APPENDIX O-VII

PRESSURE DISTRIBUTION NETWORK DESIGN

Septic tank effluent or other pretreated effluent can be distributed in a soil treatment/dispersal unit either by trickle, dosing or uniform distribution. Trickle flow, known as gravity flow, occurs each time wastewater enters the system through 4" perforated pipe. The pipe does not distribute the effluent uniformly but concentrates it in several areas of the absorption unit. Dosing is defined as pumping or siphoning a large quantity of effluent into the 4" inch perforated pipe for distribution within the soil absorption area. It does not give uniform distribution but does spread the effluent over a larger area than does gravity flow. Uniform distribution, known as pressure distribution, distributes the effluent somewhat uniformly throughout the absorption area. This is accomplished by pressurizing relatively small diameter pipes containing small diameter perforations spaced uniformly throughout the network and matching a pump to the network.

This material has been extracted and modified from a paper entitled “Design of Pressure Distribution Networks for Septic Tank- Soil Absorption Systems” by Otis, 1981. It also includes material from the “Pressure Distribution Component Manual for Private Onsite Wastewater Treatment Systems” by the State of Wisconsin, Department of Commerce, 1999.

Design Procedure

The design procedure is divided into two sections. The first part consists of sizing the distribution network which distributes the effluent in the aggregate and consists of the laterals, perforations, and manifold. The second part consists of sizing the force main, pump, dose chamber, and suitable controls.

A. Design of the Distribution Network: Steps:

1. Configuration of the network.

The configuration and size of the absorption field must meet all soil and site criteria. Once any limitations have been established, the distribution network can be designed.

2. Determine the length of the laterals.

Lateral lengths are defined as the distance length from the manifold to the end of the lateral. For a center manifold it is approximately one half the length of the absorption area. For end manifolds it is approximately the length of the absorption area. The lateral should end about 6" to 12" from the end of the absorption bed.

3. Determine the perforation size, spacing, and position.

The size of the perforation or orifices, spacing of the orifices and the number of orifices must be matched with the flow rate to the network.

Size: The typical perforation diameter has been 1/4", but with the requirement of Class I effluent, carry-over particles have been greatly reduced allowing smaller diameter orifices to be used. Orifices as small as 1/8" are commonly used in sand filter design, however orifice shields are generally used to protect the orifice from being compromised by the aggregate. Smaller diameter perforations are also at risk from burrs when drilling. Shop drilling the orifices under tight specifications reduces the concern. A sharp drill bit will drill a much more uniform orifice than a dull drill. Replace drills often. Remove all burrs and filing from pipe before assembling it. As a compromise, one might consider using 5/32” or 3/16” diameter orifices which will allow for more orifices than if 1/4" orifices were used.

Spacing: It is important to distribute the effluent as uniformly as possible over the system to increase effluent/soil contact time and maximize treatment efficiency. Typical spacing has been 30-36" but some designers have set spacing further apart to reduce pipe and pump sizes. Typical spacing for beds has been 6 ft^2/orifice (J.C.Converse; 2000).

Positioning: In cold climates, it is essential that the laterals drain after each dose event to prevent freezing. Because of the longer laterals normally encountered in mounds, the orifices are typically placed downward for draining as it is much more difficult to slope the lateral toward the manifold/force main because of their greater length.

4. Determine the lateral pipe diameter.

Based on the selected perforation size and spacing, Fig. A-1a through A-3b should be used to select the lateral diameter. Lateral diameter is also used to determine dose volume. (Fig. A-5).

5. Determine the number of perforations per lateral.

Use: $N = (p/x) + 0.5$ for center feed/center manifold
$N = (p/x) + 1$ for end fed/end manifold

Where:
N = number of perforations,
p = lateral length in feet and
x = perforation spacing in feet.
Round number off to the nearest whole number.

6. Determine the lateral discharge rate.

Based on the distal pressure selected, Table A-1 gives the perforation discharge rate. The designer must choose an operational pressure (in units of feet) at a distal point. This is the starting point of selecting a pump and determining if the system has equal distribution.

