OF HORIZONTAL ELLIPTICAL PIPES

FIGURE 10.3.2

SECTION 11 STORAGE/DETENTION

11.1 Introduction

Detention facilities captures excess runoff due to the increased basin imperviousness and releases it at a rate mimicking the runoff volumes of the basin prior to development. The intent is to protect downstream property and infrastructure from excess (or influx) of stormwater runoff.

Detention is intended to reduce the flooding and stream degradation impacts associated with urban development by controlling peak flows in the stream for a range of events. Roofs, streets, parking lots, sidewalks, and other impervious surfaces increase peak flows, frequency of runoff and total volume storm runoff when compared to pre-development conditions. This increase is most pronounced for the smaller, more frequent storms and can result in stream degradation and water quality impacts as well as flooding during the large events.

Criteria for stormwater detention design has evolved from a focus on the minor and major events to an approach which better controls peak flows for a wide range of events. In the interest of stream stability, specific focus should be placed on frequent events. Incorporating a slow release of the water quality capture volume (WQCV) helps to address very frequent urban runoff events; however, it is also important to extend the volume of water attenuated to capture the range of flows that transport the most bed load in the receiving stream. This range of flows depends on reach-specific characteristics but is typically between the annual event and the 5-year peak flow rate. Runoff events in this range can produce profound geomorphic changes in ephemeral, intermittent and perennial streams resulting in severe erosion, loss of riparian habitat, and water quality degradation.

The following design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 2 “Storage” chapter. Volume 3 “Treatment BMPs” has examples and criteria that is also applicable to detention.

Refer to Section 12 – Stormwater Quality - for guidelines to incorporate water quality considerations within the design and construction of detention ponds.

11.2 Storage Requirements

On site detention is required for all proposed residential and commercial developments unless specifically waived by the City of Evans. Examples of when the detention requirements may be waived are:

- development on the site decreases the percentage of impervious area already present
- the site is adjacent to a major outfall (river) and runoff will not influence it’s time to peak or adversely impact downstream facilities
- the latter phase of a subdivision is submitted and the previous phases have already met the detention requirements for the entire site

Detention ponds cannot be located in the FEMA mapped 100-year floodplain.

Off-site flows cannot be routed through the detention pond outlet. They must be routed around the site.

Whenever an approved master plan recommends detention sites and release rates or onsite detention storage and release rates, the final design of the project must match that presented in the master plan.

Detention ponds shall be sized to store the stormwater runoff generated by the 100-year, one-hour storm event from the fully developed site and to release the stormwater at a rate not to exceed the pre-development five-year, one-hour storm event with an imperviousness of 2% or less.

Detention ponds accommodate water quality capture (WQCV) volume in the design. WQCV shall be considered to be a portion of the total 100-year detention pond volume. Generally, a 40-hour drain time is to be used in the water quality capture volume calculations depending on the specific facility being designed, and fully drain within 72 hours. A detention pond that does not drain in less than 72 hours, can cause injury to water rights, and is in violation of State or Federal law.

11.2.1 Parking Lot Detention

The maximum allowable depth of ponding for parking lot detention is 12 inches for the 100-year flood and 6 inches for the 5-year storm.

The City recommends two different options for the outlet of a parking lot detention pond: a drop inlet or a weir control outlet. In the case of the drop inlet, all storm sewer criteria will apply. If flow is being controlled with an orifice plate, the opening shall have a minimum diameter of 3 inches.

All parking lot detention areas shall post a minimum of two signs identifying the detention pond area, warning of periodic flooding, and noting the potential range of water depth.

11.2.2 Underground Detention

Underground detention facilities shall be constructed of corrugated aluminum pipe or reinforced concrete pipe with a minimum pipe diameter of 36 inches. See Figure 11.2.1 for an example underground detention design.

Pipe segments shall be sufficient in number, diameter, and length to provide the required minimum storage volume for the 100-year design. Above ground detention or parking lot detention can be used in conjunction with underground detention as long as the minor design storm runoff volume can be stored in the underground pipes. The outlet pipe shall have a minimum diameter of 15 inches and outlet into the standard manhole or open drainageway.

An oil/sediment separator shall be required for the water quality capture volume requirement for all underground detention facilities. It shall be installed underground as part of the detention facility, and be structurally designed to withstand a HS-20 traffic loading (minimum). It shall have one or more access points from the surface to be adequately maintained.

The oil/sediment separator shall remove oil and sediment from frequent runoff events, and shall treat a minimum of 75 percent of the annual runoff volume, while capable of removing up to 80 percent of the total suspended sediment load (TSS) and greater than 90 percent of the floatable free oil. The separator shall have the ability of trapping silt and clay size particles in addition to large particles and local TSS load reduction requirements.

Permanent buildings or structures shall not be placed above underground detention facilities.

11.3 Design Criteria

The detention pond shall include a trickle channel for low flow conditions. The trickle channel shall meet the requirements for the trickle channel of a grass lined open channel. The minimum bottom slope shall be 0.5 percent, measured perpendicular to the trickle channel. See section 8.4 “Channel Types” in this document.

The side slope of detention facilities shall be no greater than 4H:1V for earthen embankments. All earthen embankments shall be revegetated with grass or covered with soil riprap. Soil riprap covered embankments may have a maximum slope of 3H:1V. For embankments greater than 5 feet in height, the side slope shall be such to maintain slope stability.

All new outlet works should be sized using the latest UDFCD criteria. At the time that this criteria was prepared, Full Spectrum detention is the preferred alternative. The outlet pipe must contain a minimum of two concrete cutoff walls embedded a minimum of 18 inches into undisturbed earthen soil. The cutoff walls must be a minimum of 8 inches thick. The outlet pipe bedding material must consist of native earthen soil, not granular bedding material, to at least the first downstream manhole or daylight point.

Each detention pond shall contain an emergency spillway capable of conveying the peak 100-year storm discharge draining into the detention pond. The invert of the emergency spillway must be equal to or above the 100-year water surface elevation. The depth of flow out of the emergency spillway shall be less than 6 inches. The spillway must have effective erosion protection. In order to protect the emergency spillway from catastrophic erosion failure, buried riprap shall be placed from the emergency spillway downhill to the embankment toe of slope and covered with 6 inches of topsoil. The riprap must be sized at the time of final engineering design. Grouting of the riprap may be required.

In order to prevent damage to publicly-owned infrastructure (roads, roadside ditches, etc.), a concrete cutoff wall, 8 inches thick and 3 feet deep, and extending a minimum of 5 feet into the embankment on each side of the emergency spillway opening, is required on all detention ponds. The concrete cutoff wall permanently defines the emergency spillway opening. The emergency spillway elevation must be tied back into the top of the embankment using a maximum slope of 4:1.

To assist Home Owners’ Associations with maintenance, an operations and maintenance manual for detention facilities and associated infrastructure must be developed and included with the final drainage report.

