Introduction

Selecting the appropriate pipe size for a gravity flow application is essential for ensuring long, trouble free service from a drainage system. This may seem like a daunting task; however, this selection process is simplified with the use of the Manning's formula. The Manning's formula is an open channel flow equation that is widely used throughout the drainage industry. There are two basic design methods that are based on Manning's formula that can be used to size corrugated high-density polyethylene (HDPE) and polypropylene (HP) pipe.

The first method uses discharge curves to size the pipe based on design flow and pipe slope. Each product, whether it is single or dual wall pipe, has its own curve based on its Manning's "n" value, or roughness coefficient. It is important to consider pipe connections, bends, and the collection of sediment and debris in the pipes will reduce hydraulic efficiency ultimately lowering the actual flow capacity. These factors should be considered before the selection of a final pipe size.

The second method involves the use of conveyance factors. Conveyance factors are determined by combining all of the coefficients and constants in the Manning's equation down to a single factor. This method typically produces more than one appropriate pipe size which will allow the user to determine the most cost-effective solution.

The velocity conditions should also be considered before the final selection of people. Higher velocities will help sediment and debris from collecting in the pipe which will in turn reduce the maintenance requirements and ensure the hydraulic function of the pipe throughout its design life. However, these velocities must be kept below the maximum limits for the pipe.

Discharge Curves

The mathematical relationship between the flow capacity, slope, and Manning's "n" values are often shown graphically through discharge curves. These curves allow for the selection of an adequate Prinsco pipe under gravity flow and steady state conditions. Figures 1 & 2 show discharge curves for Prinsco's pipe. Example 2, at the bottom of this technical note, illustrates how discharge curves are properly used to size Prinsco pipe.

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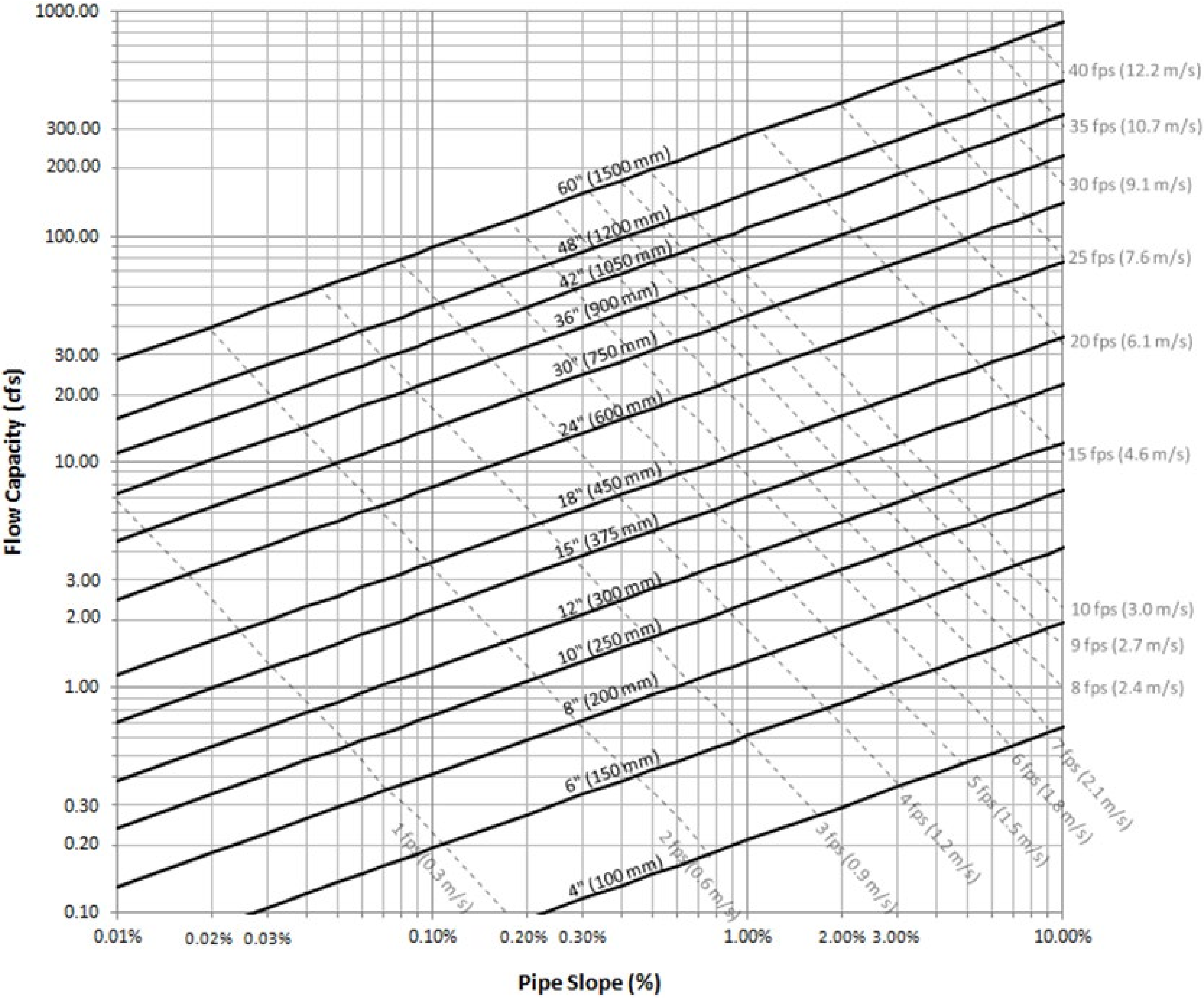

