Water Supply and Sewerage Network

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Flow in Sewer

Most sewers are designed to flow as open channels and not under pressure, even though they may flow full at times. There are exceptions, such as inverted siphons and discharge lines from sewage pumping stations which are always under pressure. Occasionally the capacity of storm sewers will be overtaxed, inlets will be full and overflowing, and water will rise in manholes. Sewers in such condition are said to be surcharged. Sanitary sewers may also be surcharged by excessive inflow during storms, by stoppages in the lines, or by flows greater than those designed for. Vacuum and pressurized collection systems are designed to flow full.

When water enters a pipe or channel at a constant rate, and escapes freely at the lower end, steady uniform flow will soon be established. Steady flow is that in which the same volume of liquid flows past any given point in each unit of time. In the usual sewer design problem, steady flow may be assumed. Water moves downstream in a pipe or channel impelled by the force of gravity. It will move at such a velocity that the available head or fall will be used up in overcoming friction and, in small part, in attaining kinetic energy or velocity head.

- The Manning's formula is widely used for calculating flow in open channel:-

$$V = \frac{k}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

k = 1 for SI units and 1.49 for US units

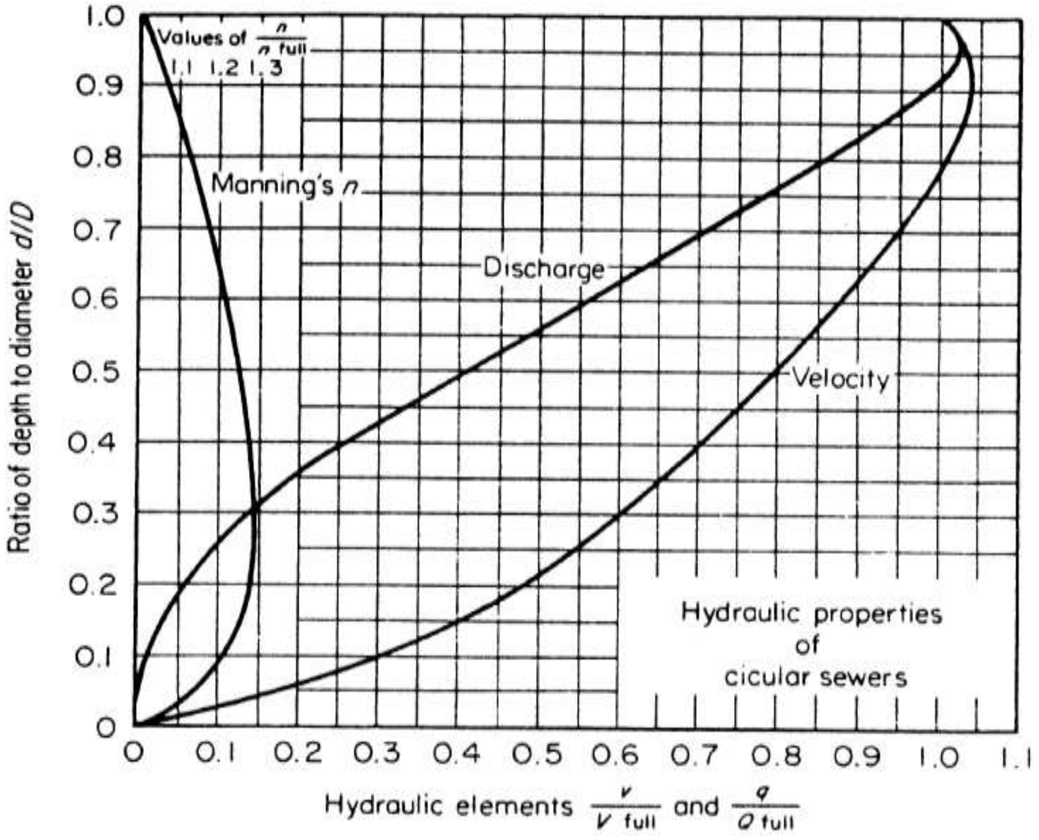
n	Character of surface
0.009	Plastic pipe
0.009	Well-planed timber evenly laid
0.010	Neat cement. Very smooth pipe
0.012	Unplaned timber. Cast-iron pipe of ordinary roughness
0.013	Well-laid brickwork. Good concrete. Riveted steel pipe. Well-laid vitrified clay pipe
0.015	Vitrified tile and concrete pipe poorly jointed and unevenly settled. Average brickwork
0.017	Rough brick. Tuberculated iron pipe
0.020	Smooth earth or firm gravel
0.030	Ditches and rivers in good order, some stones and weeds
0.040	Ditches and rivers with rough bottoms and much vegetation

