CHAPTER 3

DESIGN CRITERIA

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3.1 GENERAL

All storm drain systems, detention facilities and appurtenance designs shall take into account the requirements of the Town of Bennett for Storm Sewer Construction and shall be in conformance with the subdivision regulations. Drainage Reports shall be prepared by a registered professional engineer in the State of Colorado, unless exemption is granted in writing, by the Town of Bennett.

3.2 ACCEPTABLE METHODS

Analysis and determination of the amount of flow at various points in the drainage system shall be made by approved systematic and comprehensive methods. The following methods shall be used to verify the adequacy of designs submitted for approval.

3.2.1 Rational method for simple basins of less than 160 acres.

3.2.2 Urban Hydrographic Method for basins in excess of 160 acres.

3.2.3 Soils Conservation Service Method for basins in excess of 160 acres and/or containing large areas of undeveloped and/or farm land.

3.3 PARAMETERS

3.3.1 The **major storm** shall be the 100-year undeveloped (historic) frequency event. 1HR

3.3.2 The **design storm** shall be the 10-year (developed) frequency event. 1HR

3.3.3 The 10-year and 100-year release rates shall be limited to undeveloped (historic) levels or to the SCS soil group-based release levels, whichever is less.

3.3.4 The initial design storm system shall be so designed as to provide protection against regularly recurring damage, to reduce street maintenance costs, to provide an orderly urban drainage system and to provide convenience to the urban residents. Storm sewer systems consisting of underground piping, natural drainage ways and other required appurtenances shall be considered as a part of the initial storm drainage system. The initial storm flows shall be contained in such a manner that no curb overtopping occurs and without exceeding the limitations set forth in subsection 2.4.

3.3.5 The storm sewer system shall commence at the point where the maximum allowable encroachment occurs.

3.3.6 The major storm drainage system shall be so designed as not to cause major property damage or loss of life from storm runoff expected from the major storm. The effects of the major storm on the initial drainage system shall be noted.

3.3.7 Streets shall not be used as floodways for the major storm runoff. The primary use of streets shall be for the conveyance of traffic. The computed amount of runoff allowed in streets shall not exceed the requirements set forth in Subsection 3.4.

3.3.8 The use of onsite detention and natural drainage ways is recommended and encouraged whenever possible. The changing of natural drainage way locations will not be approved unless such change is shown to be without unreasonable hazard and liability, substantiated by thorough analysis and investigation.

3.3.9 Flood plain information will be required on all final drainage drawings, and shall include the area inundated by the major storm runoff.

3.3.10 Where a master drainage plan for the Town is available, the flow routing for both the design storm and major storm runoff shall conform to said plan. Drainage easements conforming to the Master Plan will be required and shall be designated on all drainage drawings and subdivision plats.

3.3.11 In areas where a master plan is not yet available and where subdivision platting and building is contemplated along natural drainage ways without significant upstream and/or downstream development, drainage easements which will include the major storm runoff shall be required. These easements shall be shown on all drainage drawings and subdivision plats.

3.3.12 Approval will not be made for any proposed building or construction of any type of structure including retaining walls, fences, etc., or the placement of any type of fill material, which will encroach on any utility or drainage easement or which will impair surface or subsurface drainage from surrounding areas.

3.4 ALLOWABLE STREET FLOW CAPACITIES

Pavement encroachment for the design storm flow shall not exceed the limitations set forth in the following table:

Street Classification	Maximum Encroachment*
Local	No curb overtopping. Flow may spread to crown of street.
Collector	No curb overtopping. Flow spread must leave the equivalent of one 10-foot driving lane clear of water.
Arterials	No curb overtopping. Flow spread must leave the equivalent of two 10-foot driving lanes clear of water, one lane in each direction.
Freeways	No encroachment is allowed on any traffic lane.

* Where no curbing exists, encroachment shall not extend past property lines.