7. Determine the number of laterals and the spacing between laterals.

Since the criteria of 6 ft²/orifice is the guideline, the orifice spacing and laterals spacing are interrelated. For absorption area widths of 3 ft, one distribution pipe along the length of trench requires an orifice spacing of 2 ft. For a 6 ft wide absorption area with the same configuration it would require orifice spacing of 1 ft. or the system could utilize a manifold with several laterals and have better coverage. **Ideally, the best option is to position the perforations to serve a square such as a 2.5' by 2.5' area** but that may be difficult to do but a 2' by 3' is much better than a 6' by 1' area.

8. Calculate the manifold size and length.

The manifold length is the length pipe between the outer laterals. For smaller systems assume the manifold size is the same as the force main diameter since the manifold is an extension of the force main. There are procedures for determining the manifold size for larger systems (Table A-2) from Otis, 1981.

9. Determine the network discharge rate.

This value is used to size the pump. Take the lateral discharge rate and multiply it by the number of laterals or take the perforation discharge rate and multiply it by the number of perforations.

B. Design and Selection of the Force Main, Pump, Dose Chamber and Controls.

1. Develop a system performance curve.

The system performance curve predicts how the distribution system performs under various flow rates and heads. The flow rate is a function of the total head that the pump works against. As the head becomes larger, the flow rate decreases but the flow rate determines the network pressure and thus the relative uniformity of discharge throughout the distribution network. The best way to select the pump is to evaluate the system performance curve and the pump performance curve. Where the two curves cross, is the point where the system operates relative to flow rate and head.

The total dynamic head that the pump must work against is the:

1. System network head (1.3 x distal pressure)

2. Elevation difference between the pump and the highest point in the system.

3. Friction loss in the force main.

The system network head is the pressure maintained in the system during operation to assure relatively uniform flow through the orifices. The 1.3 multiplier relates to the friction loss in the manifold and laterals which assumes that the laterals and manifold are sized correctly.

The elevation difference is between the pump and the highest point in the system in feet (the pump industry uses the bottom of the pump tank).

The friction loss in the force main between the pump tank and the inlet to the network is determined by using Table A-3. Equivalent length for fittings should be included. Equivalent lengths are found in Table A-4.

2. Determine the force main diameter.

The force main diameter is determined from Table A-2. The number of laterals and/or length of manifold should not exceed these maximums.

3. Select the pressurization unit.

Pumps

Using pump performance curves, select the pump that best matches the required flow rate at the operating head. Plot the pump performance curve on the system curve. Then determine if the pump will produce the flow rate at the required head. Do not undersize the pump. It can be oversized but will be more costly.

4. Determine the dose volume required.

The lateral pipe void volume determines the minimum dose volume. The recommended dose volume is 10 times the lateral volume. It is required that the system be timed dosed daily based on the design flow. Small doses need to be applied; however, sufficient volume is needed to distribute the effluent uniformly across the network. Table A-5 gives the void volume for various size pipes.

5. Size the dose tank.

For residential applications, the dose tank must be large enough to provide for:

a. The dose volume.
b. The dead space resulting from placement of the pump on a concrete block.
c. A few inches of head space for floats
d. 24 hour reserve capacity based on 150 gallons per bedroom.

The pump tank must have sufficient surge capacity to allow for timed dosing. See Section E of the manual for additional information and requirements for dosing other applications.

6. Select controls and alarms.

Select quality controls and alarms. Follow electrical code for electrical connections.

DESIGN EXAMPLE

This example will follow these steps to design a pressure distribution network for a bed system. All requirements found in Section F; *Absorption Field Methods* and *Guidelines for Class I Effluent* of the manual must be followed.

The bed absorption area is 452 ft^2 (113 ft long by 4 ft wide). The force main is 125 ft long and the elevation difference is 9 ft with three 90° elbows. Central manifold distribution system will be used.