Required Velocities

An important consideration in sewer design is the velocity obtained in sewers. Experience indicates that a velocity of not less than 0.6 m/s (2 ft/s) is required in sanitary sewers in order to prevent settlement of the sewage solids. The *minimum allowable slopes*, therefore, are those which will give this velocity when the sewer is flowing full

Storm sewers require greater velocities than in sanitary sewers because of the heavy sand and grit which is washed into them. The minimum allowable velocity is 0.75 m/s (2.5 ft/s), and 0.9 m/s (3 ft/s) is desirable. Because of the abrasive character of the solids, excessively high velocities should be avoided, 2.4 m/s (8 ft/s) being considered the desirable upper limit.

In very flat areas where there is difficulty in obtaining the minimum grades, there is a temptation to use larger pipes because they will provide a velocity of 0.6 m/s at lower grades. It should be recognized, however, that a cleaning velocity of 0.6 m/s will be reached only when the pipes flow full or 78 percent of full. As may be seen from Figure, pipes flowing less than 78 percent full will have velocities less than pipes flowing full. Therefore, using larger pipes for low flows may make matters worse. The actual flow that is anticipated and the actual velocity produced in the partially filled sewer should be considered in selecting an appropriate slope. In storm sewer designs it may be necessary to use grades that are too low for self-cleansing velocities.



SEWAGE FLOW & QUANTITY

Sanitary and industrial sewage is derived from water supply, so it has a relationship with amount of water consumption. Generally, 70- 80% of water consumption is taken as wastewater for domestic purposes. For industrial purposes per unit production caused generation of wastewater will be multiplied by the total product can be taken. Similarly, storm water can be calculated either by Rational Method or by soil conservation services techniques.

Like water supply flow varies from time to time and since sewers must be able to accommodates the maximum flow, the variation in sewage flow need to be studied.

- The variation of maximum, average and minimum is sometime great and need a particular multiplying factor known as Peak Factor and is defined as

$$PF = 1 + \frac{14}{(4+\sqrt{P})} \qquad P \ \ldots \ in\, Thousands$$

Water and Sanitary Agency (WASA)

Average flow (m^3/d)	Peak Factor
< 2500	4.0
2500 to 5000	3.4
5000 to 10000	3.1
25000 to 50000	2.7
50000 to 100000	2.5
100000 to 250000	2.3
250000 to 500000	2.15
> 500000	2.08

Example: The residential area of a city has a population density of 15000 persons/ km^2 and an area of 120000 m^2 . If average water consumption is 400 (LPCD). Find the average and maximum sewage flow in m^3/day.

Pop. Density = 15000 per/km^2 Area =120000 m^2 Avg. Water Consumption= 400 lpcd

Total population = **15000 x 120000 / (1000)²** = 1800 persons

Avg. sewage flow = **1800 x 400 x (80/100)** = 576000 l/day = 576 m^3/day

$$PF = 1 + \frac{14}{(4+\sqrt{P})} = 1 + \frac{14}{(4+\sqrt{1.8})} = 3.62$$

Max sewage flow = 3.62 x 576 = 2085 m^3/day

Full Flow & Partial Flow Diagrams

Figures 15-1 to 15-3 are nomograms for the solution of the Manning formula for various ranges of quantities and pipe sizes and with n equal to 0.013. Use of the diagrams can best be explained by means of an example. Figures 15-1 to 15-3 can also be used in designing sewers to run half full. It is then necessary, however, to double the expected quantity before using the diagrams. Figure 15-4 is a nomogram based upon the Manning formula which introduces various values of n. It can be used for pipes and conduits of all shapes and for open channels.

