Drainage Design Criteria

Town of Silverthorne

SILVERTHORNE
COLORADO

C. 1980

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1.0 General

1.1 Introduction

The Town of Silverthorne considers storm and snow melt drainage to be of significant importance to the orderly development of the community. While affected by criteria developed for other infrastructure systems, orderly development of the drainage system requires special consideration of its own requirements. The purpose of this Section is to provide prospective builders and developers with specific design requirements, criteria, and analytical methods to be utilized in the Town of Silverthorne. In using this document, the builders, developers, and their professions need to recognize that there are many varied conditions to be encountered within the Town and that the requirements herein are to be considered minimums. The builders and developers still retain the responsibility to conduct additional investigations and/or use more stringent designs to meet the conditions encountered.

The Town of Silverthorne has completed a Drainage Master Plan encompassing the corporate Town limits as of January 1980. The Drainage Master Plan is conceptual in scope and identifies the location of significant drainage paths, flows, design concepts, and approximate size of required drainage structures that could be identified at the time the report was completed. In addition, the Town has completed pre-design level drainage studies in some areas.

The Drainage Master Plan describes the Goals, Objectives, Principles, and Policies adopted by the Town of Silverthorne, and this section of the Developer's Handbook is intended to be used in connection with the Drainage Master Plan. In the area of drainage, Silverthorne's overall goal is to have a unified program that eliminates and/or avoids property damage and life hazards that can be caused by surface flooding and property damage caused by high groundwater. Specific objectives include:

- Systematically reduce the existing level of flood damages and nuisance water for street drainage and maintenance;
- Ensure that corrective works are consistent with the overall goals of the Town;
- Minimize erosion and sedimentation problems and enhance water quality;
- Plan for both the large flooding events and the smaller, wore frequent, flooding by providing both major and minor drainage systems; and
- Minimize future operational and maintenance expenses

1.2 Abbreviations

USDCM. Urban Storm Drainage Criteria Manual, Urban Drainage and Flood Control District, Denver Colorado.
NOAA. National Oceanic and Atmospheric Administration
Q = Discharge, usually in cubic feet per second
C = Coefficient used to measure degree of imperviousness in Rational
Formula I = Intensity, measured in inches per hour
A = Area, measured in acres cfs = cubic feet per second
1034. Summit County Regulation 1034 pertaining to water quality.

1.3 General Description of Drainage System

Relative to the purpose served, the drainage system is composed of two separate and distinctive drainage components, the minor drainage system (also called the initial drainage system) and the major drainage system. The minor drainage system serves a convenience function for people and transportation. The minor drainage system is designed for runoff frequencies ranging from two (2) to ten (10) years. The major drainage system serves a function of protecting lives and property against potential major damages from a frequency of the 100-year runoff. The major drainage system also preserves primary roads for use by emergency equipment. The major drainage system can be further described as that route which runoff follows during a large rainfall event, whether or not the route is planned and designed and whether or not development is wisely situated relative to that route.

While separate as to purpose, the minor and major drainage systems relate to one another. The small swales and pipes, and the roadside ditches and gutters feed into the major drainage system. Often a well-planned major drainage system can substantially reduce the cost of the minor drainage system. In any case, it is necessary for outfalls (usually major drainage) to exist with capacity to accept the runoff from the minor system without causing a greater burden or hazard to other properties.

Within the Town's area of interest, the ability of the major drainage system to transport larger runoff events varies widely. Downstream of where development is occurring, much of the existing major drainage system has a limited capacity. Furthermore, although downstream drainage conveyance facilities may increase, the work will be accomplished by individual developers as the land is developed, which may be a number of years in the future.

As a result, detention is required for all sites and subdivisions, except single-family and duplex units in existing subdivisions. New subdivisions of all types require detention to limit flow rates to historic levels; however, on-site detention will generally not be permitted.

In addition to the conceptual level design, many pre-design level reports have been completed (or may be completed) within the same area as encompassed by the Conceptual Drainage Master Plan. Land outside of the Conceptual Master Drainage Plan area requires development of a Master Drainage Plan at the time of annexation or subdivision approval. In addition, due to the fact that many unplatted areas within the Town boundaries do not have approved drainage master plans, these parcels require approval of a master drainage plan along with other development approvals.

Because this policy has been followed for past annexations, pre-design level studies may be available at many locations within the Town of Silverthorne. Where sufficient land planning had been completed or sufficient development had occurred prior to the completion of the Master Drainage Plan, flow rates, flow paths, approximate sizes of facilities, and approximate location of facilities may be known. If a parcel has not been studied, or if a substantial change is proposed compared to the conditions at the time of the Master Drainage Plan preparation, the developer may be required to undertake additional investigation as a part of the platting or site approval process.

Responsibility for the costs of design, construction, and maintenance are as shown in Table 1. With few exceptions, it is the intent of the Town that developers design and constrict all drainage facilities passing though or adjacent to the property being developed. The design of these drainage facilities must be compatible with the requirements of the Master Drainage Plan of the Town and/or the subdivision and must also be compatible with the conditions of adjacent properties. In other words, it is not permissible to alter the drainage conditions relative to adjacent sites simply to suit the purposes of the site that is being developed.

1.4 Submittal Requirements

Drainage reports should be completed in a professional manner under the direct supervision of a Professional Engineer licensed in the State of Colorado. It is not intended that the analysis for a 1/2-acre site with no off-site tributary run-off would be as complex as would be required if 200-acre new subdivision. It is required that the builders and developers discuss the requirements with the Town's staff prior to undertaking the drainage investigation, which will be discussed at the Pre-Application Conference.

1.5 Policies

Except as revised by the requirements of this document, the Town of Silverthorne requires that drainage planning and design be completed in accordance with the Urban Storm Drainage Criteria Manual (USDCM) as published by the Urban Drainage and Flood Control District in Denver, Colorado. In additional the hydrologic methods employed shall be one described as acceptable in this document.

The Town has adopted specific policies which become criteria when applied to the design of drainage facilities. The following is a partial list of those policies:

- It will generally be required to maintain pedestrian access through private developments for major drainage facilities for maintenance purposes; Figures 1 and 2 illustrate this concept with respect to streets. The roadside ditches, culverts, streets and gutters, inlets, and storm servers are designed first to meet the criteria of the minor stoma system requirements, which is either a 2-year or 5-year event. The depths of flow resulting from the 100-year event are checked assuming the facilities (if any) for the minor storm event are in place. In the instances where inundation requirements or depth limitations of major drainage criteria are not rivet, facilities are installed or enlarged sufficiently to reduce the flooding depths to allowable limits.

1.6 Hydrology

Requirements for hydrologic analyses range front the simplest procedures to rigorous procedures. It is the intent of this section to provide the designer with a list of hydrologic methods acceptable to the Town, as well as the limitations which apply to those methods. When possible, acceptable coefficients and applicable design parameters will be listed.

It is acknowledged that there are many hydrologic methods that could be used in the Silverthorne area; however, the methods listed for use in Silverthorne have been calibrated to the unique aspects of the area. As a result, other hydrologic methods will not be accepted unless the alternate methods are specifically approved by the Town.

Figures and 4 are derived from the NOAA Precipitation Frequency Atlas of the Western United States, Volume III, Colorado, 1973 and shall be used as the rainfall data in Silverthorne. The following methods are described for their use in Silverthorne.

1.6.1 Rational Method

The specific method to be employed is known as the Summation Rational Method and is described in the USDCM. The formula is:

$$Q=CIA$$

in which,

Q = discharge in cubic feet per second (cfs)
C = coefficient used to estimate relative effects of infiltration and imperviousness
I = intensity of rainfall measured in inches per hour, as determined front Figure 4, for a duration equal to the time of concentration
A = Area, measure in acres

The use of this method is described in the USDCM, and depending on the version, “C” may be determined in different manners. The more recent versions of the USDCL4 eliminate the use on an additional coefficient which is used to account for antecedent precipitation, and uses a table consisting of specific coefficients for each frequency of storm.

Table 1 Responsibility for Costs

Legend *X = Town Responsibility* *O = Developer Responsibility* **-** *= Not Applicable*	Original Platted Town		Remainder of Existing Town			New Annexations	Town Initiated Action
	Site Review	Re Sub-Division	Site Review	Re Sub-Division	Sub-Division		
Design							
Existing Public Rows	X	X	X	X	O[1]	O	X
New Public Rows	X	O[1]	O[1]	O[1]	O[1]	O	X
Private Drainage Facilities	O	O	O		O	O	-
Construction							
Existing Public Rows	X	X	X	X	O	O	X
New Public Rows	X	O	X	O	O	O	X
Private Drainage Facilities	O	O	O	O	O	O	-
Maintenance							
Existing Public Rows	X	X	X	X	X	X[2]	X[2]
New Public Rows	X	O	X	O	O	O	X
Private Drainage Facilities	O	O	O	O	O	O	-

1 Town will prepare Master Plan for general drainage facilities and Pre-Design Reports for all facilities shown on Master Plan. Developer will provide pre-design report for all other facilities and all other drainage reports, designs, drawings and specifications.

2 Town will maintain drainage facilities in previously existing drainage easements. After the drainage facilities meet current Town Standards.

Table 2 lists the coefficients to be used for each application in Silverthorne. As with other aspects of this Manual, these coefficients are to be considered as the minimum required to undertake studies, and if conditions are encountered that are outside the range of values shown in the tables or in the figures, the more stringent of the conditions are to be applied by the Designer.

Table 2 Runoff Coefficients for Rational Method
Using Coefficients for Storms Greater than 10-Year

Coefficients					
Land Use	% Impervious	Frequency 2	Frequency 5	Frequency 10	Frequency 100
Business Commercial	95	.87	.87	.88	.89
Neighborhood	70	.60	.65	.70	.80
Lawns	0	.05	.10	.20	.40
Roofs	90	.80	.85	.90	.90
Streets					
Paved	100	.87	.88	.90	.93
Gravel	13	.15	.25	.35	.65
Drives and Walks	96	.87	.87	.88	.89
Undeveloped	0	.02	.05	.10	.20

Time of Concentration

Unless conditions exist for which Figure 5 does not apply, this figure is to be used for determination of the time of concentration, which is used to determine the rainfall intensity, "I", in the Rational Formula. It should be noted that this figure is only to be used with this method and is not to be applied to other methods used in this manual.