A. Design of the distribution network.

Steps:

1. Configuration of the network.

This is a narrow absorption bed on a sloping site. (4’ x 113’ = 452 ft^2)

2. Determine the lateral length.

Use a center feed, the lateral length is:

Lateral Length = (B / 2) - 0.5 ft   Where: B = bed absorption length.
= (113 / 2) - 0.5 ft
= **56 ft**

3. Determine the perforation spacing and size.

Perforation spacing:

It is recommended that each perforation covers a maximum area of 6 ft^2. The absorption area is 4 ft wide.

Two laterals on each side of the center.

Spacing = (area/orifice x no. of laterals / (absorption area width)

= (6 ft^2 x 2) / (4 ft)
= **3 ft.**

Best option: Ideally, the best option is to position the perforations to serve a square but that may be difficult to do. In this example, each perforation serves a 2' by 3' rectangular area. With an absorption area of 6 ft wide with one lateral down the center, perforation spacing would be 1 ft apart and the perforation would serve an area of 6 by 1 ft which would be undesirable.

Perforation size:

Smaller diameter perforations may reduce system discharge flow rate, reduced pump requirements, at the same time increasing the number of orifices benefitting equal distribution through out the system. This example uses **3/16" perforations.**

4. Determine the lateral diameter.

Using **Fig. A-2a (3/16")** to determine the minimum lateral diameter:

The laterals on each side of the center manifold each has the length of 56 ft with 3 ft spacing between orifices, these point to a **lateral diameter of 1.5".**

5. Determine number of perforations per lateral and number of perforations.

Using 3.0 ft spacing in 56 ft a lateral yields 19 perforations each:

N = (p/x) +0.5 = (56 / 3.0) +0.5 = 19 perforations/lateral

Number of perforations = 4 lateral x 19 perforations/lateral = 76

Check - Maximum of 6 ft_2 / perforation =

Number of perforations = 412 sqft/6 ft^2 = 75; (76 > 75**, is okay**)

6. Determine lateral discharge rate (LDR).

Using network pressure (distal) pressure of 3.5 ft and 3/16" diameter perforations,
Table A-1 gives a discharge rate of 0.78 gpm, regardless of the number of laterals.

LDR = 0.78 gpm/perforation x 19 perforations = **14.8 gpm/lateral**

7. Determine the number of laterals.

This was determined in Step 3 and 4.

Two laterals on each side of center feed = **4 laterals spaced 2 ft apart.**

8. Calculate the manifold size.

The force main diameter is determined from Table A-2 on the manual. The manifold is generally the same size as force main as it is an extension of the force main or it could be one size smaller. This example will use a **2” manifold**.

9. Determine network discharge rate (NDR)

NDR = 4 laterals x 14.8 gpm/lateral = 59.2 or **60 gpm**

Pump has to discharge a minimum of 60 gpm against a total dynamic head yet to be determined.

10. Total dynamic head.

Sum of the following:

System head = 1.3 x distal head (ft)
= 1.3 x 3.5 ft
= **4.5 ft**

Elevation head = **9.0 ft** (Pump shut off to network elevation)

Head Loss in Force Main = Table A-3 and A-4 for 60 gallons and 125 ft of force main and 3 elbows.

Equivalent length of pipe for fittings can be found in Table A-3

3- 2" 90° elbows @ 9.0 ft each = **27 ft** of pipe equivalent.

Head Loss through 100’ of PVC pipe can be found in Table A-2

125’ of 2" force main plus the head loss in the fittings equals

= 7.0 (125 ft + 27 ft)/100 = **10.6 ft**

Total Dynamic Head (TDH) = Sum of the three

TDH = System head + Elevation head + Head Loss in Force Main

4.5 + 9 + 10.6 = 24.1 ft (2" force main) = **24 ft of head**

11. Pump Summary

Pump must discharge **60 gpm** against a head of **24 ft** with 2" force main.

These are the calculated flow and head values. The actual flow and head will be determined by the pump selected. A system performance curve plotted against the pump performance curve will give a better estimate of the flow rate and total dynamic head the system will operate under.

