11.11.9 Minimum Grades

All storm drains should be designed such that velocities of flow will not be less than 0.9 m/s (3 ft/s) at design flow. For very flat grades the general practice is to design components so that flow velocities will increase progressively throughout the length of the pipe system. The storm drainage system should be checked to be sure there is sufficient velocity in all of the drains to deter settling of particles. Minimum slopes required for a velocity of 0.9 m/s (3 ft/s) can be calculated by the Manning's formula or use values given in Table 11-7.

$$S = \frac{(nV)^2}{R^{4/3}} \qquad \textbf{(11.18)}$$

Table 11-7

Minimum Slopes Necessary To Ensure 0.9 m/s (3 ft/s) In Storm Drains Flowing Full

Pipe Size, mm (in)		Full Pipe, m^3/s (ft^3/s)		Minimum Slopes m/m (ft/ft) n = 0.012	n = 0.013	n = 0.024
200	(8)	0.030	(1.05)	0.0064	0.0075	0.0256
250	(10)	0.046	(1.64)	0.0048	0.0056	0.0190
300	(12)	0.067	(2.36)	0.0037	0.0044	0.0149
375	(15)	0.104	(3.68)	0.0028	0.0032	0.0111
450	(18)	0.150	(5.30)	0.0022	0.0026	0.0087
525	(21)	0.204	(7.22)	0.0018	0.0021	0.0071
600	(24)	0.267	(9.43)	0.0015	0.0017	0.0059
675	(27)	0.338	(11.93)	0.0013	0.0015	0.0051
750	(30)	0.417	(14.73)	0.0011	0.0013	0.0044
825	(33)	0.505	(17.82)	0.00097	0.0011	0.0039
900	(36)	0.601	(21.21)	0.00086	0.0010	0.0034
1050	(42)	0.817	(28.86)	0.00070	0.00082	0.0028
1200	(48)	1.067	(37.70)	0.00059	0.00069	0.0023
1350	(54)	1.351	(47.71)	0.00050	0.00059	0.0020
1500	(60)	1.668	(58.90)	0.00044	0.00051	0.0017
1650	(66)	2.018	(71.27)	0.00038	0.00045	0.0015
1800	(72)	2.402	(84.82)	0.00034	0.00040	0.0014