A further caution needs to be noted in the selection of roughness coefficients to be used with Figure S. It is common that a designer will use the "C" value of the Rational Formula for the roughness coefficient, which is a grove error. The values described on the graph are self-explanatory and should be used.

Limitations

The use of the Rational Method is limited to developed areas under 40 acres in size and to undeveloped basins less than 10 acres in size, or when specifically permitted by the Town. Under no conditions is the Rational Method to be used where on-site flows are to be combined with off-site flows. For this condition, hydrograph analysis will be required (See HEC-1).

FAA Method

An approach sometimes known as the FAA Method (See USDCM) is used for sizing detention basins in developed areas less than 5-acres in size and where on- site flows are not combined with off-site flows. For this latter condition, hydrograph analysis is required

(See HEC-1). (The Appendix to this section contains an example of the FAA Method type of analysis.)

We conclude that with the installation of the large intensive green roof, pervious pavement, Contech StormFilter, and grass buffers on site along with proper maintenance of these BMPs will allow for 700 E. Main St. to meet the criteria outlines in the City of Aspen's current Urban Runoff Management Plan.

1.6.2 HEC-1

This method is to be used in all conditions for when the Rational Formula is not suitable and when:

a) Flows have not been predetermined by the Town in previous studies and
b) On-site flows are combined with off-site flows which require routing techniques are required, or
c) The site is sufficiently large to be beyond the permitted limits of the Rational Formula.

Larger sites and basins require better tools and greater skills on the part of the designer; therefore, it is assumed that the designer has some knowledge of more advance hydrologic techniques. HEC-1 has been selected because of its widespread use and availability.

The following procedure was developed through calibration, using basins with some statistical data and correlation to other modeling that has been done in the Silverthorne area. The procedure for use of HEC-1 will be as follows:

a) Compute the hydrograph(s) required for the basins and design frequencies determined in conjunction with the Town, using the procedure outlined under HEC-1 Methodology,
b) Prepare a summary of the input data and output to be submitted to the Town for review, and
c) After examination of the results, additional runs, using adjusted input data, will be completed and summary data resubmitted to the Town.

This procedure is required due to the variability of the conditions that may be encountered.

HEC-1 Methodology.

The SCS Dimensionless Unit Hydrograph Method in HEC-1 (September 1981 version) will be used to simulate runoff from rainfall. The time of concentration will be estimated by using the nomographs shown on Figures 6 and 7. The loss functions to be used for the 100-year runoff calculations for non-urbanized basins are:

Initial Abstraction = 0.75"
SCS Curve Number = 40
Percent of Basin that is impervious = 1.0

Depending on the complexity of the Basin(s), other means of calibration may be required, including the use of a constant loss rate instead of the use of curves and percent imperviousness; however, this method requires substantially more time and will be used only when necessary.

Initial values for other than the 100-year runoff will be developed with the Town prior to commencement of modeling. The rainfall values will be determined from Figure 3. The rainfall distribution shall be according to the USDCM.

1.7 Criteria

The Town uses the USDCM for most of the drainage criteria, a copy of which is available for review in the Town's offices; however, the Town utilizes specific technical criteria which are required to meet the Town's standards that either are not addressed in the USDCM or are different due to climatic constraints and other geographical differences. This Section is concerned with the special criteria.

1. Design Frequencies

Except as noted, the design frequency for all conveyance facilities will be the 2-year event. When approaching major arterial streets, the design frequency for conveyance facilities will be the 5-year event. The following facilities will have a 100-year design frequency

- The Blue River Parkway (Colorado Highway 9 and US Highway 6),
- West Town Swale,
- Rainbow Drive Swale north of Palmers Drive (Bobo Ditch),
- Willow Creek,
- Straight Creek,
- Ryan Gulch and Salt Lick Gulch, including overflow paths,
- Drainage routes identified in the Eagles Nest Master Drainage Plan, and
- All storm water detention sites.

Regardless of the designated design frequency, the runoff rates from the 100-year event will be checked to determine if maximum criteria for street inundation are met and that no building openings are inundated. If the preceding conditions are not met, the conveyance facility sizes will be increased as needed to reduce flood depths and/or to eliminate probable inundation of building openings (i.e., all building openings shall be above the 100-year inundation level). Alternately, for proposed buildings, it may be possible to raise the building openings.

2. Street Drainage Criteria.

In general, it is expected that the street drainage system will usually consist of roadside ditches (or swales) and culverts. Specific design criteria for channels and culverts will be addressed later in this section. Curbs and gutters will be permitted under the conditions described in the Street Design Criteria section of this manual; however, the specific criteria will be addressed separately from roadside ditch type design.

The overall approach to storm water management includes using the street system to transport runoff front the minor storms to outfall facilities, leaving the streets usable for traffic. Greater depths of flow and more lane encroachment will permit the streets to carry runoff from major storm events at a sacrifice in the ability of the streets to transport traffic. No inundation of dwellings and buildings is permitted.

Cross Flow

Drainage flows may cross streets under two conditions. The first condition is cross pans, which are not always permitted. The second condition is at the crossing of drainage ways where the vast majority of the runoff will be carried in a culvert or bridge and excessive runoff is permitted to flow over the roadway. Except for cross pans, in no other instance is the flow from the minor storm frequency permitted to cross over the surface of roads. In addition, building inundation and other inundation which will adversely affect other properties will not be permitted. Under the latter conditions, cross street flow will only be permitted up to the level that will not cause building inundation. The depth of flow for valley pans (where permitted) and at crossings for drainage are listed in Table 3.

Table 3 Allowable Depth of Cross Street Flow at Drainage Ways

Street Classification	Minor Design Run-off	Major Design Run-off
Local and Collector	6” depth at crown or in cross pan flow line	12” depth above gutter
Arterial	None	6” or less over crown
Sheet Flow		

Sheet flow across street centerlines will not be permitted except on local streets. No cross-street flow will be permitted for flows less than the one-year run-off event.

Continuity of Grade

When streets intersect, the grade of the street with the highest classification shall continue uninterrupted. Cross pans will be permitted only on local streets. Cross pans combined with roadside ditches may be used; however, the depth of the roadside ditch will not be lessened to reduce the width of the cross pan. Configurations for cross pans are shown in the section of street design criteria.

Roadside Ditches

The roadside ditches will meet the geometry requirements listed in the Street Design Criteria section:

a) Permitted Inundation. The maximum permissible depths and maximum encroachments for roadside ditches are shown in Table 4.

Table 4 Maximum Permissible Depth and Encroachment for Roadside Ditches

Type of Road	Minor Storm	Major Storm
	Depth of Flow	
All Types	30”	36”
Local	Flow may spread to crown of street	Street right of way
Collector	Flow spread must leave at least one lane free of water	Flow shall remain in street right of way
Arterial	Flow spread must leave at least one lane free of water in each direction	Flow shall remain in street right of way. Maximum depth at crown = 6 inches

Figures 1 and 2 show the depth parameters as applied from Table 4. The most conservative parameter shall be applied.

b) Hydraulic Design. Theoretical capacities of roadside ditches shall be computed assuming that driveways will exist for access to adjacent property. Figure1 illustrates the geometric conditions that exist for driveways which span roadside ditches. As a result, the street capacity is limited to discharge which results in a depth of flow at the inlet of the driveway culvert of 18 inches for minor storm runoff limits, and the major storm discharge from a 36-inch headwater acting on the driveway culvert plus the flow over the top of the driveway embankment. This capacity shall be reduced by 80% to allow for plugging and trash which may hang- up behind the embankment.

Street Drainage

The maximum permissible depths for roadside and for curbs and gutters are as shown in Table 5.

Table 5 Maximum Permissible Depth and Encroachment for Curbs and Gutters

Classification of Road	**Minor Storm**	**Major Storm**
	Depth of Flow	
All Roads Top of Curb	18”	
Local	Flow may spread to crown of street	Flow shall remain in street right of way. Maximum depth in gutter = 12 inches
Collector	Flow spread must leave at least one lane free of water	Flow shall remain in street right of way. Maximum depth in gutter = 12 inches
Arterial	Flow spread must leave at least one lane free of water in each direction	Flow shall remain in street right of way. Maximum depth at crown = 6 inches. Maximum depth in gutter = 12 inches

Figures 1 and 2 show the depth parameters as applied from Table 5. The most conservative parameter shall be applied.

(a). Curb Cuts. When curb and gutter streets are permitted, curb cuts shall be permitted within 25 feet upstream on an inlet and shall not be made by building-up the gutter. Driveways shall slope up to an elevation equal to the top of the curb to prevent runoff front flowing onto adjacent property.

(b). Hydraulic design. Theoretical capacities of curb and gutter sections shall be computed using the nomograph shown of Figure 8. After theoretical capacities have been obtained, these values shall be reduced according to the values obtained from Figure 9.

3. Open Channels

Open channels, including roadside ditches, will meet the criteria listed in this item. The criteria listed in this item apply to both major and minor drainage facilities and shall be applied for the specific design frequency required. All major drainage channels will meet these design requirements for the 100-year event.

(a). Grass-lined Swales. Design will generally be based on a natural waterway appearance. Criteria included:

- Design velocity for the 100-year discharge will not exceed 7.0 fps for heavily grassed and irrigated channels, and 5.0 fps for non-irrigated, grass-lined channels.
- Side slopes generally 4 (horizontal): 1 (vertical) or flatter. Side slopes of 3:1 are acceptable if channel maximum velocities are reduced by 1.0 fps, and if mowing is not required for maintenance.
- Freeboard will not be less than 1.0 foot.
- Riprapping, check dams, or drop structures will be used singly or in combinations to reduce scour, particularly at pipe outlets.

(b). Armored Channels. Where well-graded combinations of gravel and large stones exist, these channels may be used where the following criteria are met.

- Design velocity less than 5.0 fps.
- Design depth less than 2.0 feet.
- Maximum side slopes 2:1 or flatter.

(c). Roadside Ditches. These facilities must assume characteristics appropriate to the different conditions under which they are used. Unless special channel armoring is approved by the Town, the maximum slope along roadside ditches will be 2.0%. Drops and check structures may be used as required to meet the maximum slope requirement. All roadside ditches not armored shall be grassed.