12. Select the Pump

Using a performance curve from the pump manufacture, the point where the flow rate intersects (60 gpm) the total dynamic head (24 ft) should fall under the pump curve. A pump can be over sized, but undersized pumps will lead to failure in performance and/or longevity.

4. Determine the dose volume.

Determine the pipe void volume from Table A-5. Use 10 times the lateral void volume.

Dose Volume = 10 x length of lateral x number of laterals x Void volume

Lateral diameter = 1.5"
Lateral Length = 56'
No. of laterals = 4
Void volume = 0.092 gal/ft

10 x 56 x 4 x 0.092 = **206 gal./dose**

5. Size the dose tank.

The pump tank size should be based on the dose volume, 24 hour storage volume, and room for a block beneath the pump and control space. This example is for a residential application, additional information on dosing requirements can be found in Section E of the manual.

6. Select controls and alarm.

Time Dosing: The advantage of time dosing provides more frequent doses and levels out peak flows to the bed.

CONSTRUCTION AND MAINTENANCE

Good common sense should prevail when constructing and maintaining these systems. Water tight construction practices must be employed for all tanks. Surface runoff must be diverted away from the system. Any settling around the tanks must be filled with the soil brought to grade or slightly above to divert surface waters.

Table A-1 **Perforation Discharge Rates (GPM)**

Distal Pressure	Perforation Diameter (in)					
(ft)	1/8	5/32	3/16	1/4	5/16	3/8
	---GPM---					
1.0	0.18	0.29	0.41	0.74	1.15	1.66
1.5	0.23	0.35	0.50	0.90	1.41	2.03
2.0	0.26	0.41	0.58	1.04	1.63	2.34
2.5	0.29	0.45	0.66	1.17	1.82	2.62
3.0	0.32	0.50	0.72	1.28	1.99	2.87
3.5	0.34	0.54	0.78	1.38	2.15	3.10
4.0	0.37	0.57	0.83	1.47	2.30	3.32
4.5	0.39	0.61	0.88	1.56	2.44	3.52
5.0	0.41	0.64	0.93	1.65	2.57	3.71

Values were calculated as: gpm = $(11.79 \times d^2 \times \sqrt{h})$
Where: d = orifice dia. in inches and h = head feet.

Table A-2 Maximum Manifold Length (ft) For Various Manifold Diameters Given the Lateral Discharge Rate and Lateral Spacing (from: Otis, 1981)

Lateral Discharge Rate	**Manifold Diameter = 1¼”**					**Manifold Diameter = 1½”**					**Manifold Diameter = 2”**					**Manifold Diameter = 3”**					**Manifold Diameter = 4”**					**Manifold Diameter = 5”**				
End Manifold / Center Manifold	**Lateral Spacing (ft)**					**Lateral Spacing (ft)**					**Lateral Spacing (ft)**					**Lateral Spacing (ft)**					**Lateral Spacing (ft)**					**Lateral Spacing (ft)**				
	2	**4**	**6**	**8**	**10**	**2**	**4**	**6**	**8**	**10**	**2**	**4**	**6**	**8**	**10**	**2**	**4**	**6**	**8**	**10**	**2**	**4**	**6**	**8**	**10**	**2**	**4**	**6**	**8**	**10**
10 / 5	4	8	6	8	10	10	8	12	16	20	12	16	24	24	30	26	40	48	56	70	42	64	84	96	110	84	134	174	200	240
20 / 10	4	4	6			4	4	6	8	10	6	8	12	16	20	16	24	30	32	40	26	40	54	64	70	54	84	106	128	150
30 / 15	2					2	4	6			4	8	6	8	10	12	16	24	24	30	20	26	36	48	60	42	64	84	96	110
40 / 20											4	4	6	8	10	10	12	18	16	20	16	24	30	32	40	34	52	66	80	90
50 / 25											2	4	6	8		8	12	12	16	20	14	20	24	32	40	30	44	60	72	80
60 / 30											2	4				8	12	18	16	20	12	16	24	24	30	26	40	48	64	70
70 / 35											2					6	8	12	8	10	10	16	18	24	30	24	36	48	56	60
80 / 40											2					6	8	6	8	10	10	12	18	16	20	22	32	42	46	60
90 / 45											2					4	8	6	8	10	8	12	18	16	20	20	28	42	46	50
100 / 50																4	4	6	8	10	8	12	12	16	20	18	28	36	40	50
110 / 55																4	4	6	8	10	8	12	12	16	20	16	24	36	40	40
120 / 60																4	4	6	8	10	6	8	12	16	10	16	24	30	32	40
130 / 65																4	4	6	8	10	6	8	12	16	10	14	24	30	32	40
140 / 70																2	4	6	8		6	8	12	8	10	14	20	24	32	40
150 / 75																2	4	6			6	8	12	8	10	14	20	24	32	30
160 / 80																2	4	6			6	8	6	8	10	12	20	24	32	30
170 / 85																2	4	6			4	8	6	8	10	12	20	24	24	30
180 / 90																2	4				4	8	6	8	10	12	16	24	24	30
190 / 95																2	4				4	8	6	8	10	12	16	18	24	30
200 / 100																2	4				4	4	6	8	10	10	16	18	24	30