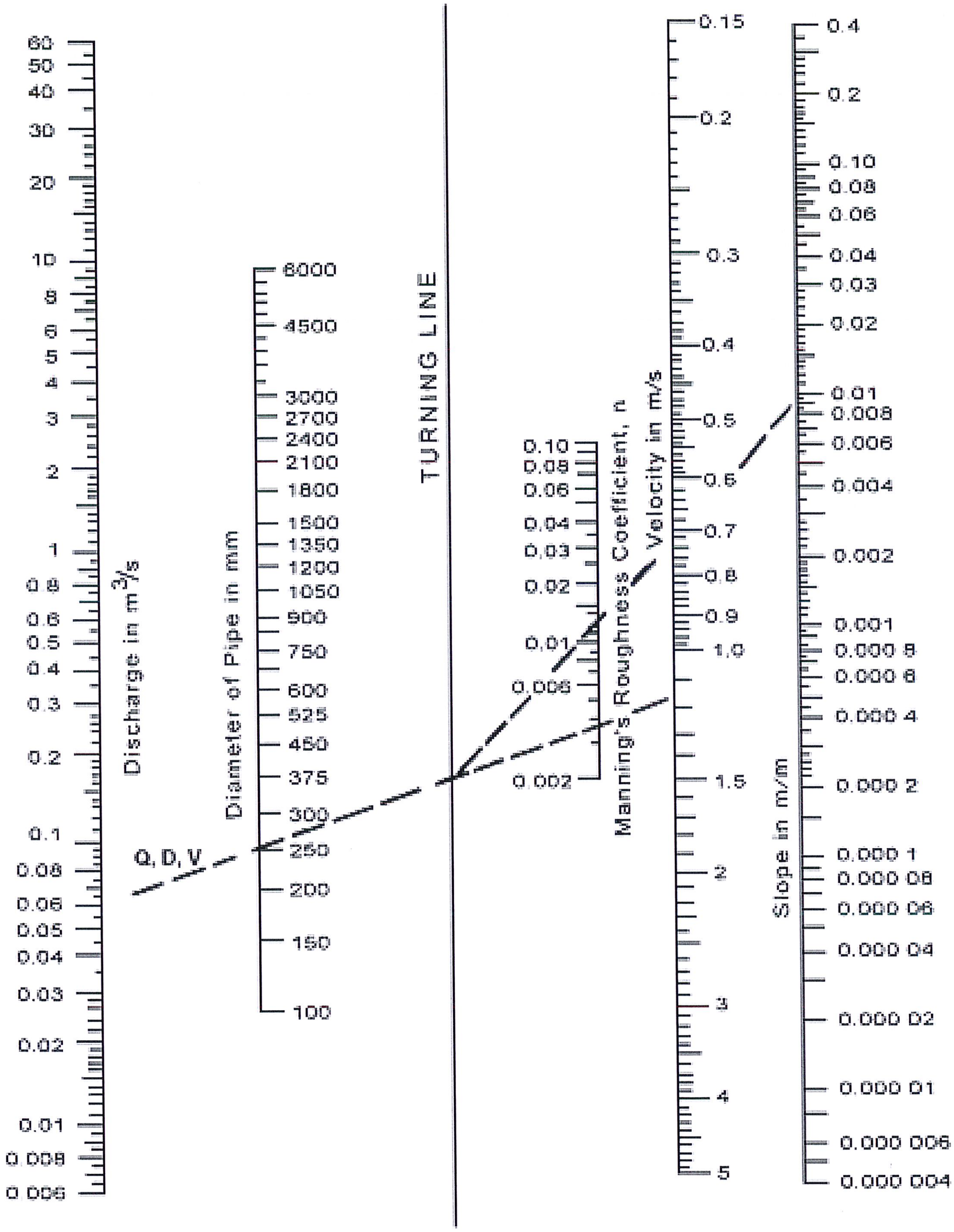

Figure 11-9 Manning's Formula For Flow In Storm Drains – Metric units

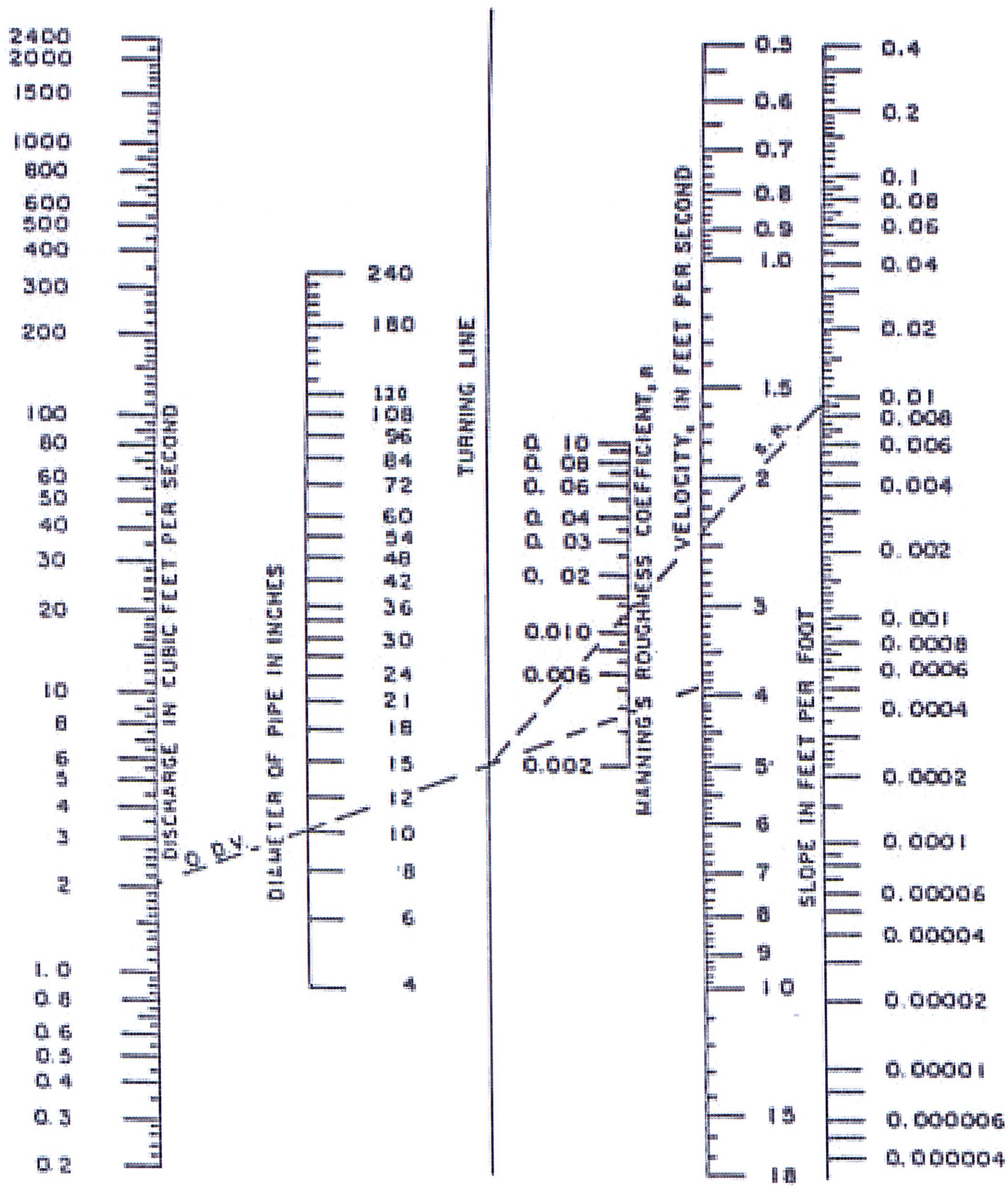

Figure 11-9.1 Manning's Formula For Flow In Storm Drains – English units

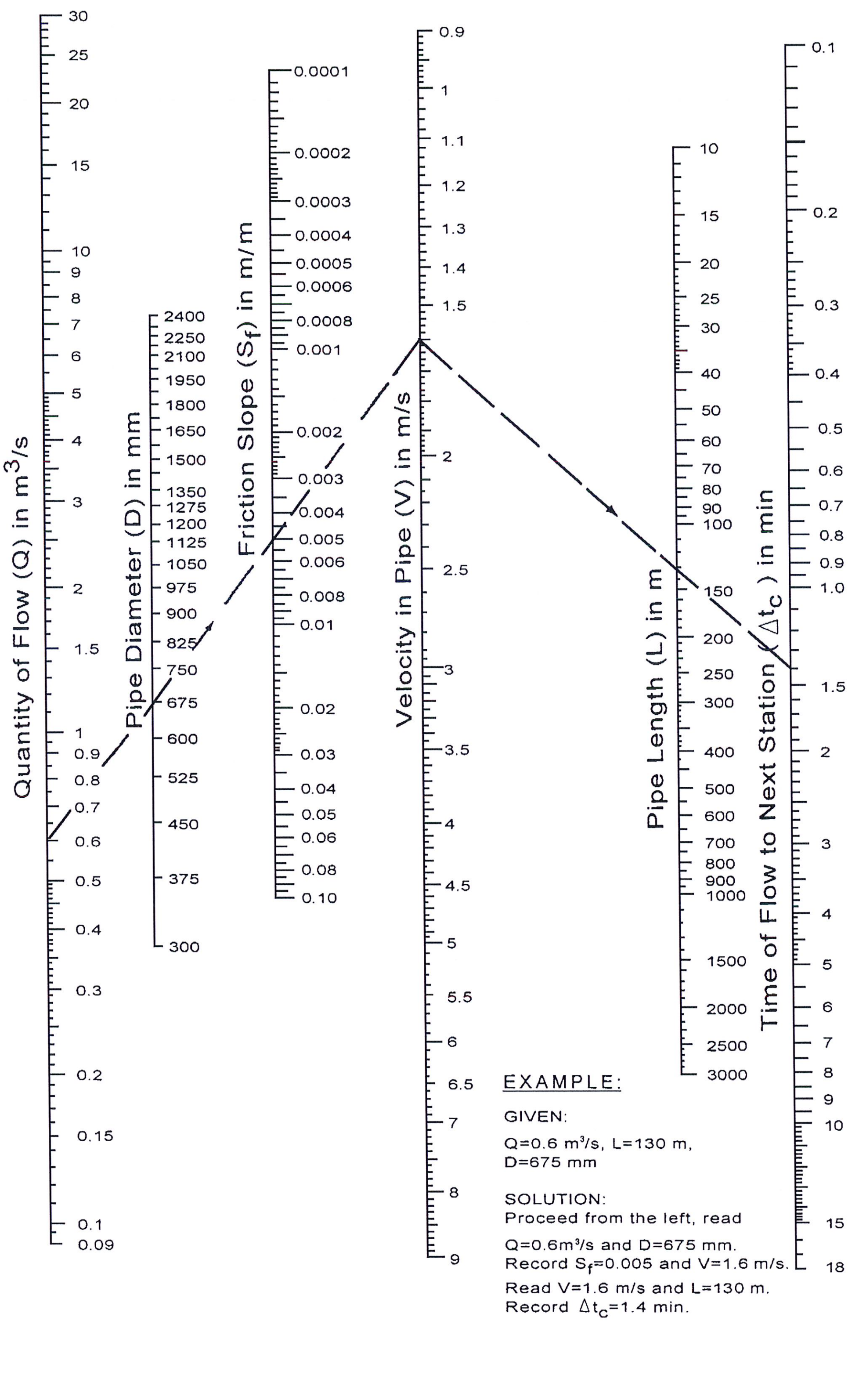

Figure 11-10 Concrete Pipe Flow Nomograph – Metric units

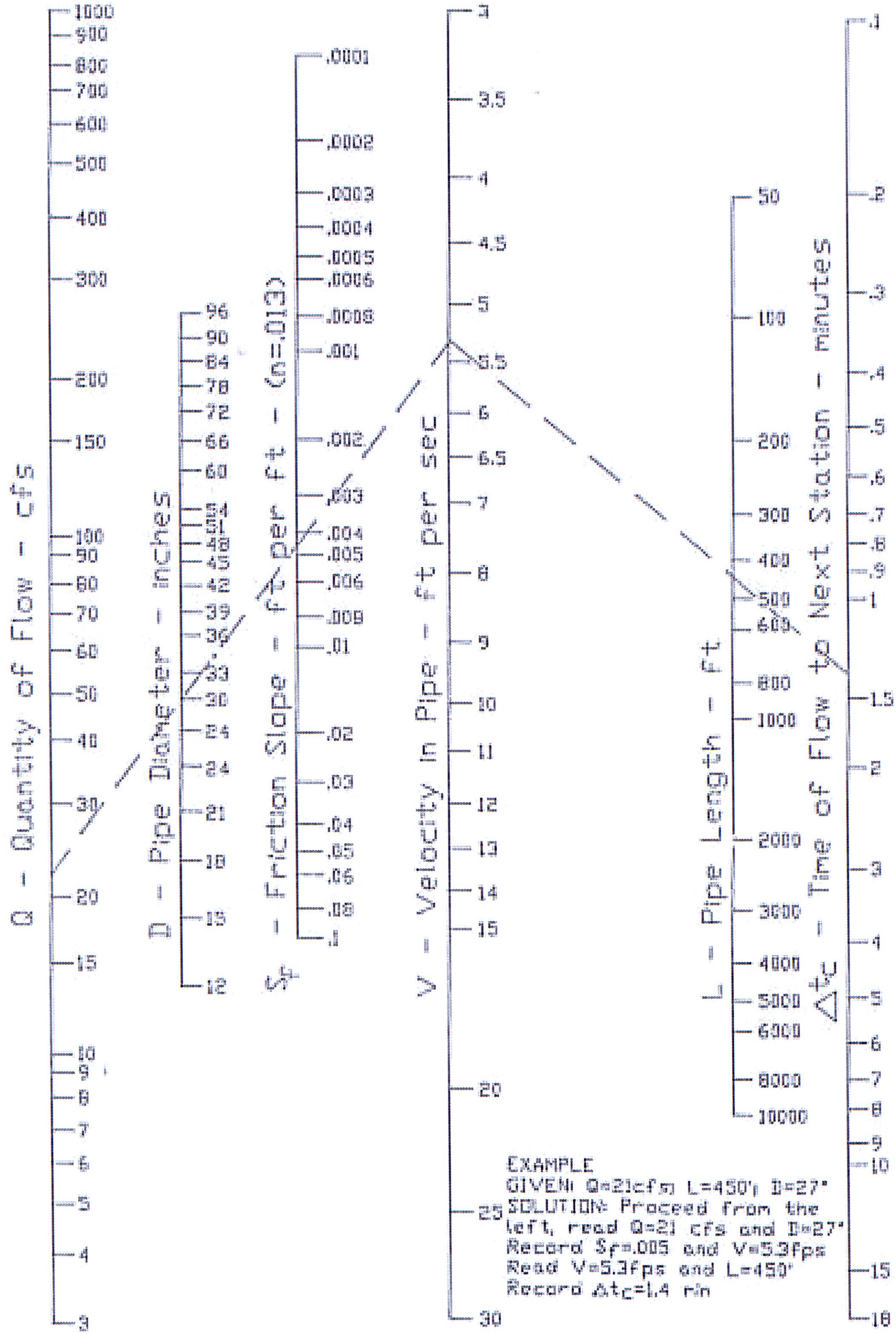

Figure 11-10.1 Concrete Pipe Flow Nomograph – English units