The side slopes shall meet the criteria listed in the Streets Section. When approved by the Town, side slopes that daylight on the opposite side of the ditch from the road will have steeper than 3:1 side slope when in rock or when armoring is used.

4. Storm Sewers

Storm sewers are infrequently used; however, applications for their use will occur. The following criteria shall apply to the design and installation of storm sewers.

a) The pipe may be either corrugated metal pipe (cmp), high density polyethylene (hdpe) or reinforced concrete pipe (rcp). The materials used shall conform to the applicable AASHTO provisions of the **Standard Specifications for Highway Materials.**
b) The minimum cover shall be 3.0 feet.
c) A minimum of 50 % of any storm server segment between manholes shall be below the frost line (usually 7.0 feet).
d) The maximum velocity will be 15 fps.
e) The minimum pipe diameter shall be 18 inches.
f) Manholes meeting the requirements of Figures 10 & 11 shall be at maximum intervals of 400 feet for pipe 24 inches and smaller, and at maximums intervals of 500 feet for pipe larger than 24 inches.
g) The design water surface should be at least 6 inches below the gutter grade or inlet grate (or opening).

h) The outlet location of the storm sewer must be approved by the Town, and outlet protection must be installed as approved by the Town. Flap gates will generally be required unless an energy dissipates is used which prevents entry to the storm sewer system.
i) Storm servers must be straight between manholes.
j) Hydraulic gradeline computations must accompany the final design drawings for review and approval by the Town.
k) Inlets shall meet the requirements shown in Figures 12 & 13. Inlet capacity shall be computed in accordance with USDCM, including the use of reduction factors.
l) Storm sewers which start with inflow directly into the pipe shall have an end section and trash rack in accordance with the requirements detailed in the section on culverts.

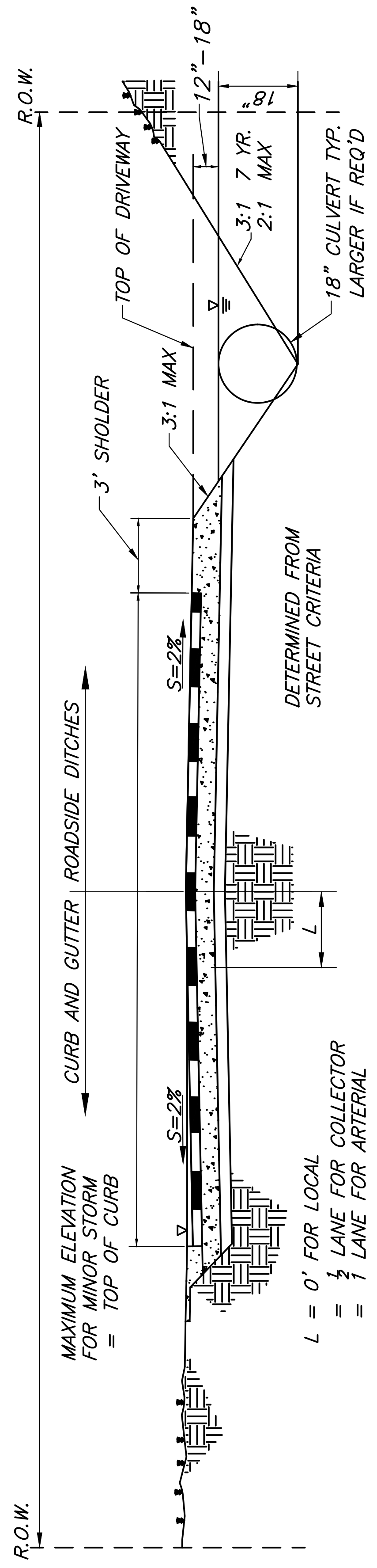
6. Detention Ponding

a) Snow storage will not be permitted in detention facilities near outlets or inlets.
b) Outlet controls will be v-notch weirs, computed in accordance with generally accepted formulas. Orifice type controls may be permitted on larger facilities when the orifice size exceeds 24 inches and when acceptable overflow provisions are provided.
c) The designers are encouraged to use submergence of the control weir(s) to maximize the angle of the weir opening and the practical depth of ponding.
d) Except at inlets and outlets, riprap will not be permitted.
e) Except near outlets, the side slopes shall not be steeper than 4:1.
f) When approved by the Town, walls may be used to increase the detention volume available.
g) The minimum slope of pavement to be inundated by detention is one percent.
h) As noted in the example, detention outlets should be depressed when adjacent to pavement to prevent saturation of the pavement's subgrade.
i) Unless otherwise approved by the Town, detention areas will be grassed.
j) Detention sites should be designed to facilitate sediment removal. Larger detention sites should have a concrete invert to permit movement by motorized removal equipment.
k) Detention facilities may be sized using 0.2 acre-feet of detention for each acre of impermeable developed area (including graveled areas), or the design may employ one of the hydrologic design approaches described in Hydrology.
l) The outlet works shall be designed to release runoff at the historic rate. Over-detention in one area to eliminate the need for detention in another area may be permitted when it is shown that:
    - The rate of outflow from the un-detained area cannot be routed through an area to which it did not previously flow nor, can it exceed the historic flow rate at the point where it exits the site (In no case will flows be permitted to be altered in such a manner as to shift or add to the burden of adjacent property owners).
    - At any time during the duration of the storm, the combination of flow rates from the various areas does not exceed the historic flow rate.

m) Detention facilities will be designed to detain the excess flow generated from the 100-year event.

n) When off-site flows are routed though the detention facilities, the hydrologic analysis shall be completed which shows that the proposed facilities will meet the flow release requirements, both for the site itself and for the site when combined with the off-site runoff

Figure 1 Street Criteria for Minor Storm



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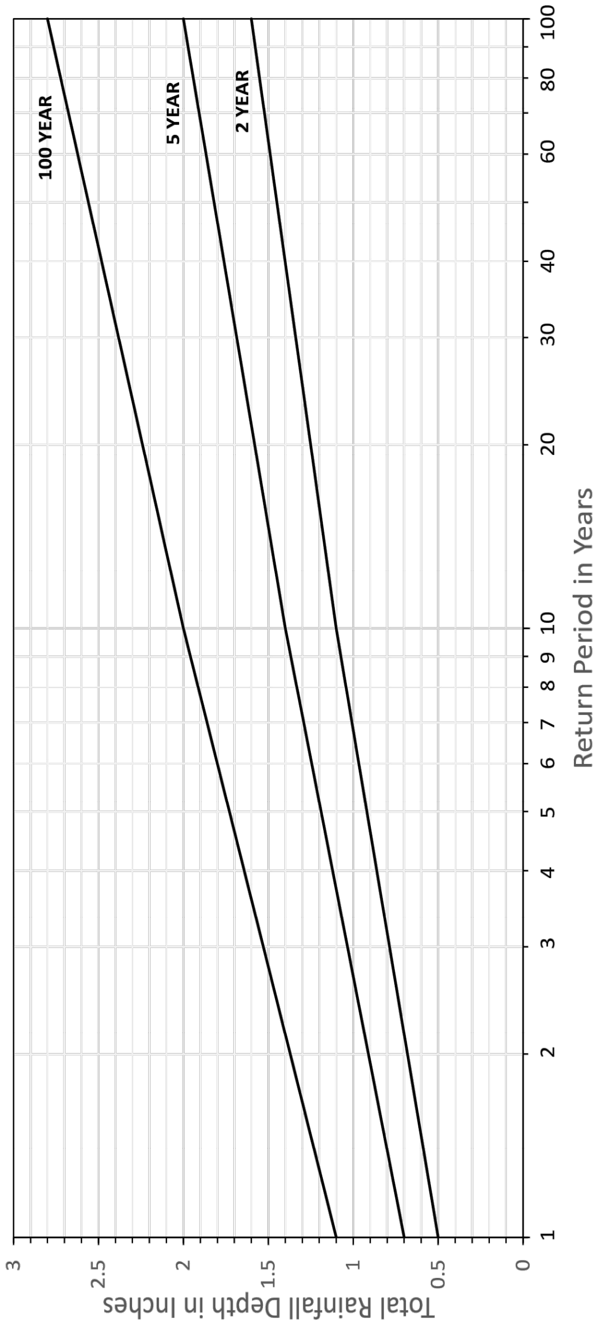
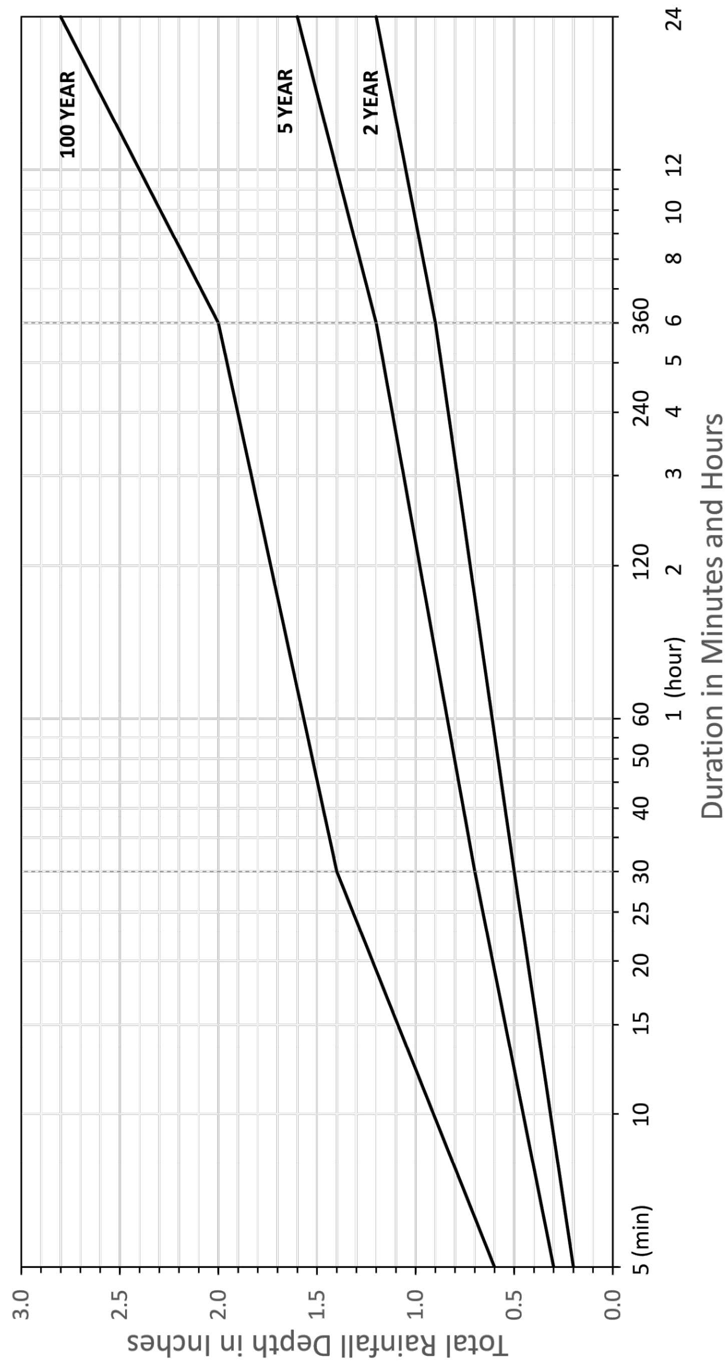
Street Criteria for Minor Storm