Example 1:- It is desired to determine the size of pipe required to carry 3.4 m^3/min, with an available slope of 0.003. Figure 15-1 is used. A straightedge is placed on 3.4 of the quantity scale and also on 0.003 of the slope ratio scale. It will be seen that the straightedge cuts the diameter scale at 305 mm and the velocity scale at 0.77, indicating that a 305-mm pipe will be required, and the velocity will be 0.77 m/s when flowing full. In a similar manner, with any two of the hydraulic quantities known the other two may be obtained. Should the necessary size not fall upon a commercial size, the next larger pipe will be used.

Example 2:- A circular pipe 1.83 m in diameter is of very old and rough brickwork. The value of n is therefore assumed to be 0.017. The slope of the pipe is 0.003. What will it carry when flowing full, and what will be the velocity? The hydraulic radius when flowing full will be 0.46 m. With n as 0.017 and s as 0.003, lay a straightedge to find the intersection with the pivot scale, as shown by the dashed line. From the intersection with the pivot scale place a straightedge to intersect the hydraulic radius scale at 0.46 m. This line crosses the velocity scale at 1.83 m/s. With this velocity and the pipe flowing full the quantity carried will be 4.8 m^3/s.

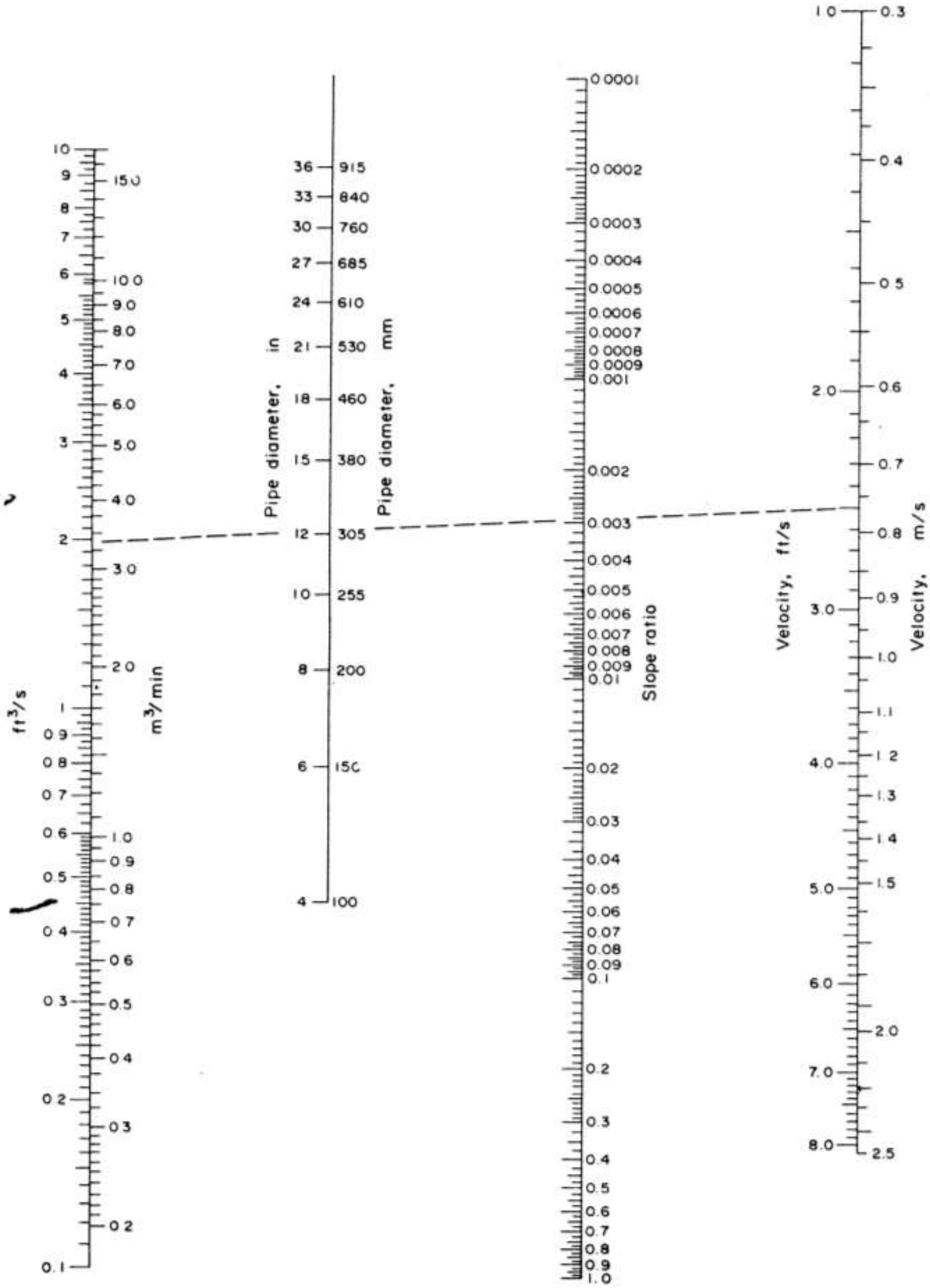


Figure 15-1 Diagram for solution of Manning formula for circular pipes flowing full. $n = 0.013$.