3.4.1 The allowable depth of flow and inundated area for the major storm shall not exceed the limitations set forth in the following table:

ALLOWABLE DEPTH OF FLOW

AND

INUNDATED AREA FOR MAJOR STORM RUNOFF

Street Classification	Allowable Depth and Inundated Area
Local and Collector	Residential dwelling, public, commercial and industrial buildings shall not be inundated at the ground line. The depth of water over the gutter flowline shall not exceed 18 inches.
Arterial and Freeway	Residential dwellings, public, commercial and industrial buildings shall not be inundated at the ground line. Depth of water at the street crown shall not exceed 6 inches to allow operation of emergency vehicles. The depth of water over the gutter flowline shall not exceed 18 inches.

3.4.2 Cross Street Flow Cross street flow can occur by two separate means. One is runoff which has been flowing a gutter and then flows across the street to the opposite gutter or inlet. The second case is flow from some external source, such as a drainage way or conduit, which will flow across the crown of the street when the conduit capacity is exceeded. The maximum allowable cross street flow depth based on the worst condition shall not exceed the limitations stipulated in the following table:

ALLOWABLE CROSS STREET FLOW

Street Classification	Design Storm Runoff	Major Storm Runoff
Local	6-inch depth at crown or in cross pan	18 inches of depth above gutter flowline
Collector	Where cross pans allowed, depth of flow shall not exceed 6 inches	18 inches of depth above gutter flowline
Arterial	None	6 inches or less over crown
Freeway	None	6 inches or less over crown

Curb Capacity Calculations. All theoretical flow capacities shall be reduced by the appropriate reduction factors to obtain allowable flow capacities. See Standard Figure SF-1.

3.4.3 DRAINAGE TRACT REQUIREMENTS. All backward draining cul-de-sacs and sump streets are required to have a minimum 16-foot drainage tract dedicated for the purpose of conveying drainage overflow. the tract shall be lines with a concrete channel sufficient to convey the major storm runoff in the event that storm sewer facilities are inoperable. The concrete channel shall be of sufficient strength to allow maintenance vehicles access.

3.5 STORM SEWERS AND STORM INLETS

Storm sewers and inlets shall be of sufficient capacity to adequately carry the expected runoff from the initial design storm. The storm sewer system and subsequent storm inlets shall commence at all locations where the allowable street capacity is exceeded or wherever ponding of water is likely to occur. No bubblers will be allowed.

The minimum allowable pipe size to be used in storm sewers and laterals shall be as listed below:

MINIMUM ALLOWABLE PIPE SIZE

Type of Conduit	Minimum Pipe Diameter	Minimum Cross Section Area
A. Main Trunk Sewer	21 Inch	2.40 Sq. Ft.
B. Individual Sewer Laterals	18 Inch	1.77 Sq. Ft.

Arch pipes will be allowed where design conditions dictate, provided, however, the minimum cross-sectional areas shall not be less than those specified above. All storm sewer conduits shall be of sufficient structural strength to withstand an H-20 design load.

The maximum allowable distance between manholes or other suitable appurtenances for cleanouts shall not exceed those listed below:

MAXIMUM ALLOWABLE MANHOLE SPACING

Inside Diameter or Minimum Head Room	Maximum Allowable Distance Between Manholes & Cleanouts
18" - 36"	400 Ft.
36" - 60"	500 Ft.
60" & Larger	750 Ft.

The capacities of conduits shall be computed using Manning's formula appropriate flow nomographs. The average full flow velocity in conduits shall not be less than 2.0 feet per second.

The value of the roughness coefficient (n) to be used shall not be less than those specified below:

MANNING ROUGHNESS COEFFICIENT - STORM SEWERS

Pipe Material	"n"
Reinforced concrete	0.013
Corrugated metal:	
Smooth flow	0.013
2 2/3" x 1/2"	0.024
3" x 1"	0.027
6" x 2"	0.030

3.5.1 Storm Inlets Where physical constraints will allow, the type "R" storm inlet shall be used. Chapter 7 provides ample information toward the design of inlets

The size of outlet pipes from storm-water inlets shall be based upon the theoretical capacity of the inlet, but shall not be less than 18 inches in diameter.