The designer is encouraged to use the spreadsheets and programs provided by the UDFCD such as UD-Detention or UD-FSD to assist in designing detention facilities. Other software programs may be used, but the designs will be verified using the UDFCD programs and spreadsheets. The most current version of the UDFCD spreadsheets can be downloaded from the UDFCD website.

11.4 Hydraulic Design

The equations listed below have been included for reference. The UDFCD spreadsheets include these equations in their calculations.

The general form of the weir flow equation for broad-crested weirs to be used for detention outlet design is:

$$Q = CL(H)^{3/2}$$

Where: Q = discharge (cfs)
C = weir coefficient
L =horizontal length (feet)
H = total energy head (feet)

For v-notch weirs:

$$Q = 2.5 \tan(\Theta/2) H^{5/2}$$

Where: ϴ=angle of the notch at the apex (degrees)

Weir flow requirements and coefficients are shown in Figure 11.4.1.

The equation governing the orifice opening for detention outlet design is:

$$Q = C_d A (2gh)^{1/2}$$

Where: Q = flow (cfs)
C_d = orifice coefficient
A = area (ft^2)
g =gravitational constant= 32.2 ft/sec^2
H =head on orifice measured from centerline (ft)

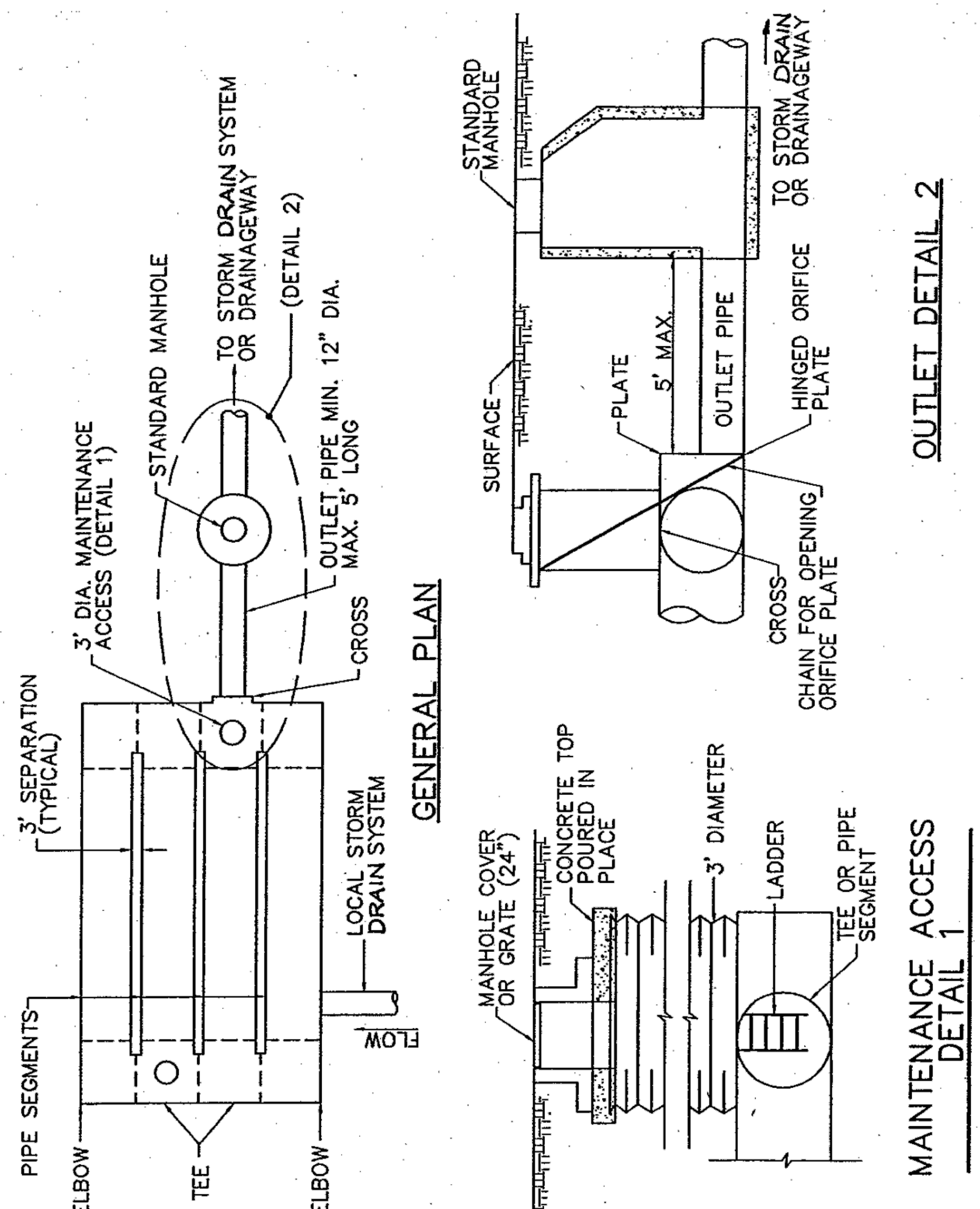
An orifice coefficient (C_d) value of 0.65 shall be used for sizing of orifice openings and plates.

11.5 Maintenance Access

Maintenance access shall be provided for all detention facilities to ensure the detention is performing as designed. Access to underground pipes and detention facilities must adhere to the requirement of Table 11.5.1. If a pipe does not daylight, a 3-foot diameter (min) maintenance access port shall be used.

Table 11.5.1 Maintenance Access Requirements

MAINTENANCE ACCESS REQUIREMENTS		
DETENTION PIPE SIZE	**MAXIMUM SPACING**	**MINIMUM FREQUENCY**
48" to 54"	150'	Every pipe segment
60" to 66"	200'	Every other pipe segment
Greater than 66"	200'	One at each end of the battery of pipes