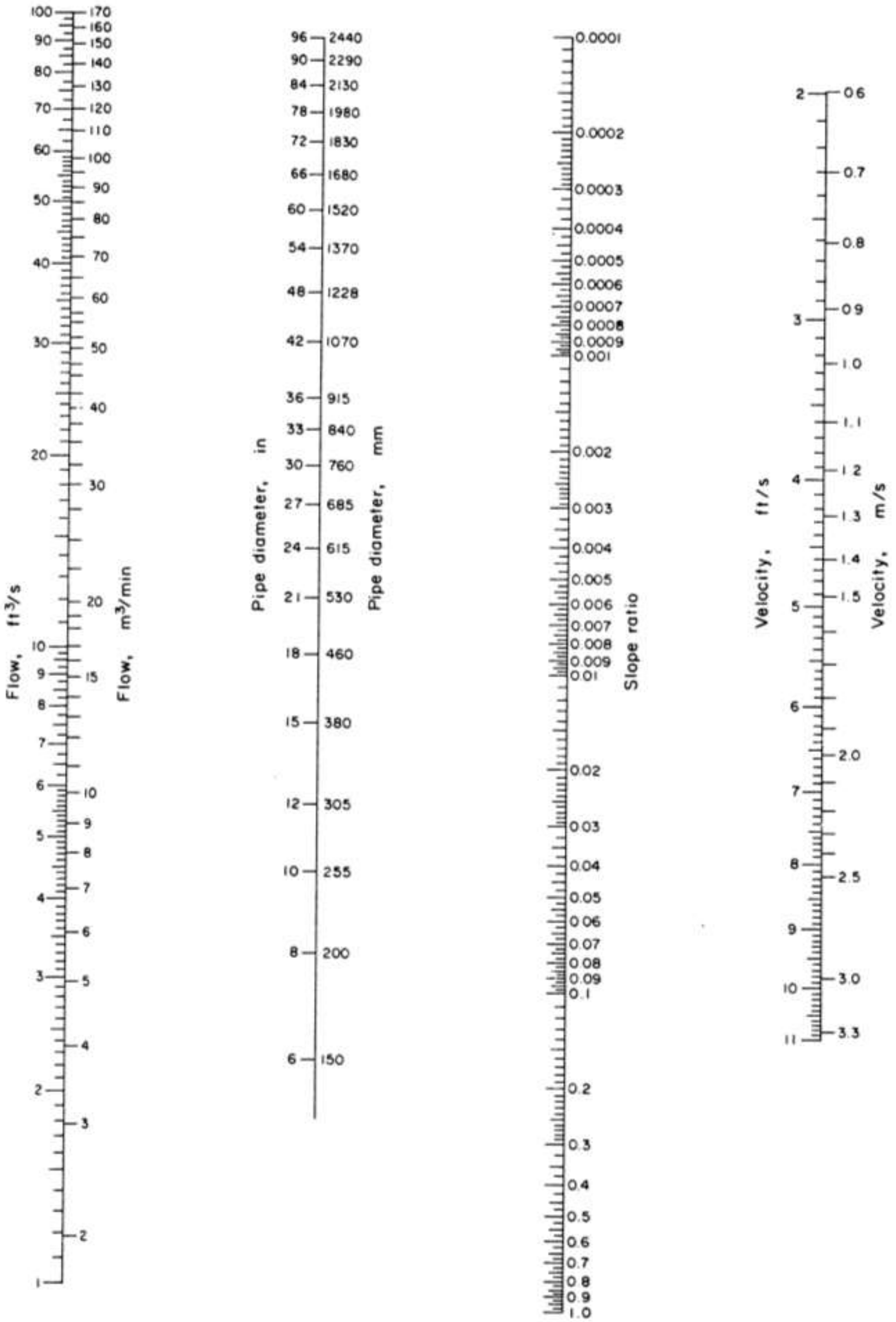


Figure 15-2 Diagram for solution of Manning formula for circular pipes flowing full. $n = 0.013$.