Figure 1

Figure 2

Figure 3 Rainfall Depth Duration





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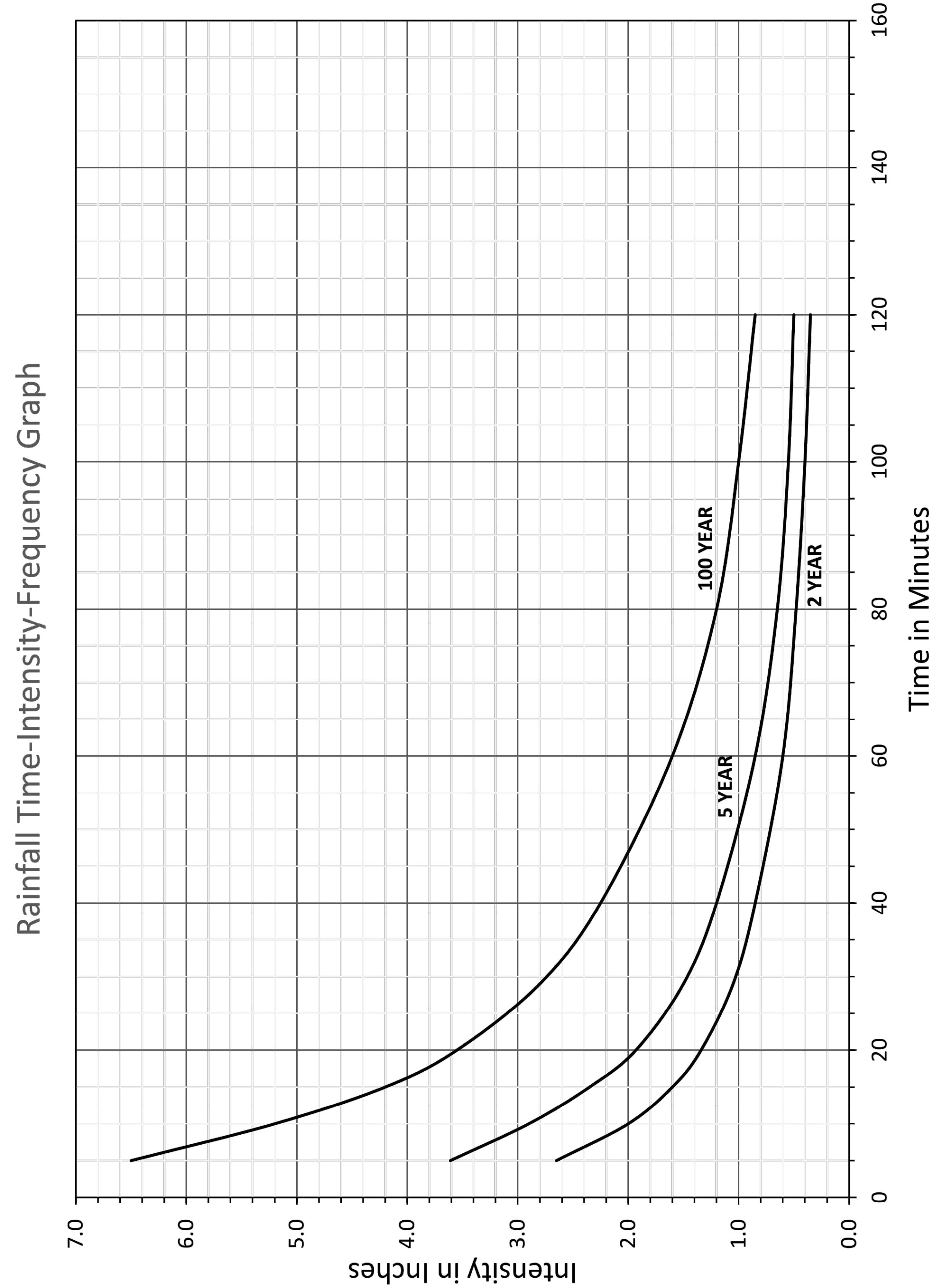
Rainfall Depth-Duration-Frequency Graph

Figure
3

Figure 4 Rainfall Time -Intensity-Duration



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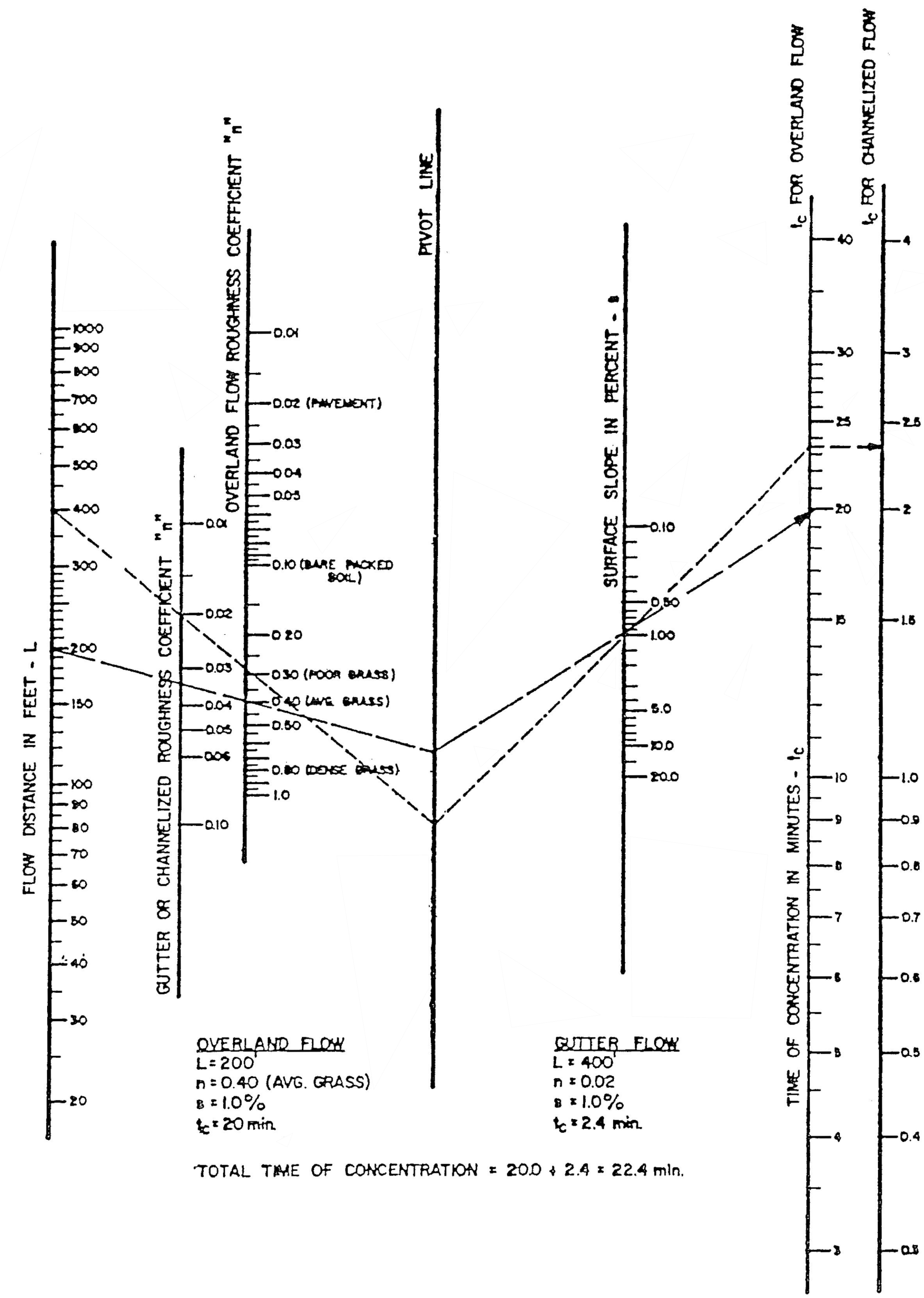
Rainfall Time-Intensity-Frequency Graph