FROM CITY OF GREELEY DESIGN CRITERIA AND CONSTRUCTION SPECIFICATIONS, STORM DRAINAGE VOLUME II

City of Evans, Colorado

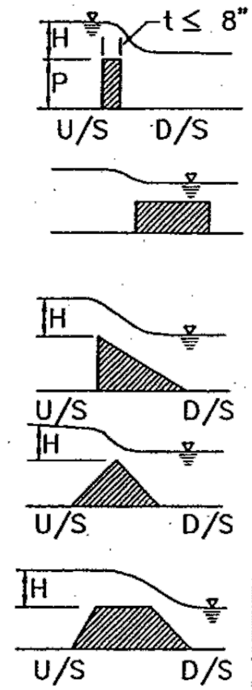
CITY OF EVANS DRAINAGE CRITERIA MANUAL

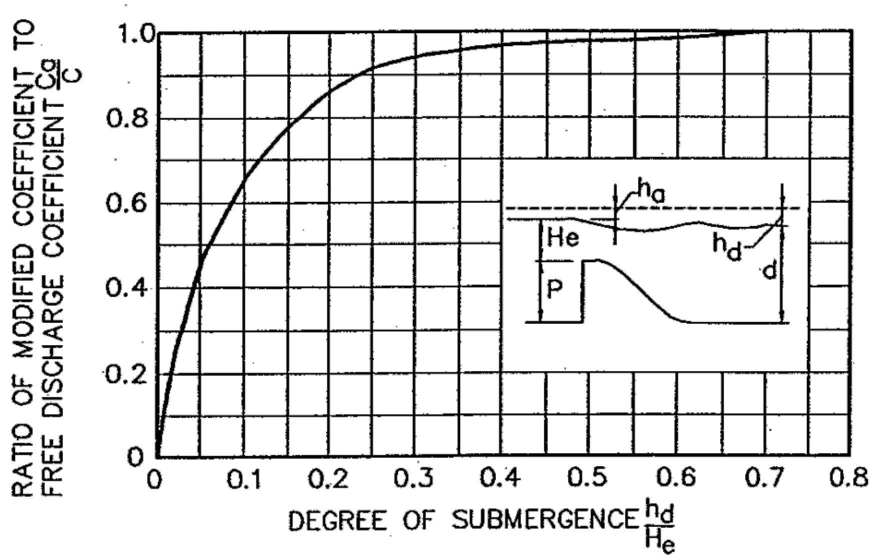
UNDERGROUND DETENTION

FIGURE 11.2.1

SHAPE	COEFFICIENT	COMMENTS
SHARP CRESTED	–	
PROJECTION RATIO (H/P = 0.4)	3.4	H<1.0
PROJECTION RATIO (H/P = 2.0)	4.0	H>1.0
BROAD CRESTED	–	
W/SHARP U/S CORNER	2.6	MINIMUM VALUE
W/ROUNDED U/S CORNER	3.1	CRITICAL DEPTH
TRIANGULAR SECTION	–	
A) VERTICAL U/S SLOPE	–	
1:1 D/S SLOPE	3.8	H>0.7
4:1 D/S SLOPE	3.2	H>0.7
10:1 D/S SLOPE	2.9	H>0.7
B) 1:1 U/S SLOPE	–	
1:1 D/S SLOPE	3.8	H>0.5
3:1 D/S SLOPE	3.5	H>0.5
TRAPEZOIDAL SECTION		
1:1 U/S SLOPE, 2:1 D/S SLOPE	3.4	H>1.0
2:1 U/S SLOPE, 2:1 D/S SLOPE	3.4	H>1.0
ROAD CROSSINGS		
GRAVEL	3.0	H>1.0
PAVED	3.1	H>1.0

SCHEMATIC





ADJUSTMENT FOR TAILWATER

REFERENCE: KING & BRATER, HANDBOOK OF HYDRAULICS, McGRAW HILL BOOK COMPANY, 1963 – DESIGN OF SMALL DAMS, BUREAU OF RECLAMATION, 1977

FROM CITY OF GREELEY DESIGN CRITERIA AND CONSTRUCTION SPECIFICATIONS, STORM DRAINAGE VOLUME II

WEIR FLOW COEFFICIENTS

FIGURE 11.4.1

SECTION 12 STORM WATER QUALITY

12.1 Introduction

The City of Evans is committed to protecting and enhancing the environment. Pollutants carried by stormwater can impair waterways, contaminate water supplies, reduce recreation, and interfere with aquatic life. The City believes water quality and erosion control are important aspects of all designs and construction. The City will adhere to the information and the design guidelines presented in the USDCM Volume 3 for stormwater quality and erosion control.

12.2 Municipal Separated Storm Sewer System (MS4)

12.2.1 Regulations

Some common pollutants stormwater will carry include oil and grease from roadways, pesticides and fertilizers, sediment from construction sites, and discarded trash. To reduce pollutants the EPA created management programs to protect the water supply.

An MS4 is a conveyance or system of conveyances that is:

- Owned by a state, county, city, town, or other public entity that discharges to waters of the United States;
- Designed or used to collect or convey stormwater (including storm drains, pipes, ditches, etc.);
- Not a combined sewer; and
- Not part of publicly owned treatment works (sewage treatment plant).

In compliance with the provisions of the Colorado Water Quality Control Act, (25-8-101 et seq., CRS, 1973 as amended) and the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.), the EPA declared rules establishing Phase I of the NPDES stormwater program in 1990.

In 1999 Stormwater Phase II Rule extended coverage of the NPDES stormwater program to urbanized areas serving populations of 10,000 to 100,000. The City of Evans falls under the Phase II MS4 regulations, and they are required to develop and implement a stormwater management program (SWMP) to reduce the contamination of stormwater runoff and prohibit illicit discharges to the "maximum extent practicable." In Colorado, the program is administered by the Colorado Department of Public Health & Environment (CDPHE) Water Quality Control Division. The Colorado program is referred to as the Colorado Discharge Permit System, or CDPS, instead of NPDES.

12.2.2 Construction

Stormwater runoff during construction and post-construction are of particular concerns to transporting pollutants. When construction activities disturb 1 acre or more of land, the permit holder is responsible for designing, implementing, and maintaining BMPs that reduce pollutants in stormwater runoff and prevent other discharges that have the potential to negatively impact water quality (e.g., construction dewatering, wash water).

In the Colorado Discharge Permit System (CDPS) general permit for stormwater discharges associated with construction activity (CDPS Construction Permit), construction activity is defined as "ground surface disturbing activities, including, but not limited to, clearing, grading, excavation, demolition, installation of new or improved haul and access roads, staging areas, stockpiling of fill materials, and borrow areas." Routine maintenance of infrastructure is not included in construction activities but is still included in continued water quality.

UDSCM Volume 3 provides guidance for onsite planning of construction and post-construction BMPs. Descriptions, maintenance and details of required BMPs are shown in Volume 3. The proper removal of trash and waste must be given sufficient attention, and the removal of BMPs after construction when the site is established must not be forgotten.

12.2.3 Detection Program

The MS4 program requires complete separation of storm drains and sanitary sewers. A program shall be developed and implemented to detect and eliminate illicit discharges to the MS4 through construction inspection.

12.3 Sediment and Erosion Control Plan

A sediment and erosion control plan (SWMP) showing the location and type of all BMPs utilized on the project shall be included in the construction plans to meet the requirements of the MS4 program and CDPHE. A copy of the sediment and erosion control plan and the permit must be kept on-site. Changes to the plan and BMPs are allowed as construction and site stabilization progress as long as these revisions are noted on the drawings.

12.4 Best Management Practices (BMPs)

City of Evans uses the BMPs that are outlined in Volume 3 of USDCM which include detailed drawings. The AutoCAD files for the BMPs can be downloaded from the UDFCD website.

BMP design and erosion control management is constantly changing. City of Evans will evaluate the use of newly developed BMPs on a case-by-case basis with complete documentation, and reserves the right to review alternative methods, comparing the other commonly used approaches, including those discussed in the USDCM.