Figure 1: Discharge Curves for Prinsco Dual Wall Pipe Products (GOLDFLO®, GOLDPRO Storm®)

Notes for Figure 1

1) Flow rates are based on a design Manning's "n" of 0.012.
2) Solid lines indicate the pipe diameter.
3) Dashed lines indicate the approximate flow velocity.
4) Pipe slope is measured in feet of invert elevation per 100 feet of pipe run.

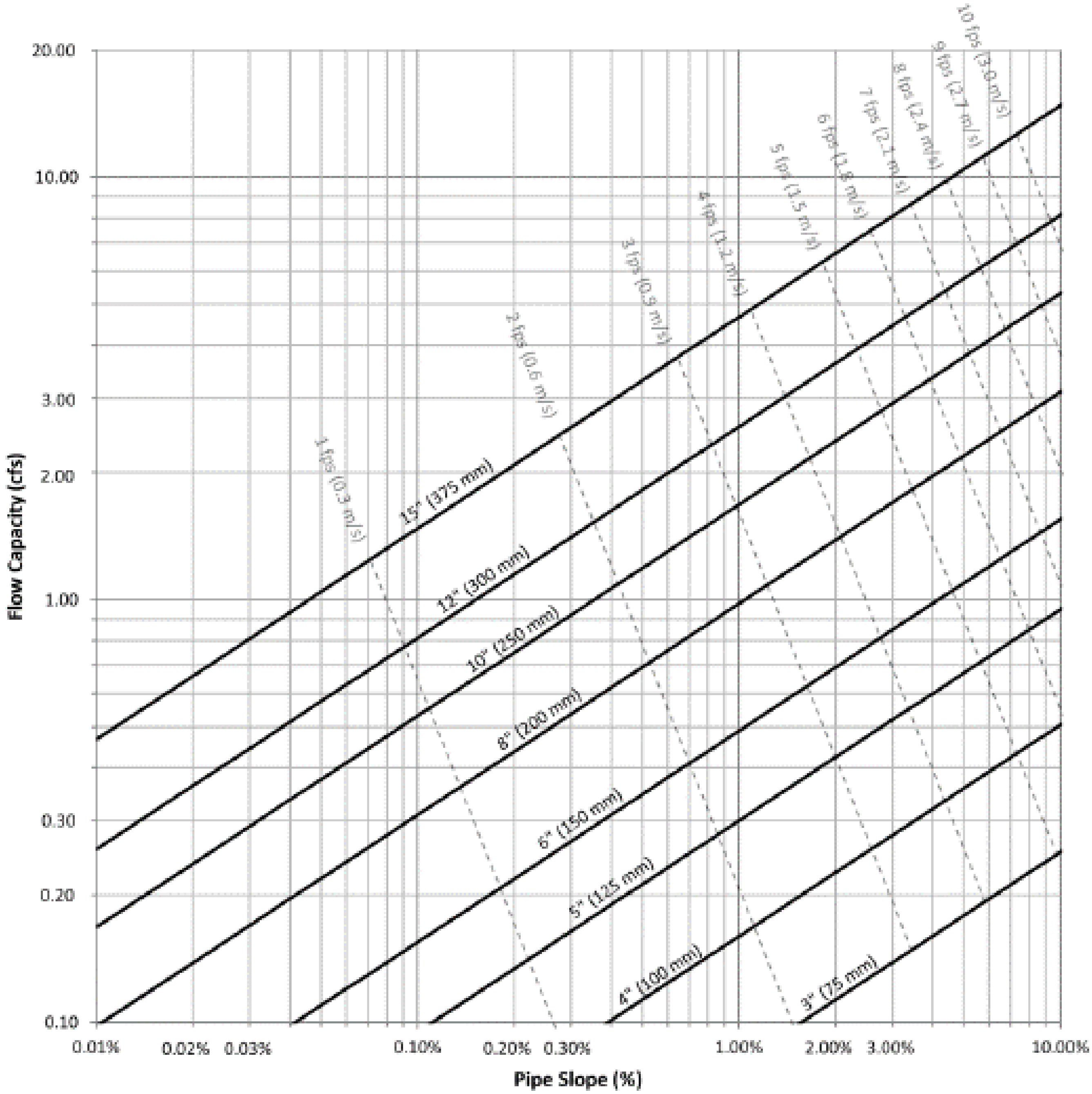

Figure 2: Discharge Curves for Prinsco Single Wall HDPE Product (GOLDLINE®)

Notes for Figure 2

1) Flow rates are based on Manning's "n" values found in Table 1.
2) Solid lines indicate pipe diameters.
3) Dashed Lines indicate the approximate flow velocity.
4) Pipe slope is measured in feet drop of invert elevation per 100 feet of pipe run.

Conveyance Method

The conveyance method provides a simplified approach of selecting a variety of pipe options to satisfy a project's flow requirements. This approach utilizes a simplified version of the Manning's equation as shown in Equations 1 and 1(a). This equation is used with the assumptions that the pipe is flowing full which allows for an accurate yet simple calculation.

$$Q = \frac{(1.486)(A)\left(R^{\frac{2}{3}}\right)\left(S^{\frac{1}{2}}\right)}{n}$$ Equation 1

Note:

Q = pipe flow capacity (cfs)

n = Manning's "n" value (unitless)

A = cross-sectional flow area of the pipe (ft^2)

P= wetted perimeter (ft); pipe inside circumference for full flowing pipe conditions

R = hydraulic radius (ft); calculated by $R = \frac{A}{P}$