Figure 4

Figure 5 Nomograph for Time of Concentration



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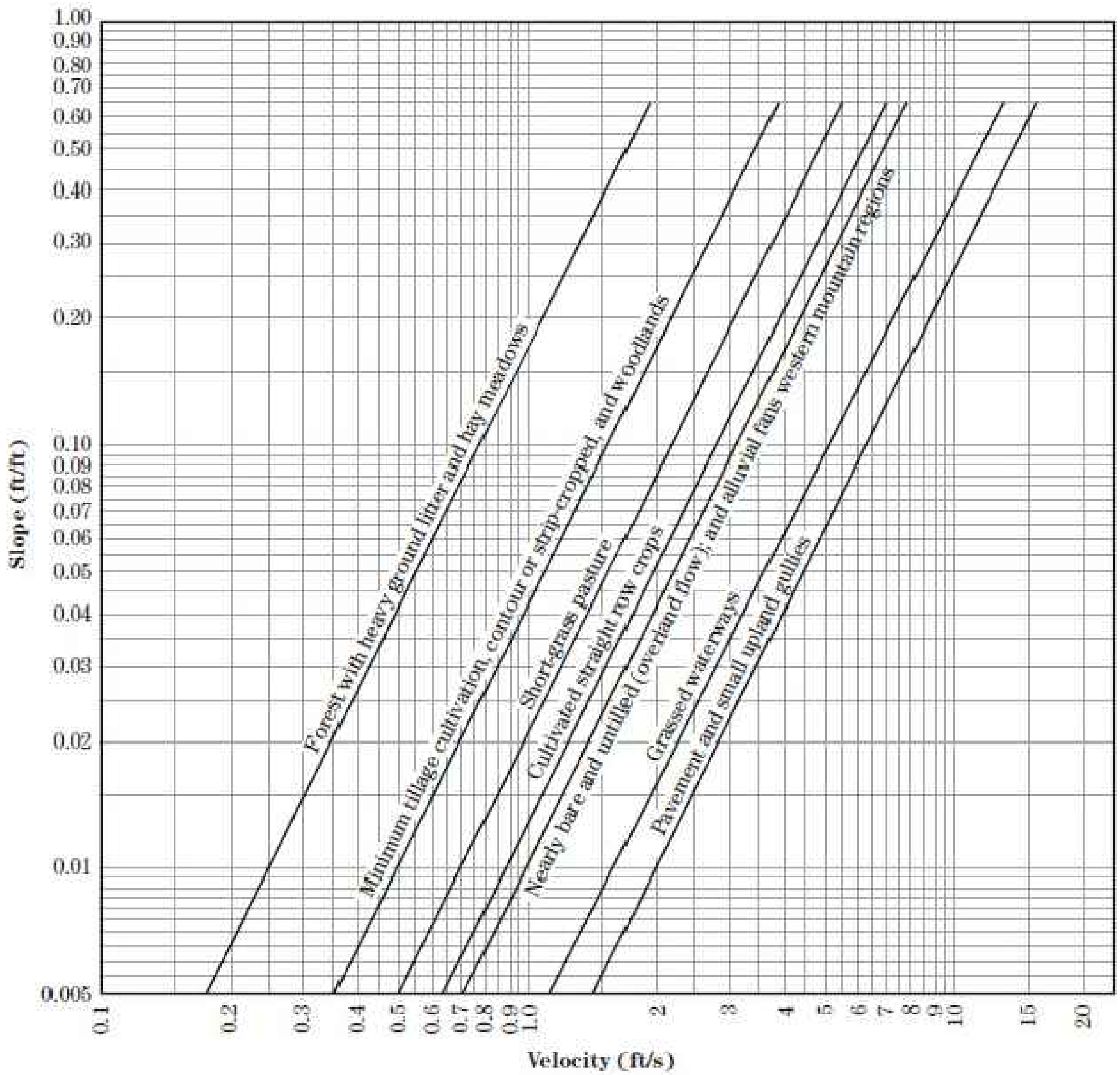
Nomograph for Time of Concentration

Figure 5

Figure 6 Average Velocities for Estimating Travel Time for Overload Flow



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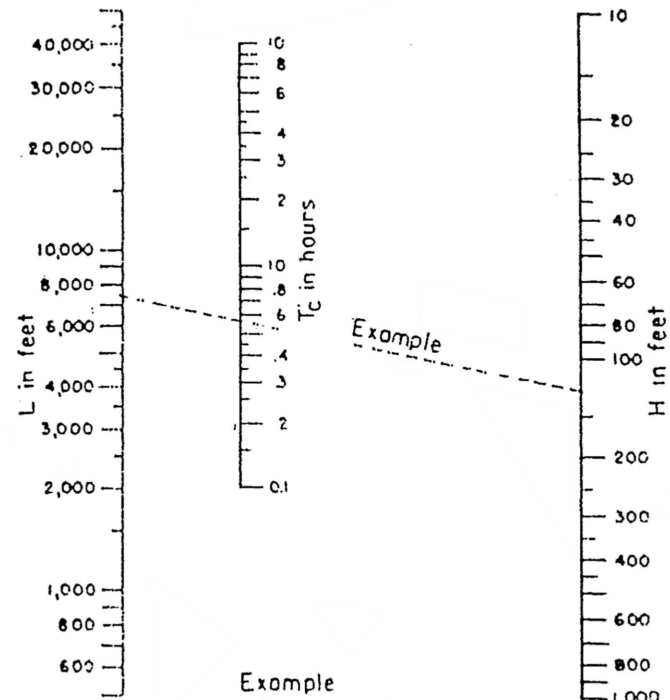
Average Velocities for Estimating Travel Time for Overland Flow

Figure 6

Figure 7 Estimating T_C from Lengths and Slopes

C. ESTIMATING T_c FROM LENGTHS AND SLOPES



Example
L = 7,250 feet
H = 130 feet
then T_c = 0.57 hours

(a) Nomograph (SCS Guide)

L = length of longest water-course in feet
H = difference in elevation in feet between outlet point and divide

(b) Solution may be made by equation from California Culverts Practice, California Highways and Public Works, September 1942.

$$T = \left(\frac{11.9 L^3}{H}\right)^{0.385}$$

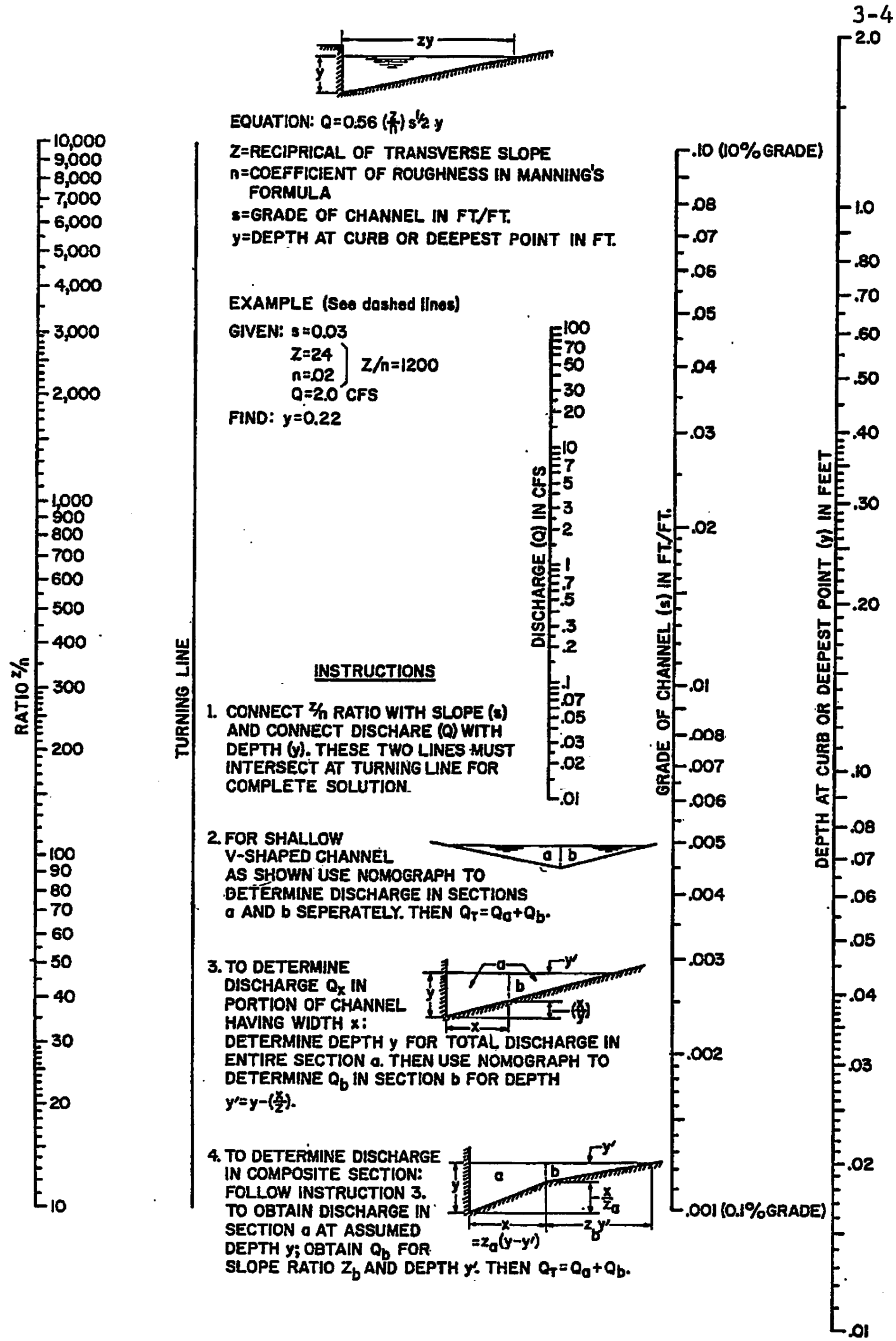
T = T_C in hours
L = length of longest watercourse in miles
H = elevation difference in feet

Lag, L, (SCS, Guide) may be estimated directly for a basin by subdividing into tributary drainage subareas and using the relationship:

$$L = \frac{\Sigma a_x T_x}{A}$$, where

L = lag in hours
a_x = the x-th increment of area in sq. mi.
T_x = travel time in hours from center of a_x to main basin outlet
A = total area of basin, sq mi.