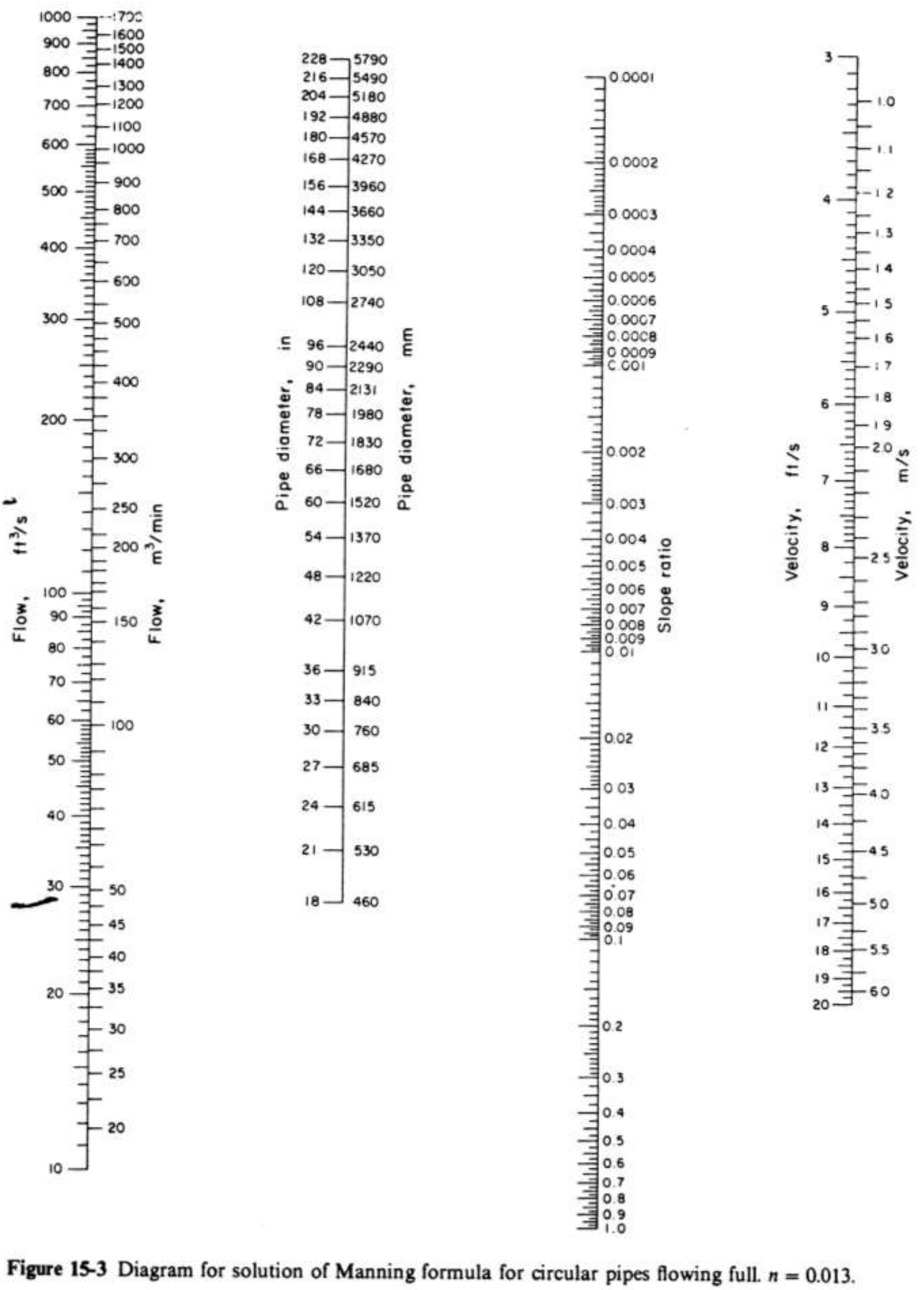


Figure 15-3 Diagram for solution of Manning formula for circular pipes