S= pipe slope (feet/foot)

Manning's equation is slightly different if the known values are in metric units. If this is the case, use the equation below.

$$Q = \frac{(A)\left(R^{\frac{2}{3}}\right)\left(S^{\frac{1}{2}}\right)}{n}$$ Equation 1(a)

Note:

Q = pipe flow capacity (m^3/s)

n = Manning's "n" value (unitless)

A = cross-sectional flow area of the pipe (m^2)

P= wetted perimeter (m); pipe inside circumference for full flowing pipe conditions

R = hydraulic radius (m); calculated by $R = \frac{A}{P}$

S= pipe slope (m/m)

For a specific full-flowing installation, the parameters n, A, and R are easily defined constants. The flow-carrying ability or conveyance factor (k), of the pipe can then be defined as shown in Equation 2 and Equation 2(a)

$$k = \frac{(1.486)(A)\left(R^{\frac{2}{3}}\right)}{n}$$ Equation 2

Or, in metric units:

$$k = \frac{(A)\left(R^{\frac{2}{3}}\right)}{n}$$ Equation 2(a)

By substitution, the Manning's formula can then be reduced to the following equation.

$$Q = kS^{\frac{1}{2}}$$ Equation 3

By solving for the conveyance factor (k), Equation 3 can also be written as shown in Equation 4.

$$k = \frac{Q}{S^{\frac{1}{2}}} \qquad \text{Equation 4}$$

Direct substitution of design conditions into Equation 4 will determine the conveyance factor allowed. Use Table 1 or Table 1(a) as a guide for selecting a Prinsco pipe having a conveyance factor of at least the value calculated.