Figure 8 Nomograph for Flow in Triangular Gutters



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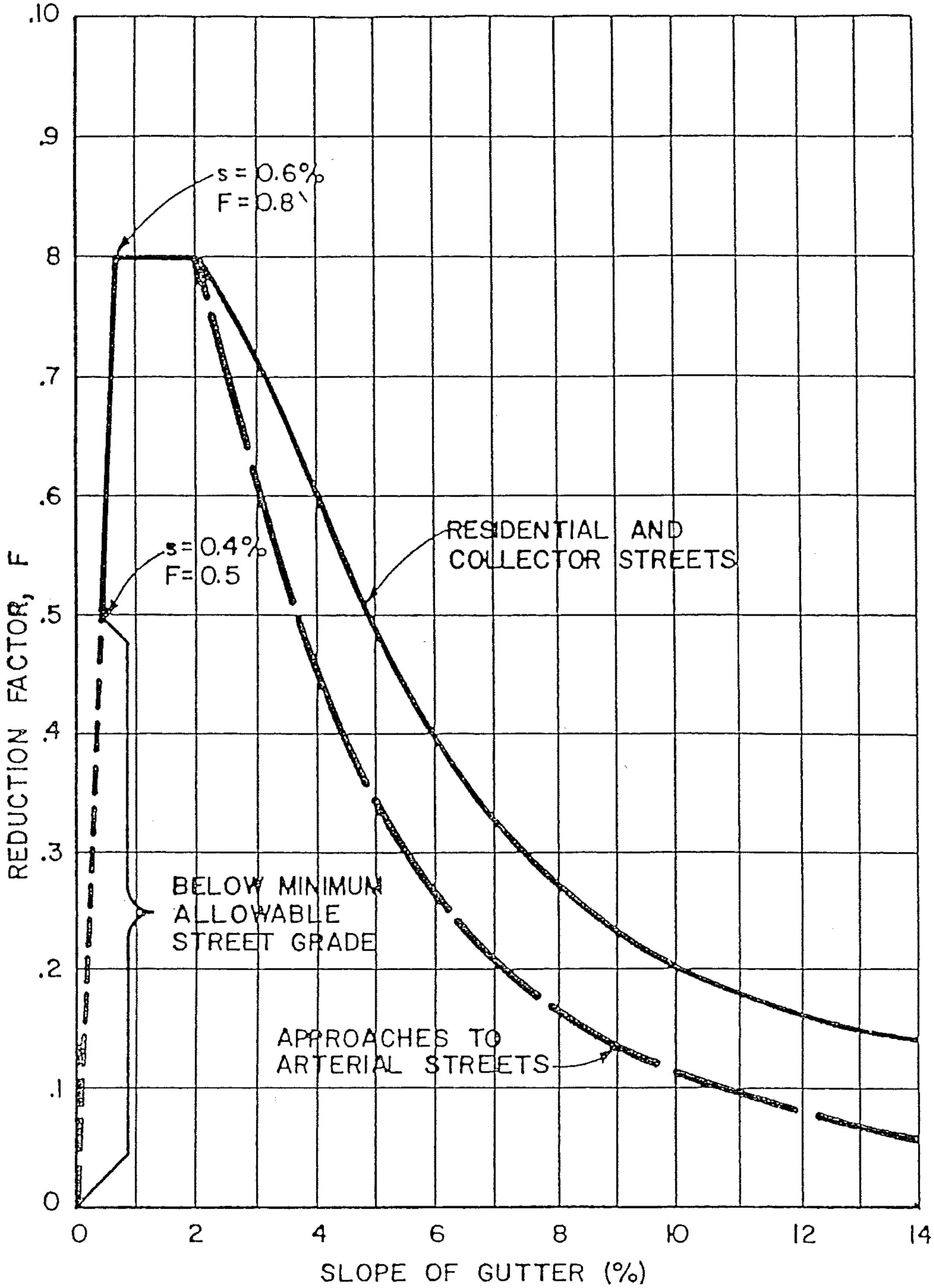
Nomograph for Flow in Triangular Channels

Figure 8

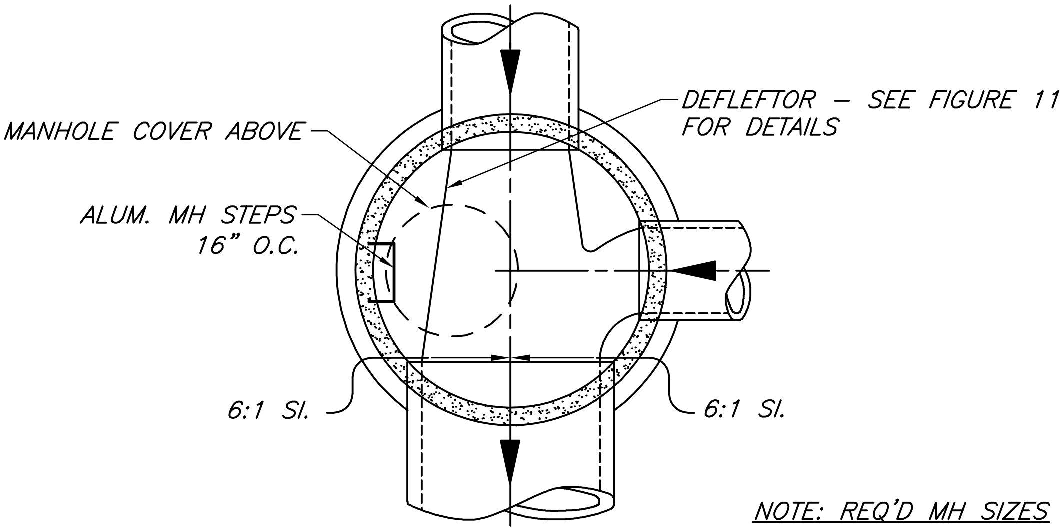
Figure 9 Reduction Factor for Allowable Gutter and Roadside Ditch Capacity



Apply reduction factor for applicable slope to the theoretical gutter capacity to obtain allowable gutter capacity

SILVERTHORNE COLORADO	Reduction Factor for Allowable Gutter and Roadside Ditch Capacity	Figure 9

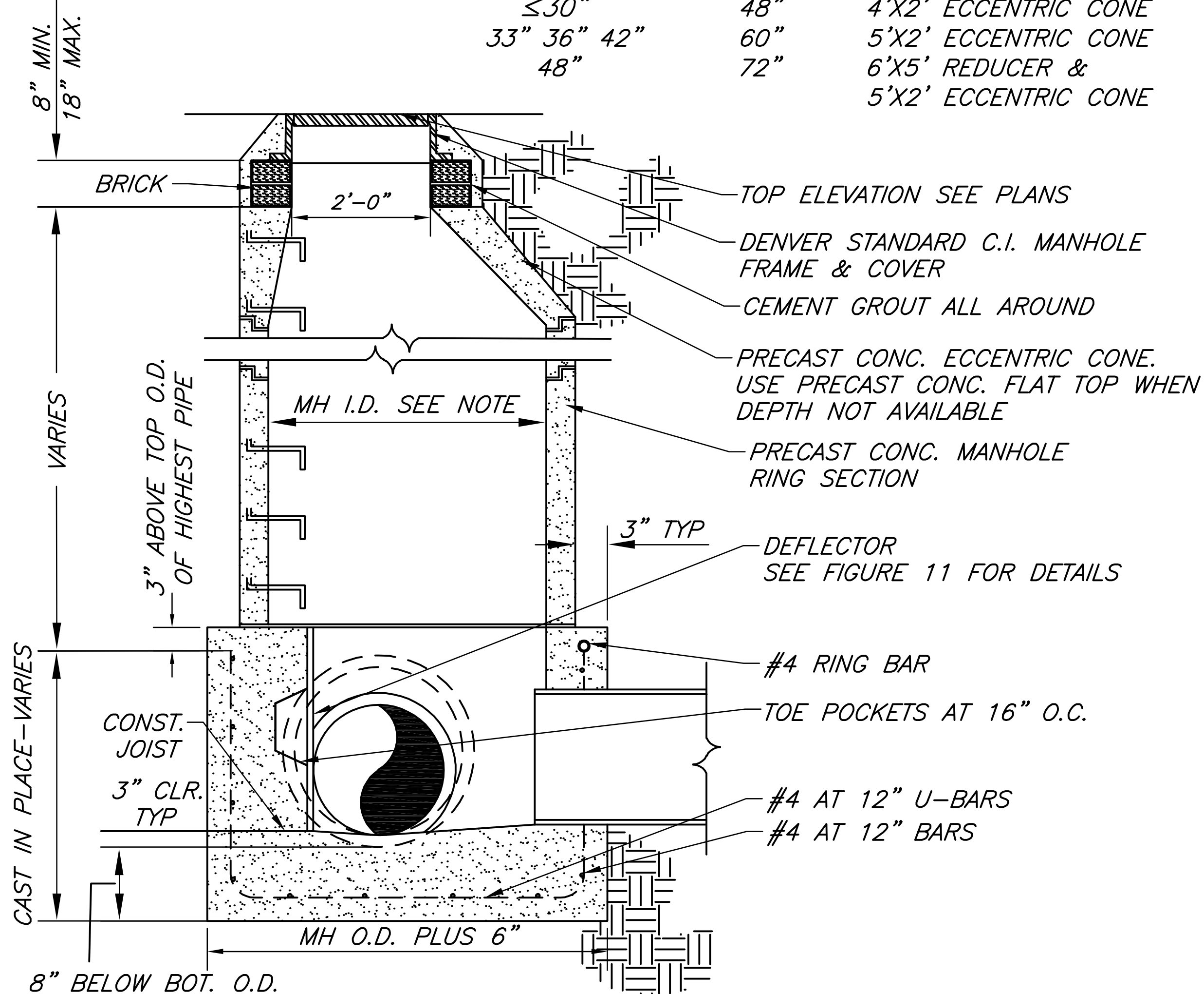
Figure 10 Storm Sewer Manhole Details



PLAN

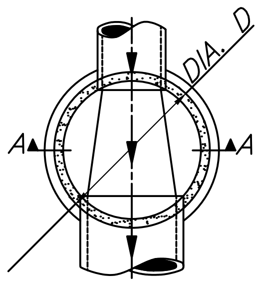
NOTE: REQ'D MH SIZES

LARGEST PIPE I.D.	REQ'D MH I.D.	CONE REQ'D
≤30"	48"	4'X2' ECCENTRIC CONE
33" 36" 42"	60"	5'X2' ECCENTRIC CONE
48"	72"	6'X5' REDUCER & 5'X2' ECCENTRIC CONE