12.5 Revegetation

Revegetation is one of the permanent BMPs, which usually completes most construction projects. The purpose of this section is to present information on methods and plant materials needed for revegetation of drainage facilities. Prior to work starting on a project, inventory of the existing vegetation should be taken and documented. During construction, proper soil preparation, planting, and mulching will greatly increase successful growth of the plants and grasses which in turn will protect from soil erosion. At all times, the appropriate steps need to be taken for controlling any noxious weeds. A list can be found on the Colorado Department of Agriculture site (https://www.colorado.gov/pacific/agconservation/noxious-weed-species). This design criteria are in addition to the requirements and recommendations set forth in the USDCM Volume 2 "Revegetation" chapter.

Appendix A

Reference Materials

Street and Inlet Design Example

5.0 UD-Inlet Design Workbook

The UD-Inlet design workbook provides quick solutions for many of the street capacity and inlet performance computations described in this chapter. A brief summary of each worksheet of the workbook is provided below. Note that some of the symbols and nomenclature in the worksheets do not correspond exactly with the nomenclature of the text. The text and the worksheets are computationally equivalent. An example problem using UD-Inlet is provided in section 6.0 of this chapter.

- The *Q-Peak* tab calculates the peak discharge for the inlet tributary area based on the rational method for the minor and major storm events. Alternatively, the user can enter a known flow. Information from this tab is exported to the *Inlet Management* tab.
- The *Inlet Management* tab imports information from the *Q-Peak* tab and *Inlet [#]* tabs and can be used to connect inlets in series so that bypass flow from an upstream inlet is added to flow calculated for the next downstream inlet. This tab can also be used to modify design information imported from the *Q-Peak* tab.
- *Inlet [#]* tabs are created each time the user exports information from the *Q-Peak* tab to the *Inlet Management* tab. The *Inlet [#]* tabs calculate allowable half-street capacity based on allowable depth and allowable spread for the minor and major storm events. This is also where the user selects an inlet type and calculates the capacity of that inlet.
- The *Inlet Pictures* tab contains a library of photographs of the various types of inlets contained in the worksheet and referenced in this chapter.

6.0 Examples

6.1 Example—Triangular Gutter Capacity

A triangular gutter has a longitudinal slope of 1%, cross slope of 2%, and a curb depth of 6 inches. Determine the flow rate and flow depth if the spread is limited to 9 feet.

Using Equation 7-1 the flow rate is calculated as:

$$Q = \frac{0.56}{n} S_x^{\;5/3} S_o^{\;1/2} T^{8/3}$$

$$Q = \frac{0.56}{0.016}\left(0.02^{5/3}\right)\left(0.01^{1/2}\right)\left(9^{8/3}\right) = 1.81 \text{ cfs}$$

The flow depth can be found using Equation 7-2:

y = (9.0)(0.02) = 0.18 ft

Note that the computed flow depth is less than the curb height of 6 inches (0.5 feet). If it was not, the spread and associated flow rate would need to be reduced.

6.2 Example—Composite Gutter Capacity

Determine the discharge in a composite gutter section if the allowable spread is 9 feet, the gutter width is 2 feet, and the vertical depth between gutter lip and gutter is 2.0 inches. The street's longitudinal slope is 1%, the cross slope is 2%, and the curb height is 6 inches.

First determine the gutter cross slope, S_w, using Equation 7-8:

$$S_w = S_x + \frac{a}{W}$$

$$S_w = 0.02 + \frac{\frac{2}{12} - 2(0.02)}{2} = 0.083\,\text{feet}$$

The flow in the street is found using Equation 7-1:

$$Q_x = \frac{0.56}{n} S_x^{\ 5/3} S_o^{\ 1/2} T^{8/3}$$

$$Q_x = \frac{0.56}{0.016} 0.02^{5/3} 0.01^{1/2} 7^{8/3} = 0.92\,\text{cfs}$$

From Equation 7-7 the ratio of gutter flow to total flow (Q_w/Q) is represented by E_o.

$$E_O = \frac{1}{1 + \dfrac{S_w/S_x}{\left[1 + \dfrac{S_w/S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

$$E_O = \frac{1}{1 + \dfrac{0.083/0.02}{\left[1 + \dfrac{0.083/0.02}{(9/2) - 1}\right]^{8/3} - 1}} = 0.63$$

Now the theoretical flow rate can be found using Equation 7-6:

$$Q = \frac{Q_x}{1 - E_o}$$

$$Q = \frac{0.92}{1 - 0.63} = 2.49\text{ cfs}$$

Then by using Equation 7-9 the computed flow depth is:

$$y = a + TS_x$$

$$y = [0.1667 - 2(0.02)] + 9(0.02) = 0.31 \text{ feet}$$

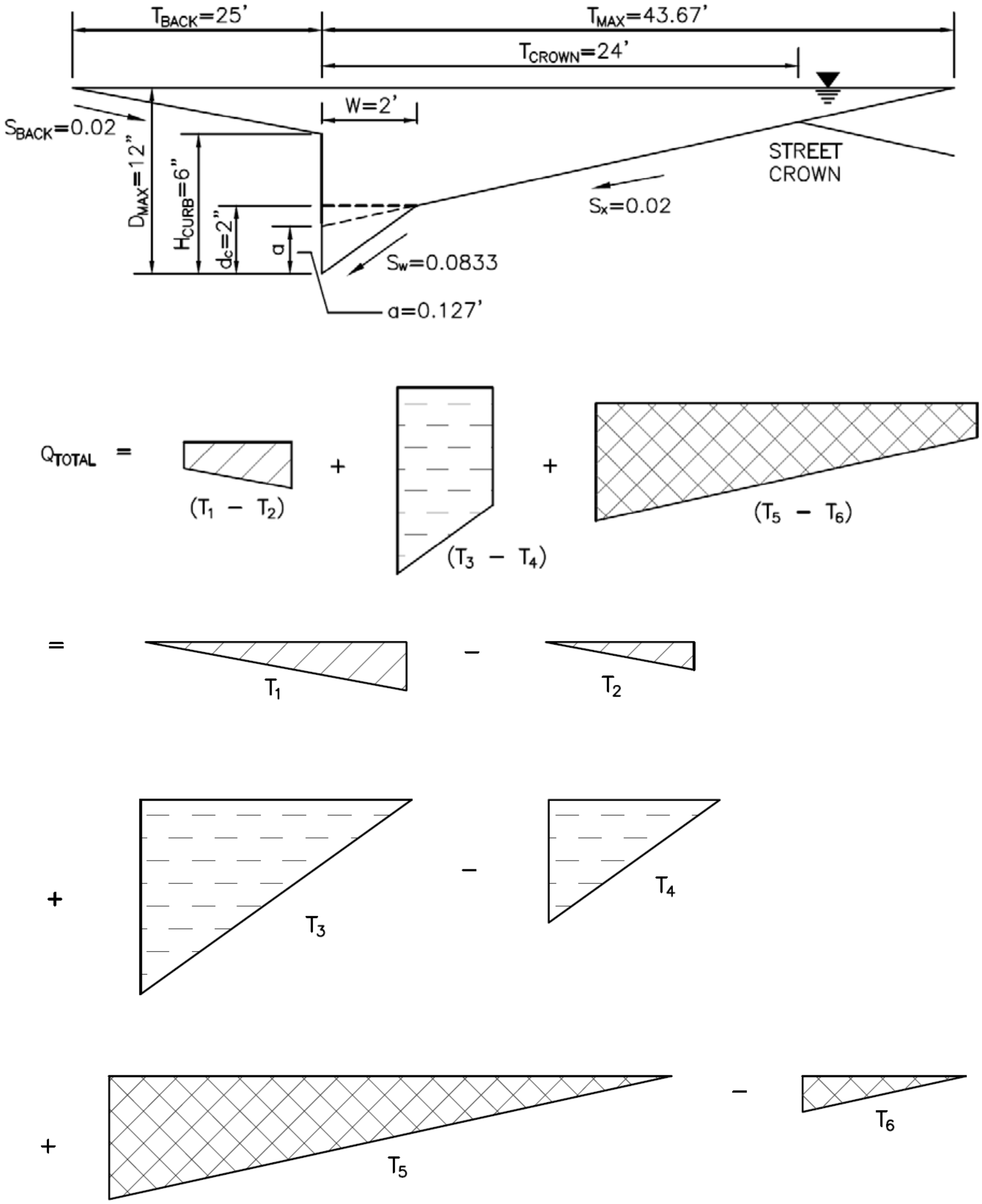
Note that the computed flow depth is less than the curb height of 6 inches.