With different background knowledge of Manning's "n" values, appropriate values can be chosen for different materials. For pipes of the same diameters, Manning's "n" will be the only factor that affects the conveyance and, therefore, the capacity. In a comparison of identical conditions, conveyance has a direct relationship to capacity. An example of this is if the slope is held constant, doubling the conveyance would double the pipe's capacity. Sample problems involving the conveyance factors are shown and explained in the Example Problems section.

Table 1: Design Manning's "n" Values for Prinsco HDPE Pipe

Product	Pipe Diameter	Design Manning's "n" value
GOLDFLO	4'' – 60''	0.012
GOLDPRO Storm	4'' – 60''	0.012
GOLDLINE	3'' – 6''	0.015
	8''	0.016
	10''	0.017
	12'' – 15''	0.018

Table 2: Conveyance Factors (English Units)

Conveyance Factors (k) for Corrugated Pipe Flowing Full (English Units)																		
		Manning's "n" Values																
Dia (in.)	Area (sq.ft.)	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.024	0.025
3	0.05	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
4	0.09	2.7	2.5	2.2	2.1	1.9	1.8	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.0	1.0
6	0.20	8.1	7.3	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.8	3.6	3.5	3.3	3.2	3.0	2.9
8	0.35	17.5	15.7	14.3	13.1	12.1	11.2	10.5	9.8	9.2	8.7	8.3	7.9	7.5	7.1	6.8	6.5	6.3
10	0.55	31.6	28.5	25.9	23.7	21.9	20.3	19.0	17.8	16.8	15.8	15.0	14.2	13.6	12.9	12.4	11.9	11.4
12	0.79	51.5	46.3	42.1	38.6	35.6	33.1	30.9	28.9	27.2	25.7	24.4	23.2	22.1	21.1	20.1	19.3	18.5
15	1.23	93.3	84.0	76.3	70.0	64.6	60.0	56.0	52.5	49.4	46.7	44.2	42.0	40.0	38.2	36.5	35.0	33.6
18	1.77	151.7	136.3	124.1	113.8	105.0	97.5	91.0	85.3	80.3	75.9	71.9	68.3	65.0	62.1	59.4	56.9	54.6
21	2.41	228.9	206.0	187.3	171.6	158.4	147.1	137.3	128.7	121.2	114.4	108.4	103.0	98.1	93.6	89.6	85.8	82.4
24	3.14	326.8	294.1	267.3	245.1	226.2	210.1	196.1	183.8	173.0	163.4	154.8	147.0	140.0	133.7	127.9	122.5	117.6
27	3.98	447.3	402.6	366.0	355.5	309.7	287.6	268.4	251.6	236.8	233.7	211.9	201.3	191.7	183.0	175.0	167.8	161.0
30	4.91	592.5	533.2	484.7	444.3	410.2	380.9	355.5	333.3	313.7	296.2	280.6	266.6	253.9	242.4	231.8	222.2	213.3
33	5.94	763.9	687.5	625.0	572.9	528.9	491.1	458.3	429.7	404.4	382.0	361.9	343.8	327.4	312.5	298.9	286.5	275.0
36	7.07	963.4	867.1	788.2	722.6	667.0	619.3	578.0	541.9	510.0	481.7	456.4	433.5	412.9	294.1	377.0	361.3	346.8
42	9.62	1453.2	1307.9	1189.0	1089.9	1006.1	934.2	871.9	817.5	769.4	726.6	688.4	654.0	622.8	594.5	568.7	545.0	523.2
45	11.04	1746.8	1572.1	1429.2	1310.1	1209.3	1122.9	1048.1	982.6	924.8	873.4	827.4	786.1	748.6	714.6	683.5	655.0	628.8
48	12.57	2074.8	1867.4	1697.6	1556.1	1436.4	1333.8	1244.9	1167.1	1098.4	1037.4	982.8	933.7	889.2	848.8	811.9	778.1	746.9
54	15.90	2840.5	2556.4	2324.0	2130.4	1966.5	1826.0	1704.3	1597.8	1503.8	1420.2	1345.5	1278.2	1217.4	1162.0	111.5	1065.2	1022.6
60	19.63	3762.0	3385.8	3078.0	2821.5	2604.4	2418.4	2257.2	2116.1	1991.6	1881.0	1782.0	1692.9	1612.3	1539.0	1472.1	1410.7	1354.3