flowing full. $n = 0.013$.

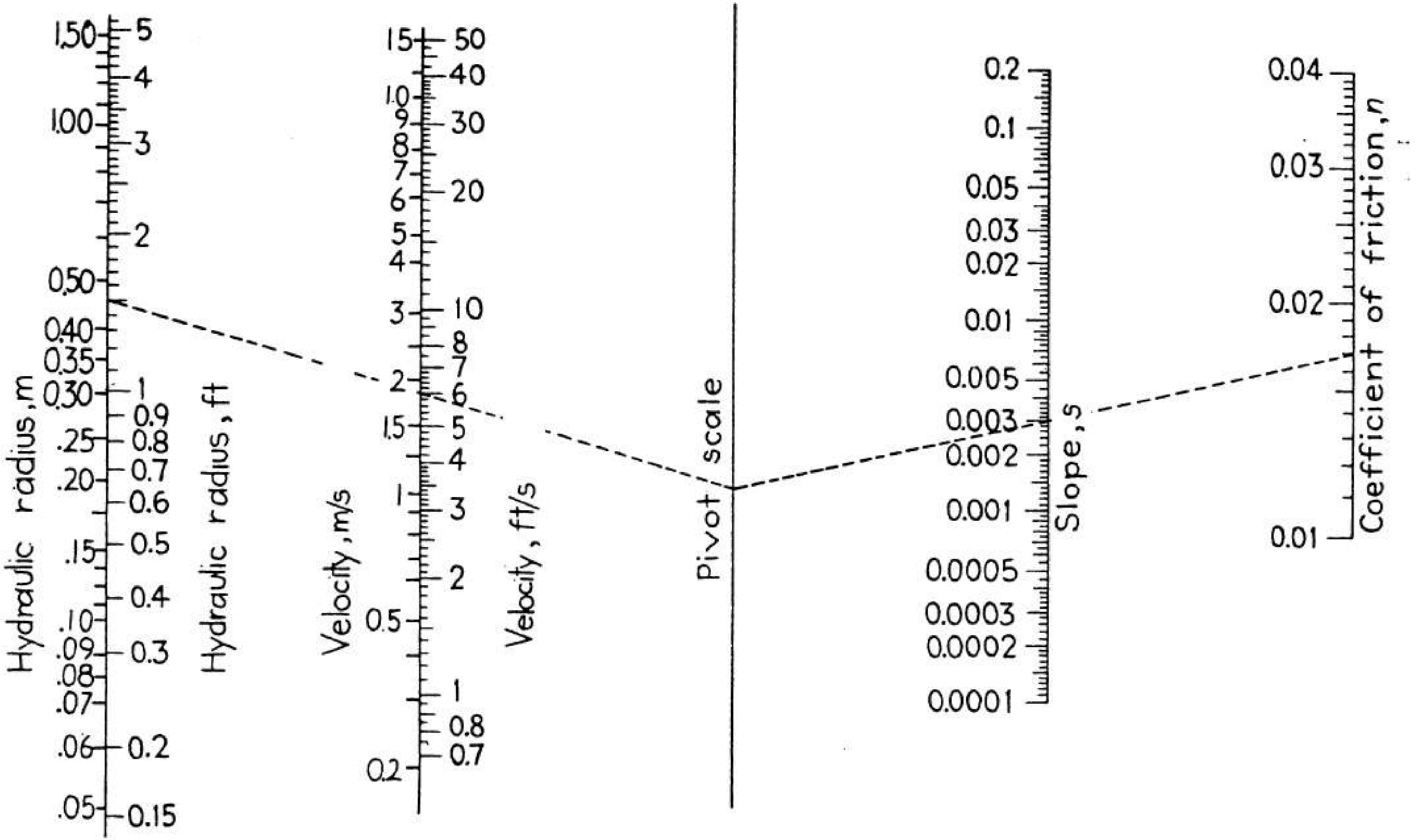


Figure 15-4 Nomogram based upon Manning formula.