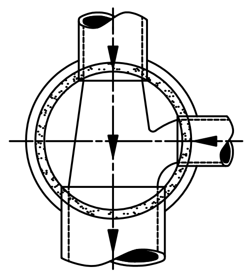


SECTION

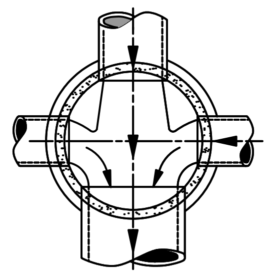
Figure 11 Storm Sewer Deflector Details



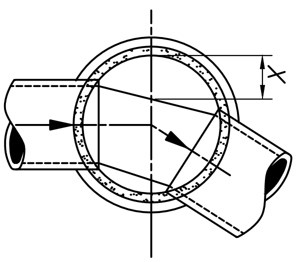
THROUGH PIPE ONLY



THROUGH PIPE WITH ONE LATERAL

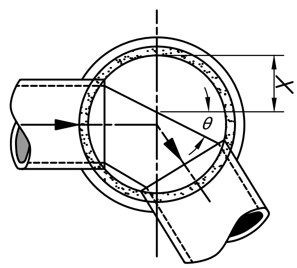


THROUGH PIPE WITH TWO LATERALS



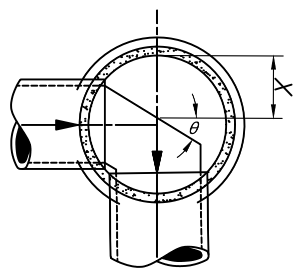
SLIGHT ANGLE

X LESS THAN $\frac{1}{3}$ D



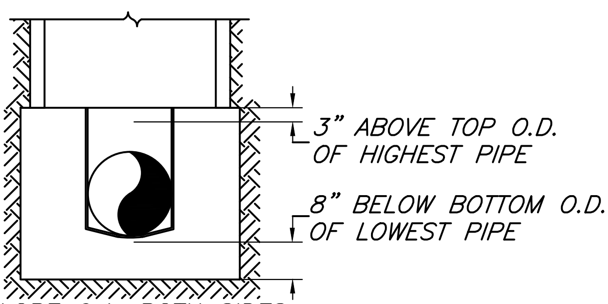
INTERMEDIATE ANGLE

X EQUALS $\frac{1}{3}$ D
θ LESS THAN 45°

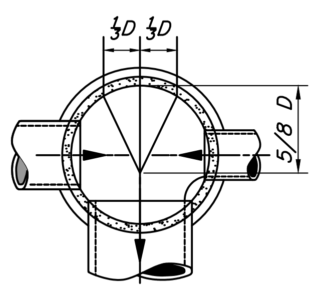


SHARP ANGLE

X EQUALS $\frac{1}{3}$ D
θ EQUALS 45°



SLOPE 6:1, BOTH SIDES
SECTION AA — TYPICAL



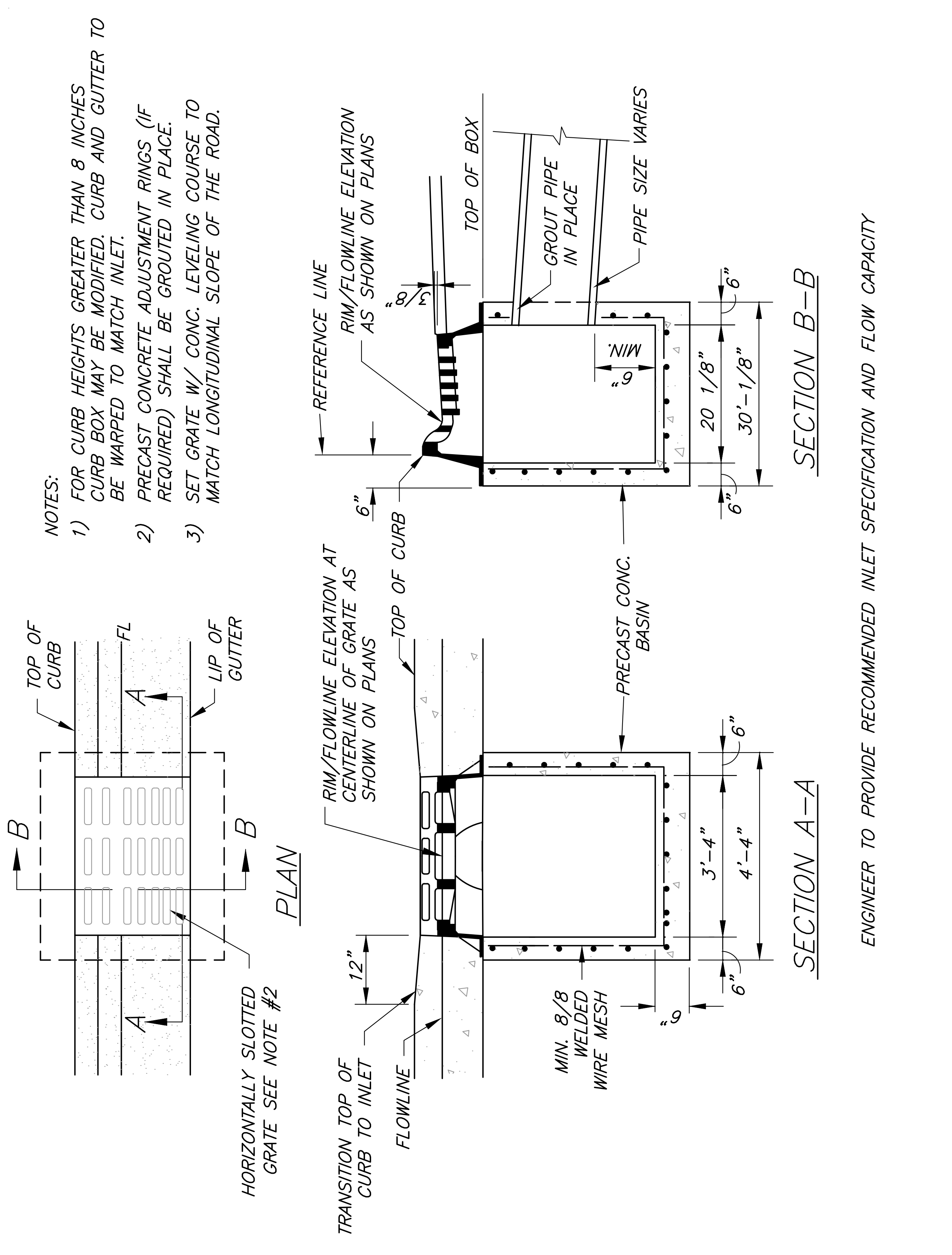
OPPOSED LATERALS

SILVERTHORNE COLORADO

Storm Sewer Deflector Details

Figure 11

Figure 12 Detail of Storm Sewer Inlet

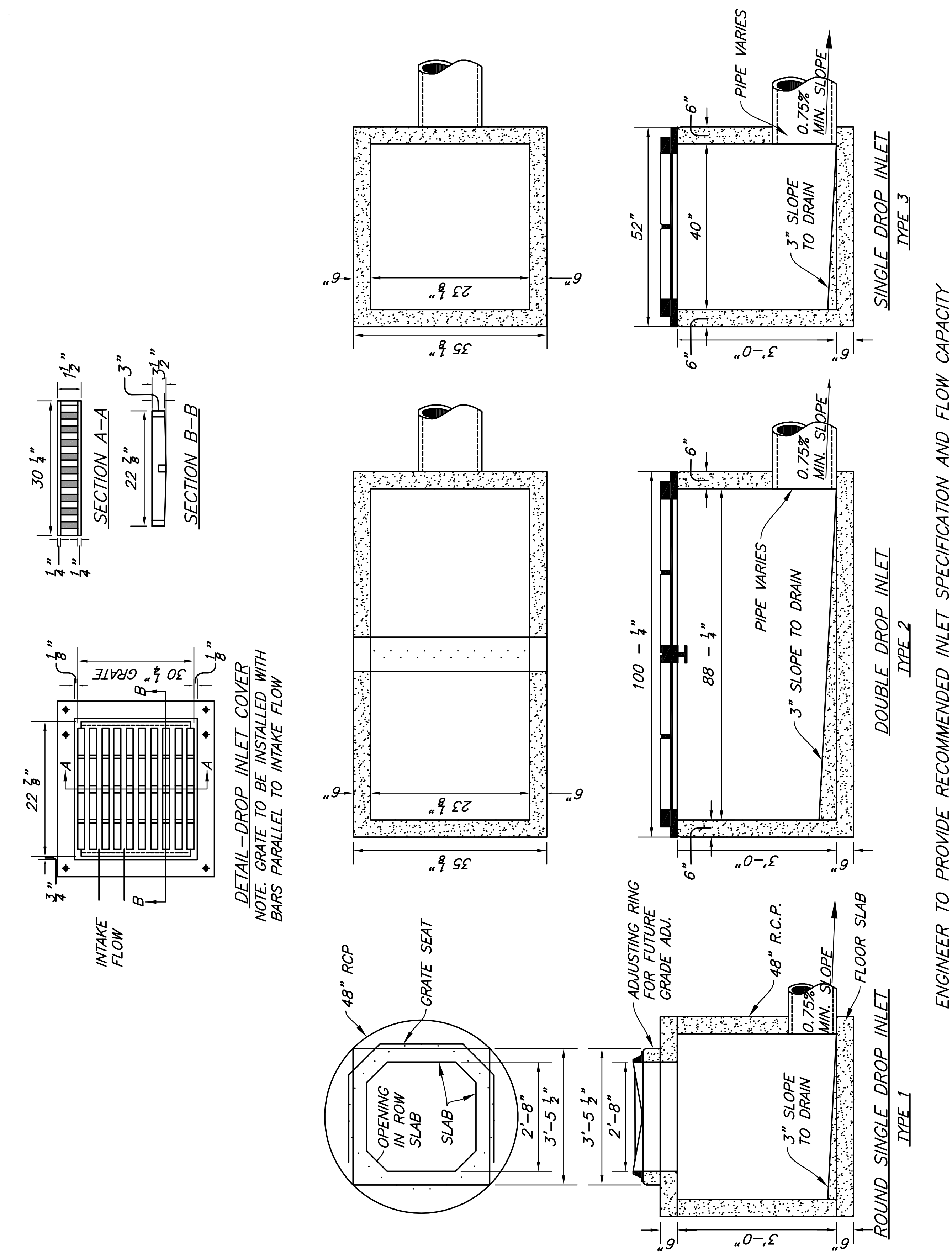