Source: Corrugated Polyethylene Pipe Association (2000) “Hydraulic Considerations for Corrugated Polyethylene Pipe”

Table 3: Conveyance Factors (Metric Units)

Conveyance Factors (k) for Corrugated Pipe Flowing Full (Metric Units)																		
		Manning's "n" Values																
Dia (mm)	Area (sq.m)	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.024	0.025
75	0.004	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
100	0.008	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
150	0.018	0.22	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.08	0.08
200	0.031	0.47	0.43	0.39	0.36	0.33	0.30	0.28	0.27	0.25	0.24	0.22	0.21	0.20	0.19	0.19	0.18	0.17
250	0.049	0.86	0.77	0.70	0.64	0.59	0.55	0.52	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.34	0.32	0.31
300	0.071	1.40	1.23	1.14	1.05	0.97	0.90	0.84	0.79	0.74	0.70	0.66	0.63	0.60	0.57	0.55	0.52	0.50
375	0.110	2.53	2.28	2.07	1.90	1.75	1.63	1.52	1.42	1.34	1.27	1.20	1.14	1.09	1.04	0.99	0.95	0.91
450	0.159	4.12	3.71	3.37	3.09	2.85	2.65	2.47	2.32	2.18	2.06	1.95	1.85	1.76	1.68	1.61	1.54	1.48
525	0.216	6.21	5.59	5.08	4.66	4.30	3.99	3.73	3.49	3.29	3.11	2.94	2.80	2.66	2.54	2.43	2.33	2.24
600	0.283	8.87	7.98	7.26	6.65	6.14	5.70	5.32	4.99	4.70	4.43	4.20	3.99	3.80	3.63	3.47	3.33	3.19
675	0.358	12.14	10.93	9.93	9.11	8.41	7.80	7.28	6.83	6.43	6.07	5.75	5.46	5.20	4.97	4.75	4.55	4.37
750	0.442	16.08	14.47	13.16	12.06	11.13	10.34	9.65	9.04	8.51	8.04	7.62	7.24	6.89	6.58	6.29	6.03	5.79
825	0.535	20.73	18.66	16.96	15.55	14.35	13.33	12.44	11.66	10.98	10.37	9.82	9.33	8.89	8.48	8.11	7.77	7.46
900	0.636	26.15	23.53	21.39	19.61	18.10	16.81	15.69	14.71	13.84	13.07	12.39	11.77	11.21	10.70	10.23	9.81	9.41
1050	0.866	39.44	35.50	32.27	29.58	27.31	25.36	23.67	22.19	20.88	19.72	18.68	17.75	16.90	16.14	15.43	14.79	14.20
1125	0.994	47.41	42.67	38.79	35.56	32.82	30.48	28.45	26.67	25.10	23.70	22.46	21.33	20.32	19.39	18.55	17.78	17.07
1200	1.131	56.31	50.68	46.07	42.23	38.99	36.20	33.79	31.68	29.81	28.16	26.67	25.34	24.13	23.04	22.04	21.12	20.27
1350	1.431	77.09	69.38	63.08	57.82	53.37	49.56	46.26	43.36	40.81	38.55	36.52	34.69	33.04	31.54	30.17	28.91	27.75
1500	1.767	102.10	91.89	83.54	76.58	70.69	65.64	61.26	57.43	54.05	51.05	48.36	45.95	43.76	41.77	39.95	38.29	36.76

Source: Corrugated Polyethylene Pipe Association (2000) “Hydraulic Considerations for Corrugated Polyethylene Pipe”

Flow Velocity Considerations

The buildup of sediment and debris can reduce the capacity of a pipe. In some situations, this buildup can limit the pipe's effectiveness until it is cleaned out. This process is time consuming and expensive, therefore preventative measures should be taken during the design process.