It is frequently necessary to determine the velocity and depth of sewage in a pipe which is flowing only partially full. Use of Fig. 15-5 will allow quick computation of the hydraulic elements of partially filled circular sewers. In using the diagram, it is first necessary to use Figs. 15-1 to 15-3 in order to find conditions when the sewer is flowing full. Then by calculating the ratio of any two known hydraulic elements the others can be found.

Example 3:- A 915-mm (36-in) circular sewer is laid on a slope of 0.003. The Manning's n is 0.013 when the sewer is full. What will be the velocity and depth of flow be when the sewer is carrying 8.5 m^3/min?

- Reference to Fig. 15-2 shows that the discharge when flowing full is 62 m^3/min and the velocity is 1.57 m/s.
- The ratio of the actual to the full discharge is q/Q = 8.5/62 = 0.14.
- Using this ratio as abscissa in Fig. 15-5, follow it upward to the discharge curve and from the point of intersection read the ordinate on the left-hand scale, which is 0.30. The depth of flow is thus 0.3 x 915 = 275 mm at a flow of 8.5 m^3/min.
- To obtain the velocity, follow the depth line (0.30) to the right until it intersects the velocity curve and read the abscissa to obtain v/ V equal to 0.60. The velocity in the pipe when it is carrying a flow of 8.5 m^3/min will thus be 0.6 x 1.57 = 0.94 m/s.

It should be recognized that partial-flow diagrams give only approximate results, particularly for high velocities. Conditions during partial flow must frequently be determined in combined sewers. Velocities during dry-weather flow must be calculated to eliminate the possibility of deposits occurring.