6.3 Example—Composite Gutter Capacity – Major Storm Event

Determine the local street capacity of a composite gutter street section if the allowable depth is 12 inches. Assume there is ponding on the crown of the road and the encroachment has extended onto the 10-foot wide sidewalk behind the curb (sloping toward the curb at 2%). The street's longitudinal slope is 1% and the cross slope is 2%. The gutter width is 2 feet, the vertical distance between the gutter lip and flowline is 2 inches, and the height of the curb is 6 inches. The distance from the gutter flowline to the street crown is 24 feet. Use a Manning's coefficient (n) of 0.013 for concrete and 0.016 for asphalt. It should be noted that at a 12-inch depth, the sidewalk behind the curb would not contain the flow. This example assumes that flow is contained by a vertical wall at the back of the walk. From a standpoint of public safety, it is of great importance to ensure that flow is contained within the right-of-way for the full length of the project. For this reason, the allowable depth of flow is typically determined by the physical constraints behind the curb rather than maximum depth criteria.

The total flow can be found by dividing the cross section into six right triangles as shown below and calculating the flow through each section using Equation 7-1.

$$Q = \frac{0.56}{n} S_x^{5/3} S_o^{1/2} T^{8/3}$$



After flow in each of the 6 triangles has been determined, add and subtract the flow in each area as shown in the above figure.

$$Q = Q_{T1} - Q_{T2} + Q_{T3} - Q_{T4} + Q_{T5} - Q_{T6}$$

$$Q_{T1} = \frac{0.56}{0.013}\left(0.02^{5/3}\right)\left(0.01^{1/2}\right)\left(25^{8/3}\right) = 33.9 \text{ cfs}$$

$$Q_{T2} = \frac{0.56}{0.013}\left(0.02^{5/3}\right)\left(0.01^{1/2}\right)\left(15^{8/3}\right) = 8.86 \text{ cfs}$$

$$Q_{T3} = \frac{0.56}{0.013}\left(0.0833^{5/3}\right)\left(0.01^{1/2}\right)\left(12^{8/3}\right) = 51.7 \text{ cfs}$$

$$Q_{T4} = \frac{0.56}{0.013}\left(0.0833^{5/3}\right)\left(0.01^{1/2}\right)\left(10^{8/3}\right) = 31.8 \text{ cfs}$$

(Solve for T using equation 7-9)

$$Q_{T5} = \frac{0.56}{0.016}\left(0.02^{5/3}\right)\left(0.01^{1/2}\right)\left(41.7^{8/3}\right) = 107.8 \text{ cfs}$$

$$Q_{T6} = \frac{0.56}{0.016}\left(0.02^{5/3}\right)\left(0.01^{1/2}\right)\left(19.7^{8/3}\right) = 14.6 \text{ cfs}$$

Therefore by combining the above calculations the total flow can be calculated as:

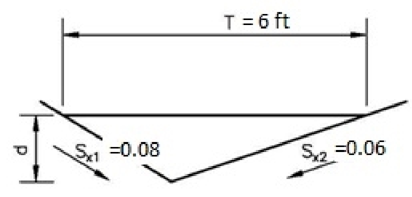
$$Q = Q_{T1} - Q_{T2} + Q_{T3} - Q_{T4} + Q_{T5} - Q_{T6} = 138 \text{ cfs}$$

Note: UD-Inlet.xls uses HEC-22 methodology to solve this problem and will provide a slightly different answer.

6.4 Example—V-Shaped Swale Capacity

Determine the maximum discharge and depth of flow in a V-shaped, roadside grass swale with side slopes of 8% and 6%, a longitudinal slope of 2% and a total width of 6 feet.

The adjusted slope, Sx, is determined using Equation 7-13:



$$S_x = \frac{S_{x1}S_{x2}}{S_{x1} + S_{x2}}$$

$$S_x = \frac{(0.08)(0.06)}{0.08 + 0.06} = 0.034$$

From Equation 7-1, the flow through the swale is computed:

$$Q = \frac{0.56}{n} S_x^{\;5/3} S_o^{\;1/2} T^{8/3}$$

$$Q = \frac{0.56}{0.03} 0.034^{5/3} 0.02^{1/2} 6^{8/3} = 1.12 \text{ cfs}$$

Using Equation 7-2 the flow depth is calculated as:

$$y = TS_x$$

$$y = 6(0.034) = 0.2 \text{ feet}$$

6.5 Example—V-Shaped Swale Design

Design a V-shaped swale to convey a flow of 1.8 cfs. The available swale top width is 8 feet, the longitudinal slope is 1%, and the Manning's roughness factor is 0.16. Determine the cross slopes and the depth of the swale.

Solving Equation 7-1 for S_x (i.e., average side slope) yields:

$$S_x = \left[\frac{Qn}{0.56 S_o^{1/2} T^{8/3}} \right]^{3/5}$$

$$S_x = \left[\frac{(1.8)0.016}{0.56(0.01)^{1/2} 8^{8/3}} \right]^{3/5} = 0.024 \text{ ft/ft}$$

Now Equation 7-13 is used to solve for the actual cross slope assuming $S_{x1} = S_{x2}$, Equation 7-13 can be rewritten and solved for Sx1 :

$$S = 2S_x = 2(0.024) = 0.048 \text{ ft/ft}$$

Then using Equation 7-2 yields a flow depth, y, of:

$$y = TS_x = (0.024)(8) = 0.19 \text{ feet}$$

The swale is 8-feet wide with right and left side slopes of 0.048 ft/ft and a flow depth of 0.19 feet.