SILVERTHORNE COLORADO

Detail of Storm Sewer Inlet

Figure 12

Figure 13 Detail of Storm Sewer Inlet



SILVERTHORNE
COLORADO

Detail of Storm Sewer Inlet

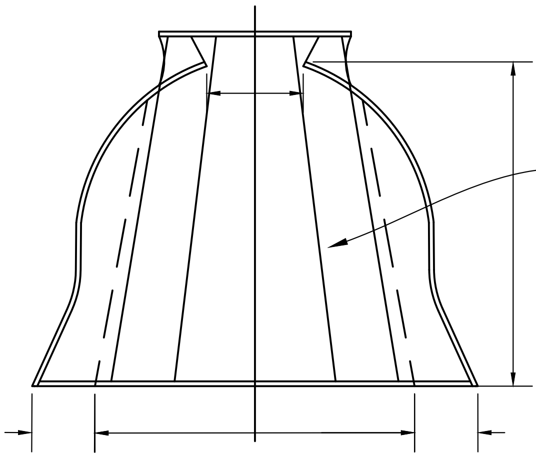
Figure
13

Figure 14 Reduction Factor for Allowable Gutter Capacity

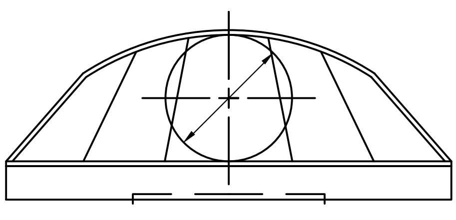
Figure 15 Capacity of Grated Inlet in Sump

Figure 16 Capacity of Grated Inlet in Sump

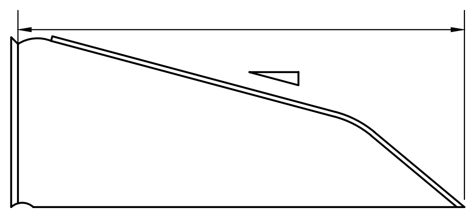
Figure 17 Trash Rack Detail



PLAN



ELEVATION

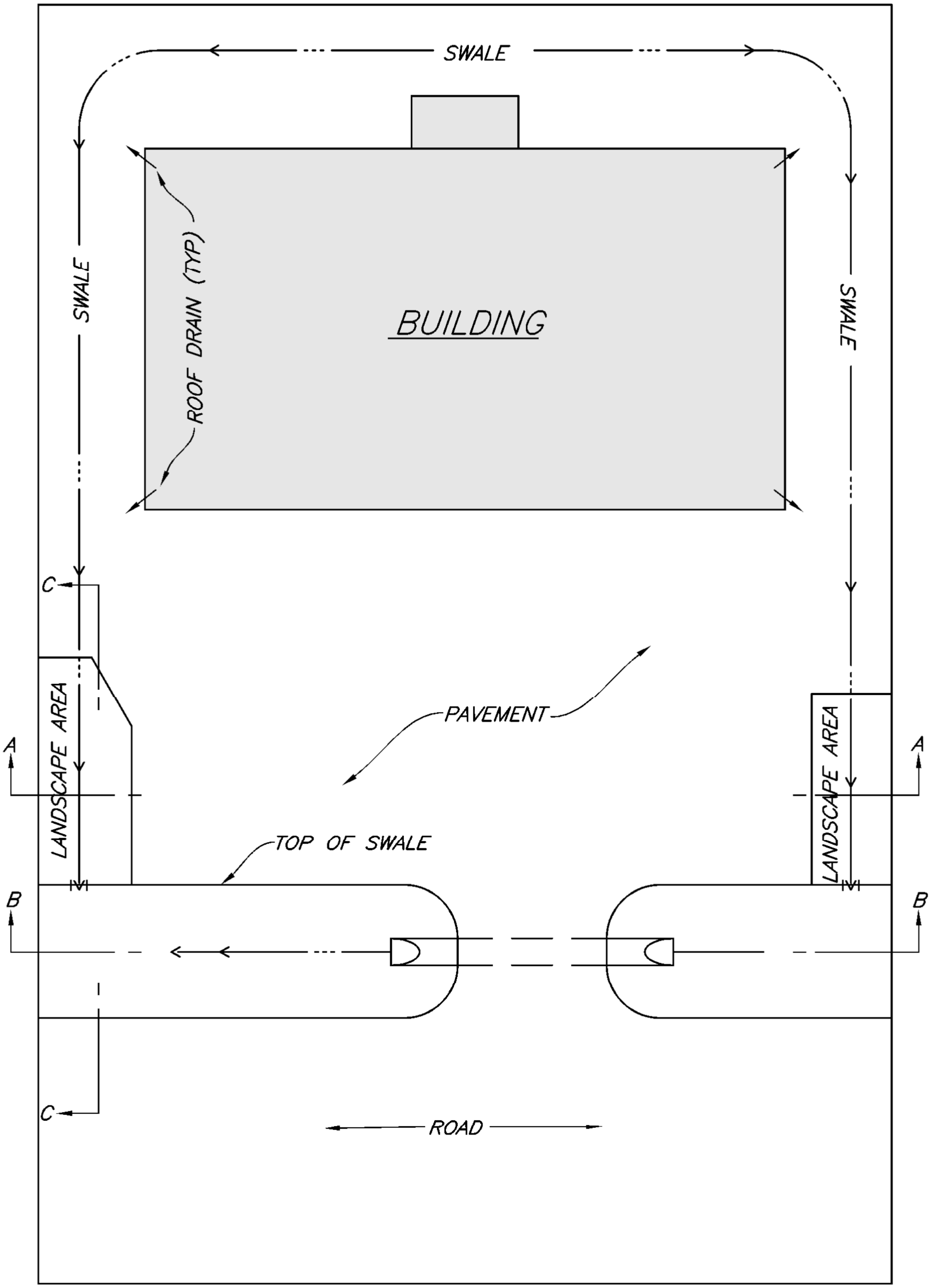


TYPICAL CROSS SECTION

SILVERTHORNE COLORADO

Trash Rack Detail

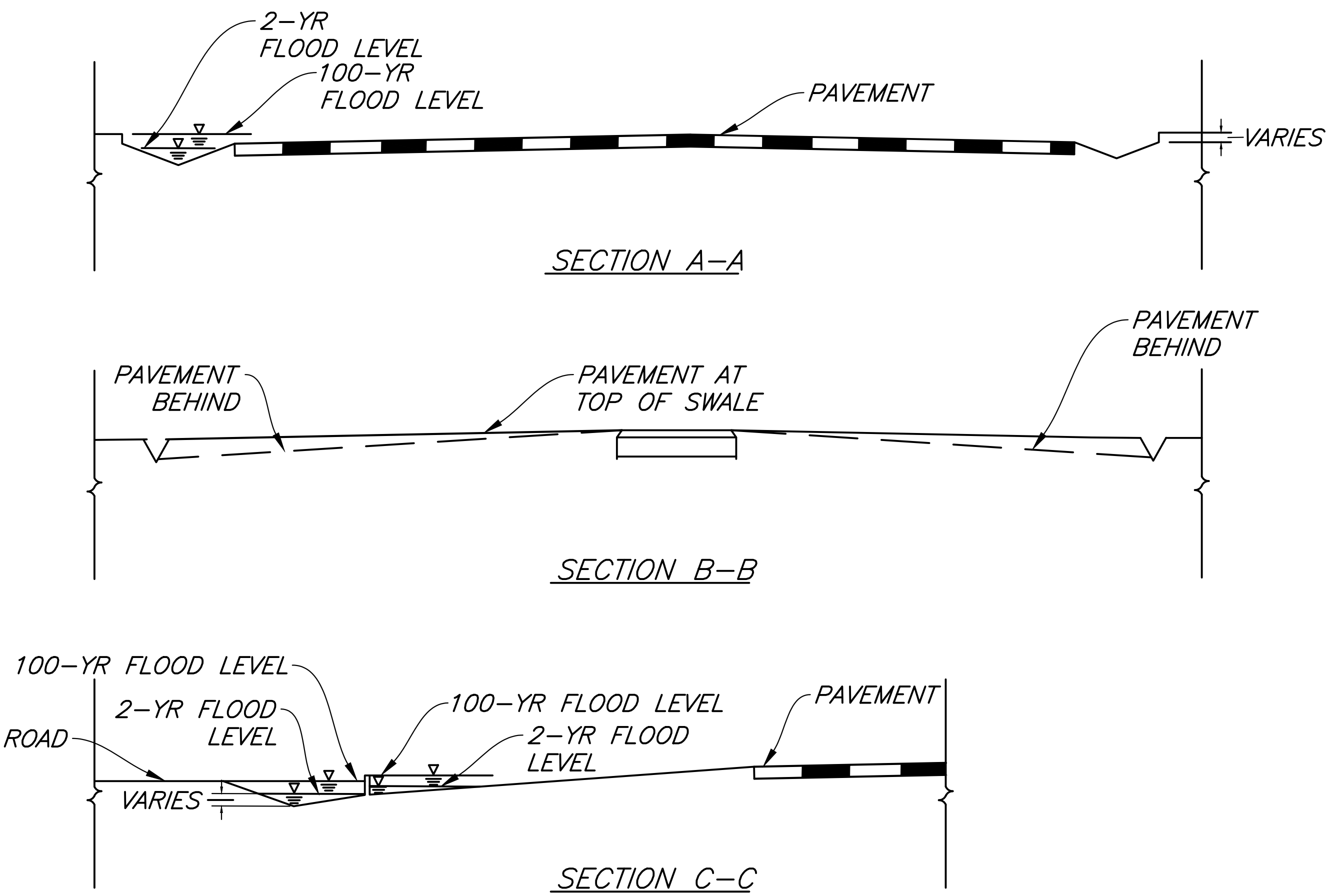
Figure 18 Cross Section Typical On-Site Detention



SILVERTHORNE COLORADO

Typical Onsite Detention

Figure 18



SILVERTHORNE COLORADO

Typical Onsite Detention

Figure 19