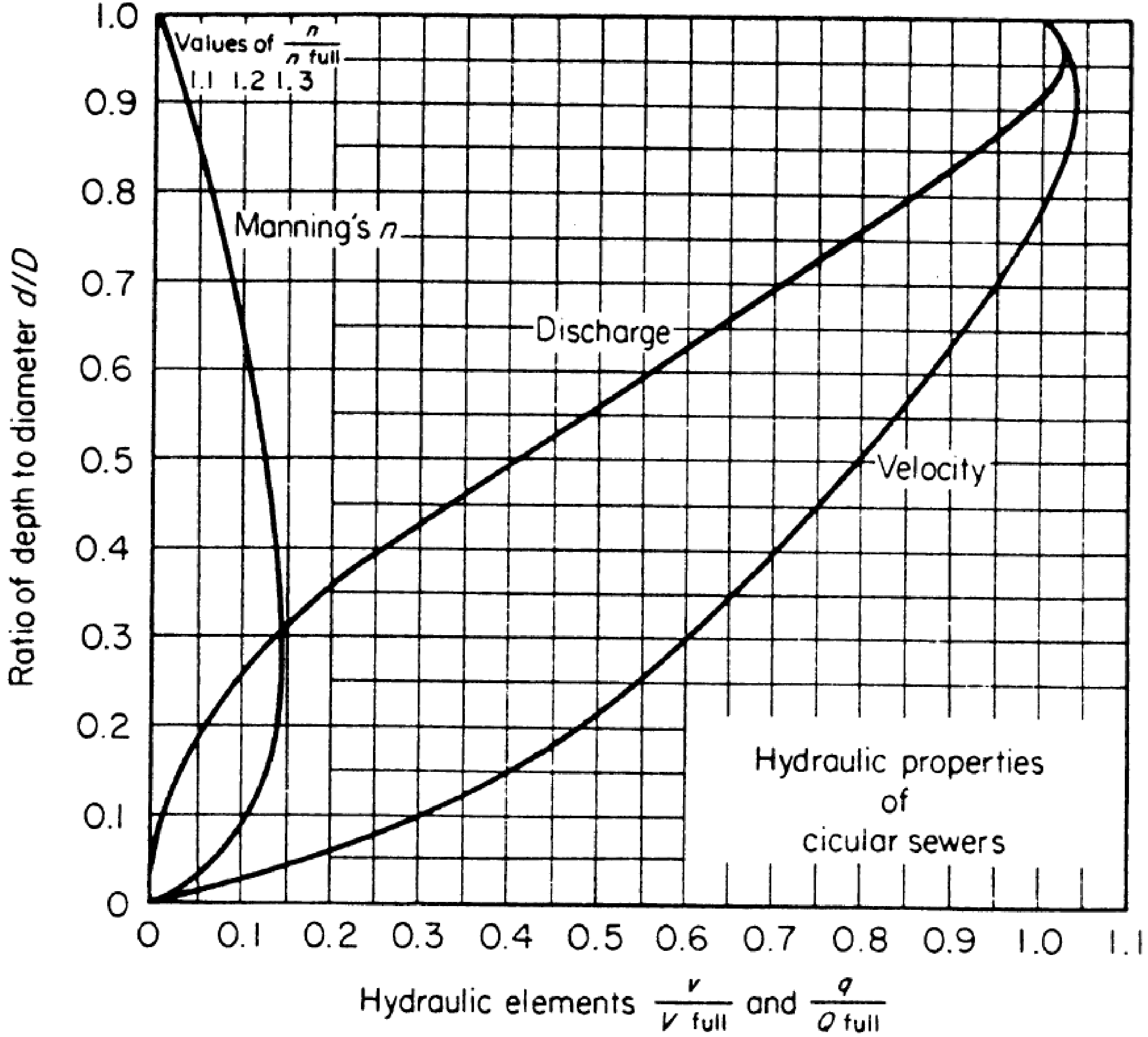


Figure 15-5 Hydraulic Elements For Circular Pipes

Example:- Design a sanitary sewer to serve a population of 5,000 people, if the average consumption is 400 liters per capita per day (lpcd). How many extra persons can be served if the slope (S=0.005) is doubled? Using "n" value of 0.013 in the Manning's formula & the return flow as 70%. Check the minimum self-cleaning velocity.

Given Data:

Population (P)	= 5000 Persons
Average water consumption (q)	= 400 lpcd
Manning Coefficient (n)	= 0.013
Return Flow	= 70 %
Assume Slope (s)	= 0.005

Required:

1. Find the Velocity (V) =? Also check minimum self-cleaning velocity
2. When the slope is doubled find the extra population to be served =?

Solution:

PART 1

Average waste water flow (q_w) = P * Return flow (%) * q
= 5000 * 0.7 * 400
= 1,400,000 lpcd
= 0.0162 m^3/sec

Let take peaking factor (P.F) = 3

Peak Hourly Waste Water Flow = 3 * 0.0162
= 0.0486 m^3/sec

Now finding the diameter of sewer pipeline using discharge formula; $Q = V * A$ $\qquad$ $V = \frac{k}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$

$$A = \frac{\pi}{4}(D)^2$$

$$0.0486 = \frac{1}{0.013} * \frac{\pi}{4}(D)^2 * \left(\frac{D}{4}\right)^{\frac{2}{3}} (0.005)^{\frac{1}{2}}$$

By using the solver D=0.264 m or (10.40 inch), USE 12”

Check the Minimum Velocity (Self-Clean Velocity)

$$V = \frac{1}{0.013} * \left(\frac{0.305}{4}\right)^{\frac{2}{3}} (0.005)^{\frac{1}{2}} = \mathbf{0.96\ m/\sec} > 0.6\ m/sec$$

PART 2

Doubling the slope S = 0.005*2=0.01

$$Q = \frac{1}{0.013} * \frac{\pi}{4}(0.305)^2 * \left(\frac{0.305}{4}\right)^{\frac{2}{3}} (0.01)^{\frac{1}{2}} \rightarrow Q = 0.0331\ m^3/\sec \quad = 2{,}859{,}840\ l/day$$

$$P = \frac{Q}{qw} = \frac{2859840\ (\frac{l}{day})}{0.7 * 400(lpcd)} = 10215\ Persons$$

So, if the slop is doubled then total of 10,216 extra persons can be served

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