Table A-3 Friction Loss in Schedule 40 Plastic Pipe

(ft/100 ft), Based on Hazan-Williams; C = 150

Pipe Diameter (Inches)

Flow (GPM)	1	1 1/4	1 1/2	2	3	4	6	8	10
1	0.07								
2	0.28	0.07							
3	0.60	0.16	0.07						
4	1.01	0.25	0.12						
5	1.52	0.39	0.18						
6	2.14	0.55	0.25	0.07		**Velocities in this area are below 2 ft/sec.**			
7	2.89	0.76	0.36	0.10					
8	3.63	0.97	0.46	0.14					
9	4.57	1.21	0.58	0.17					
10	5.50	1.46	0.70	0.21					
11		1.77	0.84	0.25					
12		2.09	1.01	0.30					
13		2.42	1.17	0.35					
14		2.74	1.33	0.39					
15		3.06	1.45	0.44	0.07				
16		3.49	1.65	0.50	0.08				
17		3.93	1.86	0.56	0.09				
18		4.37	2.07	0.62	0.10				
19		4.81	2.28	0.68	0.11				
20		5.23	2.46	0.74	0.12				
25			3.75	1.10	0.16				
30			5.22	1.54	0.23				
35				2.05	0.30	0.07			
40				2.62	0.39	0.09			
45				3.27	0.48	0.12			
50				3.98	0.58	0.16			
60					0.81	0.21			
70					1.06	0.28			
80					1.38	0.37			
90					1.73	0.46			
100					2.09	0.55	0.07		
150						1.17	0.16		
200							0.28	0.07	
250							0.41	0.11	
300							0.58	0.16	
350							0.78	0.20	0.07
400							0.99	0.26	0.09
450							1.22	0.32	0.11
500								0.38	0.14
600								0.54	0.18
700								0.72	0.24
800									0.32
900									0.38
1000									0.46

Table A-4 Friction losses through plastic fittings in terms of equivalent lengths of pipe

(Sump and Sewage Pump Manufacturers, 1998)

	--------------Nominal size fitting and pipe ------------------					
Type of Fitting	1¼	1½	2	2½	3	4
90° Elbow	7.0	8.0	9.0	10.0	12.0	14.0
45° Elbow	3.0	3.0	4.0	4.0	6.0	8.0
STD. Tee (Diversion)	7.0	9.0	11.0	14.0	17.0	22.0
Check Valve	11.0	13.0	17.0	21.0	26.0	33.0
Coupling/ Quick Disconnect	1.0	1.0	2.0	3.0	4.0	5.0
Gate Valve	0.9	1.1	1.4	1.7	2.0	2.3

Table A-5 Void volume for various diameter pipes.