6.6 Example—Grate Inlet Capacity

Determine the efficiency of a CDOT Type C Standard Grate (W = 2 feet and L = 2 feet) when placed in a composite gutter section with a 2-foot concrete gutter that has a 2-inch drop between the gutter lip and gutter flowline. The street cross slope is 2% and the longitudinal slope of 1%. The flow in the gutter is 2.5 cfs with a spread of 8.5 feet.

Using Equation 7-7, determine the ratio of gutter flow to total flow (Q_w/Q) (represented by E_o):

$$E_O = \frac{1}{1 + \frac{S_w / S_x}{\left[1 + \frac{S_w / S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

$$E_O = \frac{1}{1 + \frac{0.083/0.02}{\left[1 + \frac{0.083/0.02}{(8.5/2) - 1}\right]^{8/3} - 1}} = 0.66$$

Solve Equation 7-6 for Q_x to determine the flow in the section outside of the depressed gutter:

$$Q_x = Q(1 - E_o) = 2.5(1\text{-}0.66) = 0.85 \text{ cfs}$$

The flow in the dressed gutter section is determined by subtracting this value from the total flow:

$$Q_w = 2.5 - 0.85 = 1.65 \text{ cfs}$$

Next, find the flow area using Equation 7-10 and velocity using the continuity equation V = Q/A.

$$A = \frac{S_x T^2 + aW}{2}$$

$$A = \frac{0.02(8.5^2) + 0.127(2)}{2} = 0.85 \text{ ft}^2$$

$$V = \frac{Q}{A} = \frac{2.5}{0.85} = 2.94 \text{ fps}$$

The splash-over velocity is determined from Equation 7-20:

$$V_o = \alpha + \beta L_e - \gamma L_e^2 + \eta L_e^3$$

Where:

V_o = splash-over velocity (ft/sec)

L_e = effective length of grate inlet (ft)

$\alpha, \beta, \gamma, \eta$ = constants from Table 7-6

$$V_o = 2.22 + 4.03(2) - 0.65(2^2) + 0.06(2^3) = 8.16 \text{ fps}$$

From Equation 7-19, the ratio of the frontal flow intercepted by the inlet to total frontal flow, R_f, is determined by:

$$R_f = \frac{Q_{wi}}{Q_w} = 1.0 - 0.09(V - V_o) \text{ for } V \geq V_o \text{, otherwise } R_f = 1.0$$

$V \geq V_o$ in this example, therefore $R_f = 1.0$

Using Equation 7-21, the side-flow capture efficiency is calculated as:

$$R_x = \frac{1}{1 + \dfrac{0.15V^{1.8}}{S_x L^{2.3}}}$$

$$R_x = \frac{1}{1 + \dfrac{0.15(2.94)^{1.8}}{(0.02)(2)^{2.3}}} = 0.086$$

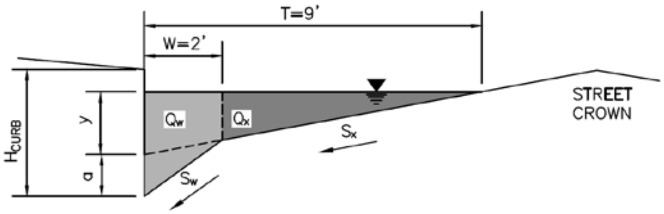
Finally, the overall capture efficiency, E, is calculated using Equation 7-22:

$$E = R_f\left(Q_w/Q\right) + R_x\left(Q_x/Q\right)$$

$$E = 1(1.64/2.5) + 0.086(0.86/2.5) = 0.69 \text{ (69\%)}$$

6.7 Example—Curb-Opening Inlet Capacity

Determine the amount of flow that will be captured by a 6-foot-long curb-opening inlet placed in the composite gutter described in Example Problem 6.2.



Equations 7-25 and 7-26 are used to determine the equivalent slope and the length of inlet required to capture 100% of the gutter flow.

First Equation 7-26 is used to calculate the equivalent cross slope, S_e.

$$S_e = S_x + \frac{(a + a_{local})}{W} E_o$$

$$S_e = 0.02 + \frac{(0.127 + 0)}{2}(0.63) = 0.060$$

The inlet length required to capture 100% of the gutter flow, LT, is found using Equation 7-25.

$$L_T = 0.38 Q^{0.51} S_L^{0.058} \left(\frac{1}{nS_e}\right)^{0.46}$$

$$L_T = 0.38(2.49)^{0.51}(0.01)^{0.058}\left(\frac{1}{0.016(0.06)}\right)^{0.46} = 11.32 \text{ feet}$$

Then, by Equation 7-23 the efficiency, E, of the curb inlet can be calculated.

$$E = 1 - \left[1 - \left(\frac{L}{L_T}\right)\right]^{1.8} \text{ for } L < L_T$$

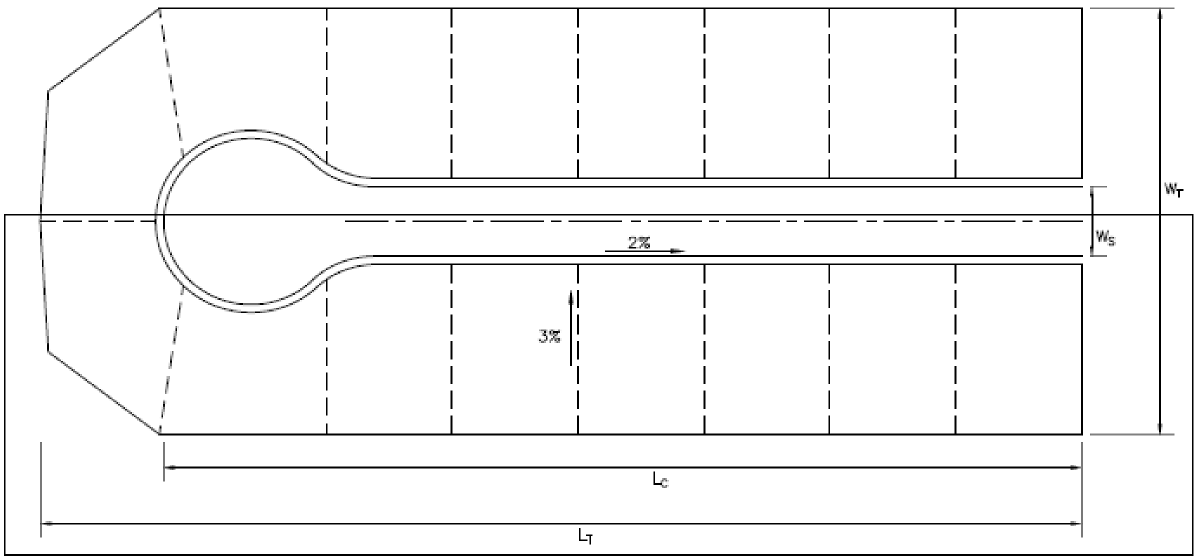
$$E = 1 - \left[1 - \left(\frac{6}{11.32}\right)\right]^{1.8} = 0.74\ (74\%)$$