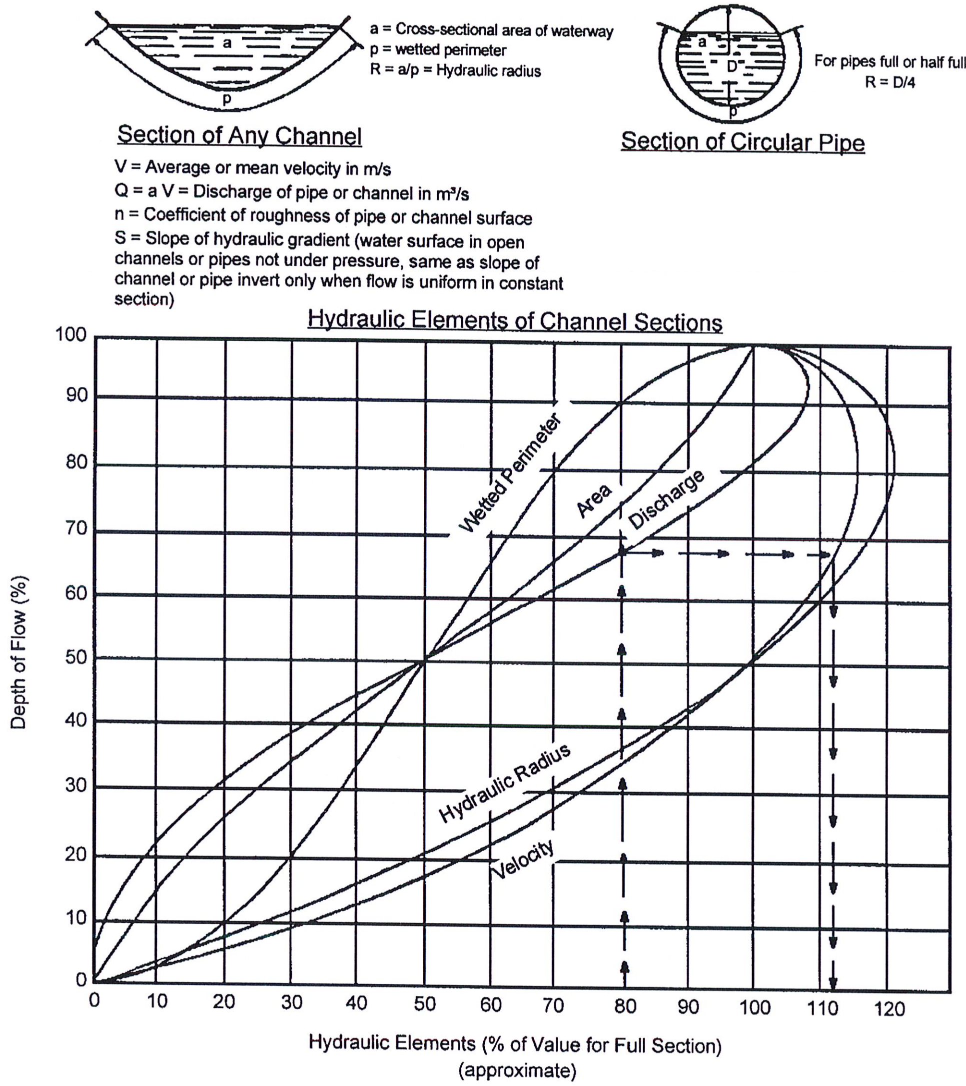

Figure 11-11 Values Of Hydraulic Elements Of Circular Section For Various Depths Of Flow – Metric or English units

Storm Drain Computation Sheet – Metric

Computed __________ Date __________

Checked __________ Date __________

Project __________
Route __________
Station __________
Town __________

Station		Flow Time, T_c (min)			A x C		(8)	(9)	Pipe							(17)	Velocity (mps)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)			(10)	(11)	(12)	(13)	Invert Elevation (m)		(16)		(18)	(19)
													(14)	(15)				
From	To	To Inlet	In Pipe	Accumulated	Increment	Total	Rainfall Intensity, I (mm/hr)	Total Flow in System, CIA / 360 = Q (cms)	Size	Type	"n"	Length (m)	Upstream	Downstream	Slope (m/m)	Full Capacity, Q_F (cms)	Flowing Full, V_F	Design Flow, V

Table 11-8 Storm Drain Computation Sheet – Metric units

Storm Drain Computation Sheet – English

Computed ________ Date ________

Checked ________ Date ________

Project ________

Route ________

Station ________

Town ________

Station		Flow Time, T_c (min)			A x C		(8)	(9)	Pipe							(17)	Velocity (fps)	
													Invert Elevation (ft)					
(1) From	(2) To	(3) To Inlet	(4) In Pipe	(5) Accumulated	(6) Increment	(7) Total	Rainfall Intensity, I (in/hr)	Total Flow in System, CIA = Q (cfs)	(10) Size	(11) Type	(12) "n"	(13) Length (ft)	(14) Upstream	(15) Downstream	(16) Slope (ft/ft)	Full Capacity, Q_F (cfs)	(18) Flowing Full, V_F	(19) Design Flow, V

Table 11-8 Storm Drain Computation Sheet – English units

11.8 Inlets

11.8.1 General

Inlets are drainage structures that collect surface water through grate or curb openings and convey it to storm drains or directly outlet to culverts.