One way to counteract this buildup is to impose a minimum, or self-cleansing, velocity. The pipe flow velocity can be increased by either increasing the slope of the pipe or by decreasing the diameter. This should not be done without first reviewing the site conditions and requirements. However, by using a corrugated HDPE pipe with a small smooth interior instead of other pipe materials, a smaller diameter pipe can be selected without affecting the capacities or slope of the pipeline.

The velocity (V) in feet per second of full flowing pipes can be approximated by using

$$V = \frac{Q}{A} \qquad \text{Equation 5}$$

Note:

Q = pipe capacity (cfs)

A = cross sectional flow area of the pipe (ft^2)

A minimum velocity of 3 feet per second (fps) is commonly used throughout the industry for storm water applications. For drainage pipes, such as those used in agricultural applications, a minimum of 0.5 fps is recommended for drains not subjected to fine sands or silt and a minimum velocity of 1.4 fps for drains that have the potential for soil infiltration

Maximum velocity should also be considered through the design to ensure long, trouble free service of the pipe. High flow velocities, greater than 12 fps, can be lessened by reducing the slope of the pipe or by selecting a larger diameter pipe. High velocities coupled with debris and sediment increase the possibility of causing durability issues due to abrasion; however, HDPE and HP pipe ill resist these conditions better than many other pipe materials.

High velocities at joints and fittings should also be considered. High velocities coupled with changes in the flow direction will exert added pressure on the fittings. Based on the bearing strength of the existing soil, thrust blocks or other devices may need to be used to counteract the added pressure.

Pressure Situations

Prinsco pipe products are designed and tested specifically for gravity flow situations taking into consideration the condition of intermediate or temporary storm surge pressures. However, the pipe is not rated for long-term pressure applications. Contact your local Prinsco representative with any questions regarding pressurized applications.

Culvert Considerations

The discharge curves and conveyance methods described above are for fully developed flows in longer runs of pipe. In many cases, culverts are inlet or outlet controlled. Therefore, in the case of culverts, the discharge curves or the conveyance method cannot be the only consideration when sizing the culvert. For additional information contact your local Prinsco representative.

Example Problems

The following example problems demonstrate the use of conveyance factors and discharge curves in sizing applications, basic velocity checks and optional designs.

Example 1 – Using Conveyance factors

- ***Given:*** Field conditions require a flow capacity of 2.5 cfs and a slope of 0.5' drop in invert elevation per 100 feet of pipe run (i.e., 0.5% slope)
- ***Find:*** The suitable Prinsco pipe product providing the optimum hydraulic solution.
- ***Solution:*** Equation 4 can be used to determine the required conveyance for the given conditions. The slope should first be converted into the units of feet/foot as shown:
  - 0.5 feet / 100 feet = 0.5% = 0.005 ft/ft

Note substitute the given values into Equation 4 as shown:

$$k = \frac{Q}{S^{\frac{1}{2}}}$$

$$= \frac{2.5\ cfs}{(0.005)^{\frac{1}{2}}}$$

$$= 35.4$$

Refer to Table 1 to select the pipe size with a minimum conveyance factor of 35.4 based on the appropriate Manning's "n" values.

The most practical solutions are:

12" GOLDFLO or GOLDPRO Storm pipe	k = 38.6
15" GOLDLINE pipe	k = 46.7

The optimum hydraulic solution would be the pipe with conveyance factor greater than or equal to the calculated value. Both of these options will function in about the same manner because their conveyances are close to that required.

Example 2 – Using Discharge Curves

- ***Given:*** Field conditions specify a pipe capacity of 2.5 cfs and a slope of 0.5%.
- ***Find:*** The suitable Prinsco pipe product providing the optimum hydraulic solution.
- ***Solution:*** Figures 1 & 2 can be used to determine appropriate pipe size. The slope should first be converted into the units of feet/foot as shown:
  - 0.5 feet/ 100 feet = 0.5% = 0.005 ft/ft

Figure 1 is used to select either a dual wall pipe. The intersection of the 0.50% and 2.5 cfs is above the 10" line but below the 12" line (see Figure 3). Therefore, the best selection would be the 12" GOLDFLO or GOLDPRO Storm pipe.