The flow intercepted by the curb-opening inlet is calculated as follows:

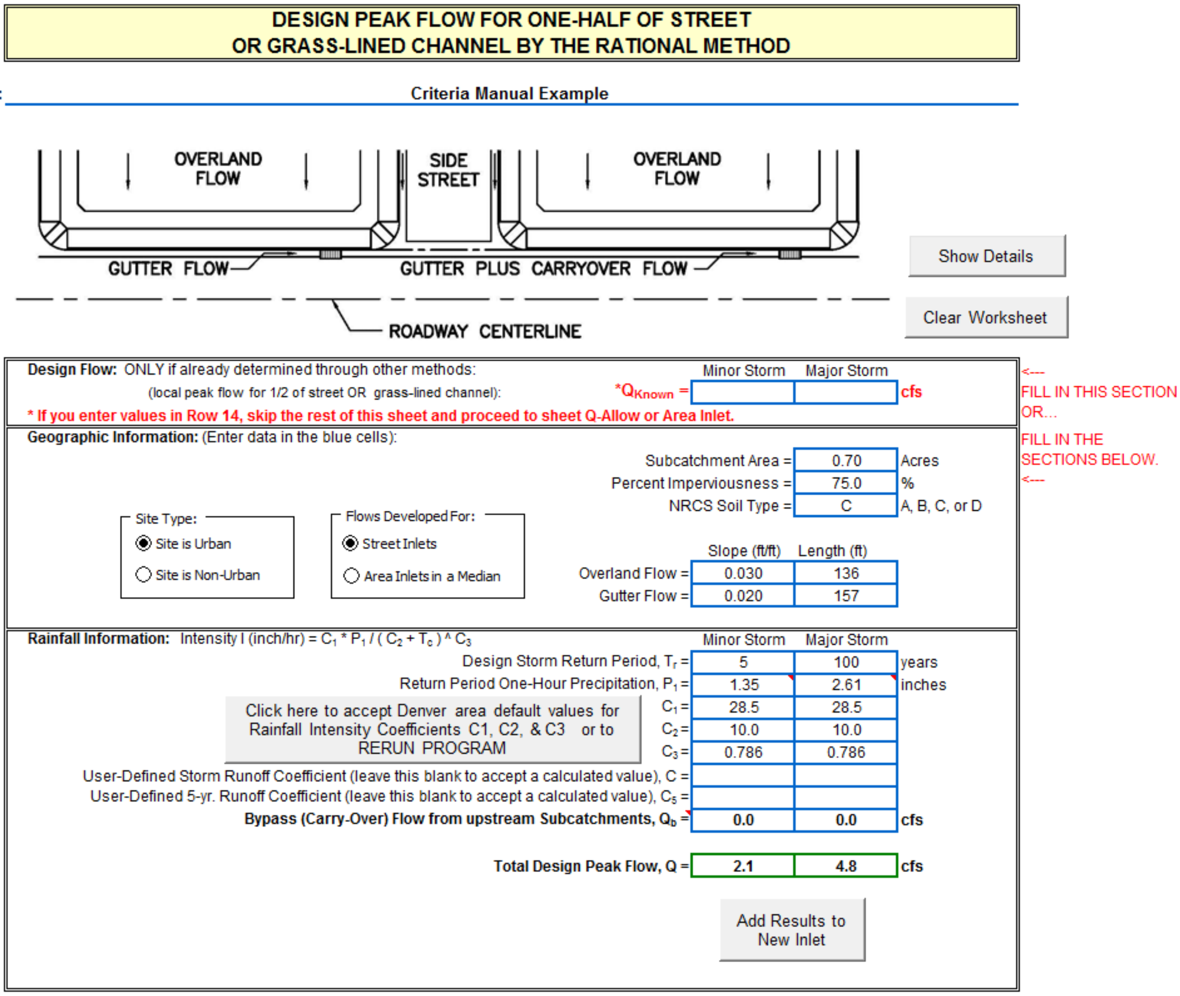
$$Q_i = EQ = (0.74)(2.49) = 1.84 \text{ cfs}$$

6.8 Example—Design of a Network of Inlets Using UD-Inlet

Determine the number of CDOT Type R curb inlets needed to maintain allowable street flow for the 5-yr and 100-year storm events for each side of the street as shown in the below figure. The area can be described as a 4.8-acre residential development in Denver with L_T = 711 ft, channel length L_C = 637 ft, W_T = 310 ft. and W_S = 30 ft. Each lot is 0.25 acres. The development has imperviousness I=75% and type C soil. The channel slope is 2% and the overland slope is 3%. All flows must be contained within the street and gutter section (i.e., no flow behind the curb). Additionally, the flow spread for the minor storm shall not exceed 9 ft.



The tributary area to be used is half of the total development (A = 2.4 acre). Based on the dimensions of the lot sizes, the overland flow length is 136 ft. Use the Q-Peak tab of the UD-Inlet workbook to calculate the 5-year and 100-year peak flow for the upper portion of the tributary area. This requires approximation of the location of the most upstream inlet and calculation of the area tributary to this inlet. The following screenshot shows the Q-Peak input and output for the upper 0.7 acres of the tributary area. Based on the geometry of the development, this corresponds to a channel flow length of 157 feet.



The *Q-Peak* inlet calculates the 5-year and 100-year peak flow based on the estimated sub-catchment area to the first inlet, percent imperviousness, soil type, appropriate time of concentration calculations, as well as location-specific rainfall information and runoff coefficients. For this problem, the 5-year flow is 2.1 cfs and the 100-year flow is 4.8 cfs. Alternatively, the user could enter known flows in this tab. Once the flows have been calculated, press the "Add Results to New Inlet" button. This adds a new inlet to the *Inlet Management* tab and opens a new tab for calculation of both the flow spread and depth in the street and the design of the receiving inlet.

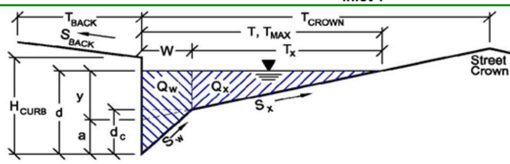
On the inlet tab, enter the geometry of half of the street section. Use the requirements stated in the problem statement for the allowable spread and depth of flow. This section indicates the maximum street flow for the minor and major storm events based on allowable spread and depth criteria. If the allowable street flow is less than the flow calculated on the *Q-Peak* tab, reduce the area and associated channel length on the *Q-Peak* tab. For this example, neither flow depth nor flow spread exceed criteria. See the screenshot below.