3.6 CULVERTS

Culverts shall be designed in conformance with the outlines provided in Chapter 6.

Culvert installations shall be designed with an emergency overflow for the major storm on all streets other than major arterials. Culverts under major arterials shall have sufficient capacity to pass all of the runoff from the major storm considering 20 per cent of the inlet plugged. In determining the amount of emergency overflow required, the following capacity credits shall apply:

CAPACITY CREDIT FOR STRUCTURES

Cross-Sectional Area of Structure	Capacity Credit (% of Full Flow Capacity)	% of Major Storm Flow to be Seen as Overflow
20 Sq. Ft.	0%	100%
20 Sq. Ft.	80%	20%

The appropriate amount of emergency overflow onto streets shall be taken into account when analyzing storm runoff and allowable street capacities for the major storm.

The following design criteria shall be utilized for all culvert design:

A. The culvert, including inlet and outlet structures, shall properly take care of water, bed-load and debris at all stages of flow.

B. Inlets. Culvert inlets shall be designed to minimize entrance and friction losses. Inlets shall be provided with either flared-end sections or head walls with wing walls. Projecting ends will not be acceptable. For large structures, provisions shall be made to resist possible structural failure due to hydrostatic uplift forces.

C. Outlets. Culvert outlets shall be designed to avoid sedimentation, undermining of the culvert or erosion of the downstream channel. Outlets shall be provided with either flared-end sections or headwalls, with wing walls. Projecting outlets will not be acceptable. Additional outlet control in the form of rip rap, channel shaping, etc., may be required where excessively high discharge velocities occur. See Standard Figures SF-2 and 3.

D. Slopes. Culvert slopes should be such that neither silting nor excessive velocities and scour occur. Generally, the minimum slope of culverts shall be limited to 0.50%.

E. Headwater. Generally, the headwater to diameter rations should not exceed those recommended below:

RECOMMENDED MAXIMUM HW/RATIOS

STORM FREQUENCY	HW/D
10-Year	1.0
100-Year	1.5

Excessive ponding above culvert entrances will not be acceptable if such ponding appears likely to cause property or roadway damage, culvert clogging, saturation of fills, detrimental upstream deposits of debris, or inundate existing or future utilities and structures.

F. Tailwater. The height of tailwater at the outlet shall be subject to the criteria set forth above.

G. Hydraulic Design. Culverts shall be analyzed to determine whether discharge is controlled by inlet or outlet conditions for both the design storm discharge and the major storm discharge. The value of the roughness coefficient (n) used shall not be less than those specified in Subsection 3.5.

H. Minimum Allowable Size. The required size of the culvert shall be based upon adequate hydraulic design analysis.
In no case, however, will approval be made for round culverts with less than 36 inches inside diameter, or for arched or oval shaped culverts with span-rise dimensions less than 43 inches x 27 inches nominal, or for culverts of any other shape which have a cross-sectional area less than 6.4 square feet.

I. Multiple Culvert Installations. Where physical conditions dictate, multiple culvert installations will be acceptable, subject to approval. However, the minimum size of any culvert to be used shall not be less than the requirements set forth in Subsection 3.6 (H) above.

3.7 CHANNELS AND DITCHES

Channels should be designed in such a manner that flows at the critical depth and supercritical flows are avoided. Channel capacities should be computed from Manning's Formula for Uniform Flow.

The channel cross section may be almost any type suitable to the location. However, the limitations for design for the major storm and initial storm design flows shall include:

A. Side Slopes. Side slopes shall be as flat as practical. Side slopes of 4 : 1 shall be considered a normal minimum. Under special conditions, slopes of 3 : 1 to 2 : 1 may be utilized; however, a slope of 3 : 1 is the practical limit for mowing equipment.

B. Depth. The maximum design depth of flow for the major storm should be limited to 3.5 feet, although depths of 4.0 feet may be acceptable where good channel maintenance may be expected and durations of peak flows are short. The design depth of flow for the initial storm runoff should not be less than 1.0 feet.