Figure 2 is used to select the GOLDLINE pipe. The intersection of the 0.50% and 2.5 cfs is above the 12" line but below the 15" line (see Figure 4). Therefore, the best selection would be the 15" GOLDLINE pipe.

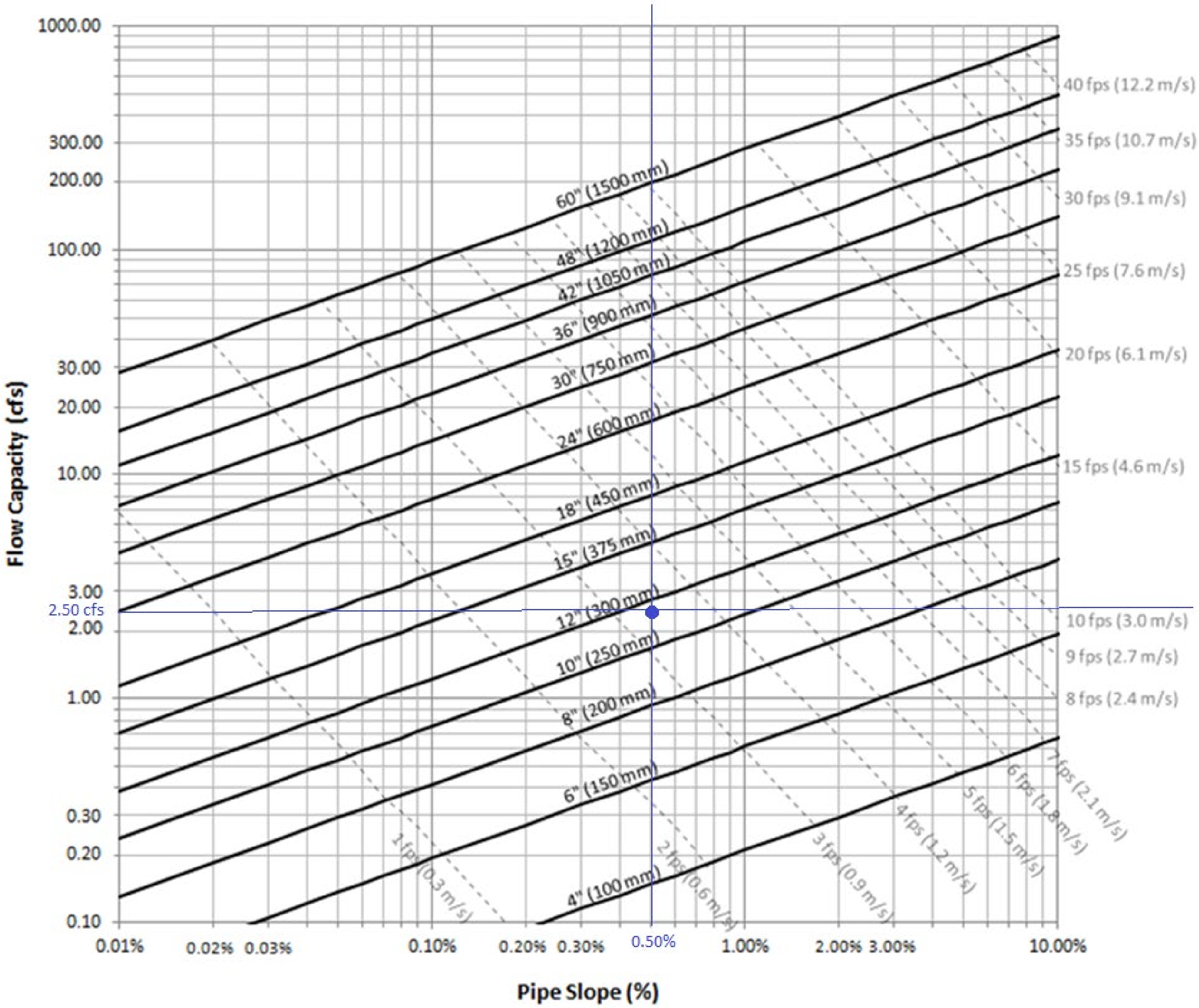

Figure 3: Example 2 Using Discharge Curves for Dual Wall Pipe

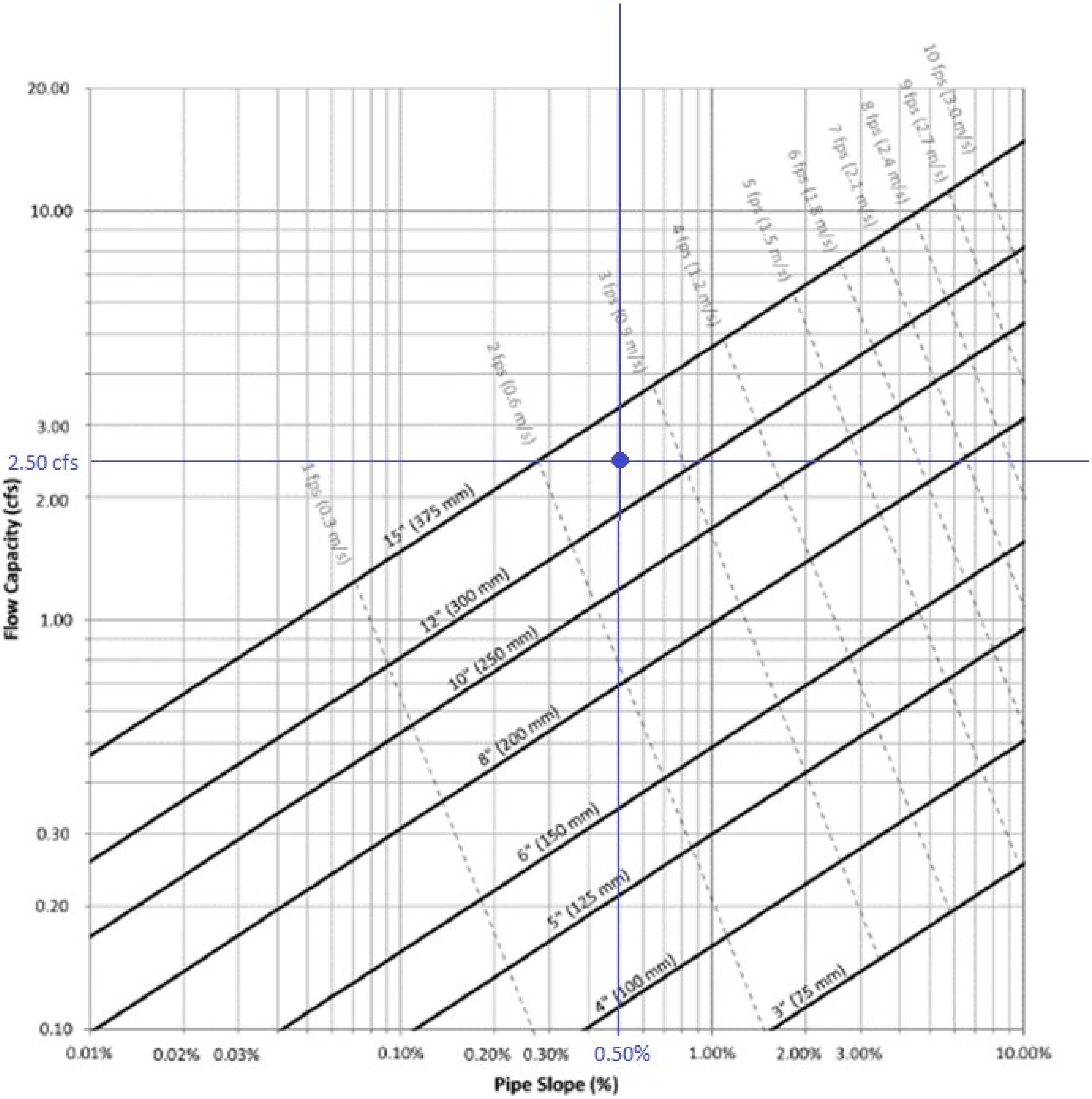

Figure 4: Example 2 Using Discharge Curves for Single Wall Pipe