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: Enter Your Project Name Here

Inlet ID: Inlet 1



Show Details

Clear Worksheet

Gutter Geometry (Enter data in the blue cells)			
Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	4.0	ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =	0.020	ft/ft
Manning's Roughness Behind Curb (typically between 0.012 and 0.020)	n_{BACK} =	0.012	
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00	inches
Distance from Curb Face to Street Crown	T_{CROWN} =	15.0	ft
Gutter Width	W =	2.00	ft
Street Transverse Slope	S_X =	0.020	ft/ft
Gutter Cross Slope (typically 2 inches over 24 inches or 0.083 ft/ft)	S_W =	0.083	ft/ft
Street Longitudinal Slope - Enter 0 for sump condition	S_O =	0.020	ft/ft
Manning's Roughness for Street Section (typically between 0.012 and 0.020)	n_{STREET} =	0.016	

		Minor Storm	Major Storm	
Max. Allowable Spread for Minor & Major Storm	T_{MAX} =	9.0	15.0	ft
Max. Allowable Depth at Gutter Flowline for Minor & Major Storm	d_{MAX} =	6.0	6.0	inches
Allow Flow Depth at Street Crown (leave blank for no)		☐	☐	check = yes

Optional: Set d-MAX to Limit V*d Product

		Minor Storm	Major Storm	
MINOR STORM Allowable Capacity is based on Spread Criterion				
MAJOR STORM Allowable Capacity is based on Spread Criterion	Q_{allow} =	3.5	11.3	cfs

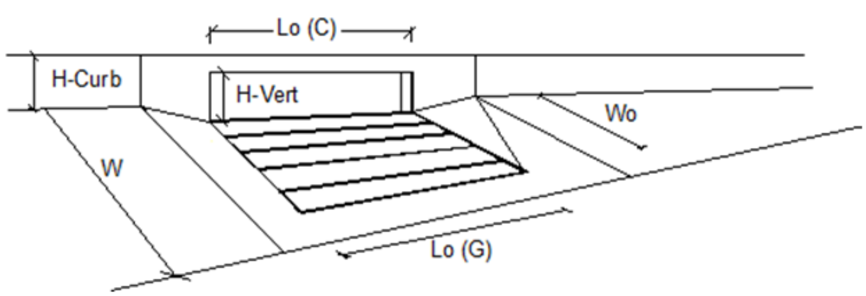
Bypass UDFCD Safety Factor

Minor storm max. allowable capacity GOOD - greater than the design flow given on sheet 'Inlet Management'

Major storm max. allowable capacity GOOD - greater than the design flow given on sheet 'Inlet Management'

The screenshot below shows the inlet design specifications. Notice that there is bypass flow for both storms. These flows will be accounted for at the next (downstream) inlet. The length of the inlet or number of units can be increased to reduce bypass flow.

INLET ON A CONTINUOUS GRADE



Show Details

Reset Defaults

Clear Worksheet

Design Information (Input)	CDOT Type R Curb Opening		MINOR	MAJOR	
Type of Inlet		Type =	CDOT Type R Curb Opening		
Local Depression (additional to continuous gutter depression 'a')		a_{LOCAL} =	3.0	3.0	inches
Total Number of Units in the Inlet (Grate or Curb Opening)		No =	1	1	
Length of a Single Unit Inlet (Grate or Curb Opening)		L_o =	5.00	5.00	ft
Width of a Unit Grate (cannot be greater than W, Gutter Width)		W_o =	N/A	N/A	ft
Clogging Factor for a Single Unit Grate (typical min. value = 0.5)		C_f-G =	N/A	N/A	
Clogging Factor for a Single Unit Curb Opening (typical min. value = 0.1)		C_f-C =	0.10	0.10	

Street Hydraulics: OK - Q < maximum allowable from sheet 'Q-Allow'		MINOR	MAJOR	
Total Inlet Interception Capacity	Q =	1.79	2.79	cfs
Total Inlet Carry-Over Flow (flow bypassing inlet)	Q_b =	0.3	2.0	cfs
Capture Percentage = Q_a/Q_o =	C% =	86	58	%

To add the next downstream inlet (Inlet 2), return to the *Q-Peak* tab and enter the same information for the next (downstream) tributary area as was required for Inlet 1. This information is automatically moved to the *Inlet management* tab when a new inlet is added. Prior to designing this inlet, ensure that bypass flows are added on the *Inlet management* tab. To do this, use the drop-down menu in the "Receive Bypass Flow from" row and select Inlet 1. The *Inlet Management* tab can also be used to adjust the subcatchment area and corresponding channel length to make adjustments as needed during design while maintaining a network of inlets that update when these changes are made. Changes made on the individual inlet tabs will also update on the *Inlet Management* tab. A screenshot of the *Inlet Management* tab is shown below.

Inlet Management

Worksheet Protected

	Delete	Delete	Delete
INLET NAME	Inlet 1	Inlet 2	Inlet 3
Inlet Application (Street or Area)	STREET	STREET	STREET
Hydraulic Condition	On Grade	On Grade	On Grade
Inlet Type	CDOT Type R Curb Opening	CDOT Type R Curb Opening	CDOT Type R Curb Opening

USER-DEFINED INPUT Show Input Details

Receive Bypass Flow from:		Inlet 1	Inlet 2
Minor Q_{Known} (cfs)			
Major Q_{Known} (cfs)			
Minor Bypass Flow, Q_b (cfs)	0.0	0.3	0.5
Major Bypass Flow, Q_b (cfs)	0.0	2.0	4.2
Watershed Characteristics			
Subcatchment Area (acres)	0.7	0.85	0.85
Percent Impervious	75	75	75
NRCS Soil Type	C	C	C
Watershed Profile			
Overland Slope (ft/ft)	0.03	0.03	0.03
Overland Length (ft)	136	136	136
Channel Slope (ft/ft)	0.02	0.02	0.02
Channel Length (ft)	157	240	240
Minor Storm Rainfall Input			
Design Storm Return Period, T_r (years)	5	5	5
One-Hour Precipitation, P_1 (inches)	1.35	1.35	1.35
Major Storm Rainfall Input			
Design Storm Return Period, T_r (years)	100	100	100
One-Hour Precipitation, P_1 (inches)	2.61	2.61	2.61

CALCULATED OUTPUT Show Output Details

Minor Total Design Peak Flow, Q	**2.1**	**2.8**	**2.9**
Major Total Design Peak Flow, Q	**4.8**	**7.7**	**9.9**

The screenshot above shows that the selected tributary area of this development will require 3 CDOT Type R Curb inlets. This will ensure that the majority of the flows don't exceed the allowable depth or spread stated in the problem. The 4.8-acre development will require a total of six inlets, three on each side of the street.