C. Freeboard. Except where localized overflow in certain areas is desirable for additional ponding benefits or other reasons, the minimum allowable freeboard shall be 1.0 feet.

D. Bottom Width. Normally the bottom width should be at least 6 to 8 times the depth of flow.

E. Slope of Channel. Grass-lined channels normally will have slopes of 0.2 to 0.6%. Where the natural topography is steeper than desirable, drops may have to be utilized.

F. Curvature. Generally, the center line curvature should not have a radius less than twice the design flow top width, but not less than 100 feet.

G. Design Velocity. Minimum velocities for all channels shall not be less than 2.0 feet per second for the initial storm runoff. Maximum velocities in unlined channels shall be limited to the following values:

PERMISSIBLE VELOCITIES - UNLINED CHANNELS

Material	n	Permissible Velocity f.p.s.
Fine Sand, colloidal	0.020	1.50*
Sandy loam, noncolloidal	0.020	1.75*
Silt loam, noncolloidal	0.020	2.00*
Alluvial silts, noncolloidal	0.020	2.00*
Ordinary firm loam	0.020	2.50
Volcanic ash	0.020	2.50
Stiff clay, very colloidal	0.025	3.75
Alluvial silts, colloidal	0.025	3.75
Shales and hardpans	0.025	6.00
Fine gravel	0.020	2.50
Graded loam to cobbles when noncolloidal	0.030	3.75
Graded silts to cobbles when colloidal	0.030	4.00
Coarse gravel, noncolloidal	0.025	4.00
Cobbles and shingles	0.035	5.00

*For these materials, permissible velocities are equal to or less than desired minimum velocities. therefore, if minimum velocities are maintained, erosion will occur and erosion-resistant lining material will be necessary.

PERMISSIBLE VELOCITIES - GRASS-LINED CHANNELS

Cover	Slope Range %	Permissible Velocity f.p.s.
Bermuda Grass	0-10	5.0
Buffalo Grass	0-10	5.0
Grass mixture	0-5	5.0
	5-10	4.0
Lespedeza sericea	0-5	3.5
Weeping love grass	0-5	3.5
Yellow blue stem	0-5	3.5
Kudzu, alfalfa	0-5	3.5
Crabgrass	0-5	3.5
Annuals	0-5	3.5

Roughness Coefficient (n). The values for Manning's "n" shall not be less than those specified in the following table:

Type of Channel and Description	Minimum n
Excavated or Dredged Channels and Ditches	
1. Earthen Straight and uniform, no brush or debris	
a. Grassed, less than 6" high with:	
(1) Depth of flow 2.0 feet	0.035
(2) Depth of flow 2.0 feet	0.030
b. Grassed, approx. 12" high with:	
(1) Depth of flow 2.0 feet	0.060
(2) Depth of flow 2.0 feet	0.035
c. Grassed, approx. 24" high with:	
(1) Depth of flow 2.0 feet	0.070
(2) Depth of flow 2.0 feet	0.035

d. Earth bottom with rip rap on sides 0.040

2. Earthen, Winding and Sluggish

a. Grassed bottom and slopes

(1) Depth of flow 3.0 feet 0.080
(2) Depth of flow 3.0 feet 0.050

b. Unmaintained with dense weeds, debris, etc.

(1) Depth of flow 3.0 feet 0.120
(2) Depth of flow 3.0 feet 0.110

3. Rock or Shale Cuts

a. Smooth and uniform 0.035
b. Jagged and irregular 0.040

Erosion. All channels shall be designed with the proper and adequate erosion control features.

3.8 Irrigation Ditches. Irrigation ditches shall not be used to transmit storm runoff unless such use is shown to be without hazard, substantiated by thorough hydraulic engineering analysis. Such analysis shall include investigation of required ditch flow and existing water rights below the design point. A Certificate of Water Rights and a letter of authorization, signed and dated by an authorized officer or representative of the owner of the ditch, shall be submitted for any contemplated use or modification of irrigation ditches for storm runoff.