11.8.2 Standard ConnDOT Inlets

- Type "C" catch basin – This inlet consists of both a curb-opening inlet and a grate placed in a side-by-side configuration. In computing the inlet capacity, the curb opening is neglected and only grate opening is considered. The curb opening provides a relief if the grate should become clogged.
  Type "C" catch basin double grate-Type I - This catch basin can be used on grades to reduce bypass since the frontal width increases by a factor of 2. The placement of this inlet needs to be evaluated to ensure that the grates do not protrude into the travelway which would cause traffic to veer away from it.*
  Type "C" catch basin double grate Type II - these inlets are predominantly used at sags. They provide greater interception capacity than the single or Type I structures since the curb opening is longer and the perimeter of the grate to accept flow is greater.
- Slotted Drain - This inlet consists of a pipe cut along the longitudinal axis with a grate of spacer bar to form slot openings. Slotted inlets function as weirs with flow entering from the sides.
- Type "C-L" catch basin – This catch basin is a grate inlet placed in a swale or edge of roadway without curbing.
  Type "C-L" catch basin double grate Type I - This is similar to the Type "C" catch basin double Grate Type I inlet except is more commonly used in swales where additional interception is required.*
  Type "C-L" catch basin double grate Type II - these inlets are predominantly used at sags. They provide greater interception capacity than the single or Type I structures since the perimeter of the grate to accept flow is greater.

  A typical detail showing grading adjacent to a type "C-L" catch basin located in a swale can be found in Appendix B.
- End Sections & End Walls - these inlets will be designed using the procedures found in the culvert chapter.
- Lawn Drains - These inlets vary in size dependant on discharge. They are economical to use in residential areas and traffic islands where minimal flow occurs.
- "D-G" type endwall - This inlet was developed primarily to drain earth and paved ditches at the top of cut slopes. These inlets should only be located beyond the area required for safe recovery of vehicles and where they will not be encountered by pedestrians. The capacity of these can be computed using the formula, $Q = 3.33\ LH^{1.5}$ (English version). Flow should not submerge the grate and the water surface developed by the outlet pipe should be low enough not to cause the weir to be submerged.
- Catch Basins without sumps – should be used where utility conflicts exist; storm sewer systems that convey watercourses; and where pipe 36 inches and larger is required. This structure has a formed invert.
- Drop Inlets – may be used where utility conflicts exist. This system has no inlet pipes other than underdrains.

*Note: These catch basins can also be used for connecting those pipes which cannot fit into the single grate structures. This avoids the need for special junction box designs in most instances. When these inlets are used for this purpose, they should be specified without sump to decrease junction losses.

11.8.3 Standard ConnDOT Grates

There are two grates currently used by the Department. These are designated Type "A" and "B" in the Roadway Standards. Type "B" grate will be used on limited access highways. Type "A" grate will be used in all other locations which are subject to bicycle and pedestrian traffic.

11.8.4 Inlets On Grade

The capacity of an inlet depends upon its geometry and the cross slope, longitudinal slope, total flow, depth of flow and pavement or swale roughness. The depth of water next to the curb is the major factor in the interception capacity of gutter inlets. At low velocities, all of the water flowing in the section of gutter occupied by the grate, called frontal flow, is intercepted by grate inlets, and a small portion of the flow along the length of the grate, termed side flow, is intercepted.

Experience indicates that for design purposes, it is safe to consider interception of the entire frontal flow and disregard side flow. The remainder of the flow outside the width of the inlet will bypass to the next inlet. All inlets are to be designed without considering depression unless the plans specify it, with contours.

11.8.5 Inlets At Low Points

In locations such as underpasses and in sag vertical curves in depressed sections, where significant ponding can occur, flanking inlets shall be placed on each side of the inlet at the low point in the sag. The flanking inlets should be placed so that they will limit spread on low gradient approaches to the level point and act in relief of the inlet at the low point if it should become clogged. (See Section 11.8.7.) Flanking inlets are not usually considered as intercepting flow in design computations.

11.8.6 Curbing

Curbs are used where runoff from the pavement would erode fill slopes. Curbs could be eliminated where other permanent erosion control measures such as rock embankments are provided. Curbs may also be required in developed areas, with sidewalks and in cut sections with positive backslopes at the gutter. Where curbs are used with positive backslopes, a minimum shoulder width of 1.2 meters (4 ft) is required to achieve the proper cross slope to contain the flow. Curbing is required for any slope steeper than 1 (vertical) : 4 (horizontal) with the exception of the high side of superelevated sections. If curbing is not possible then erosion control matting should be used to stabilize the embankments until vegetation is established. Refer to the Highway Design Manual for additional guidance for the use of curbing.

11.8.7 Inlet Locations

This section stipulates where the location of inlets should be.