Nominal Pipe Size (In.)	Void Volume (gal./ft)
3/4	0.023
1	0.041
1¼	0.064
1½	0.092
2	0.163
3	0.367
4	0.650
6	1.469

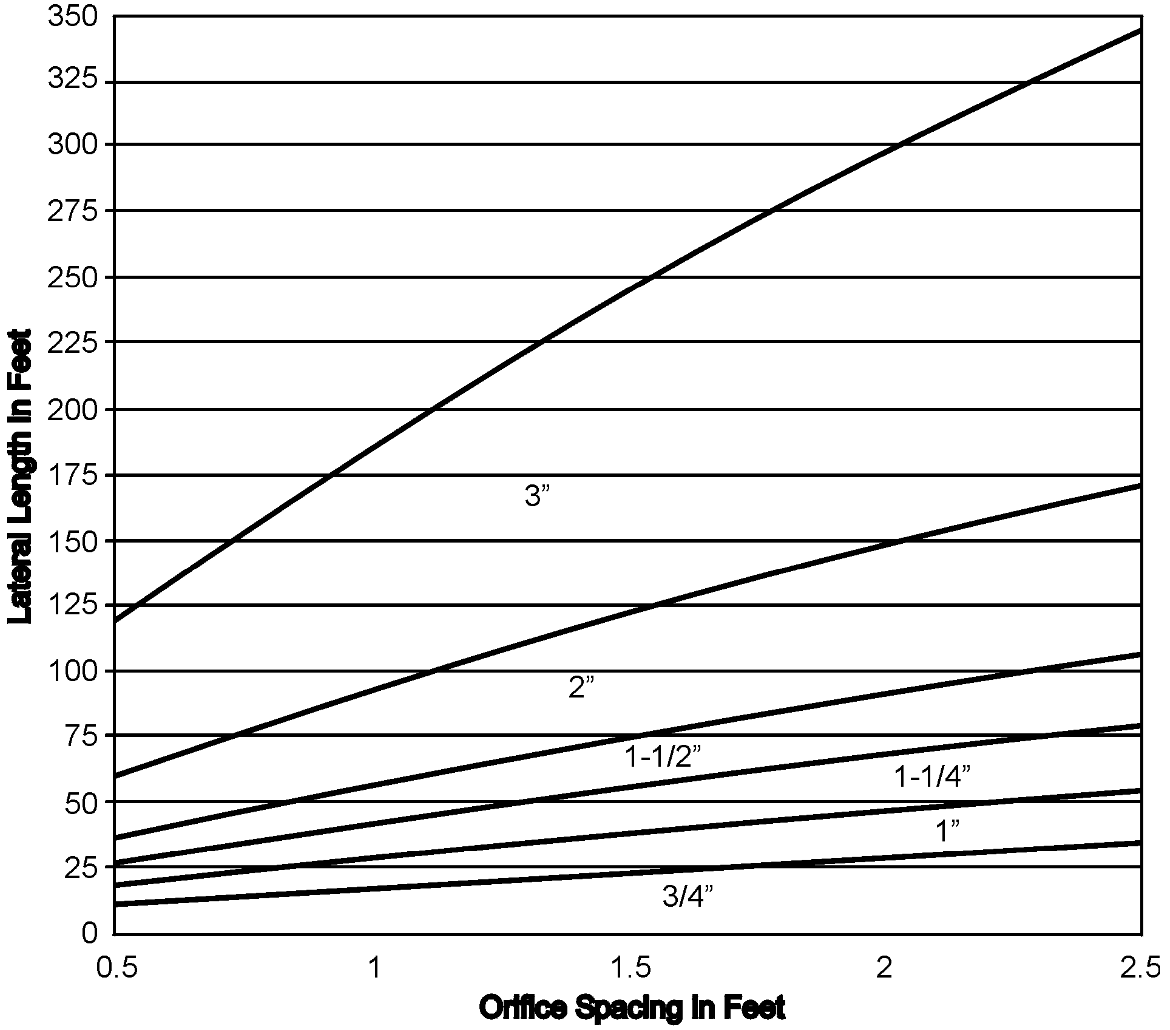

Fig. A-1a. Minimum lateral diameter based on orifice spacing for 1/8 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

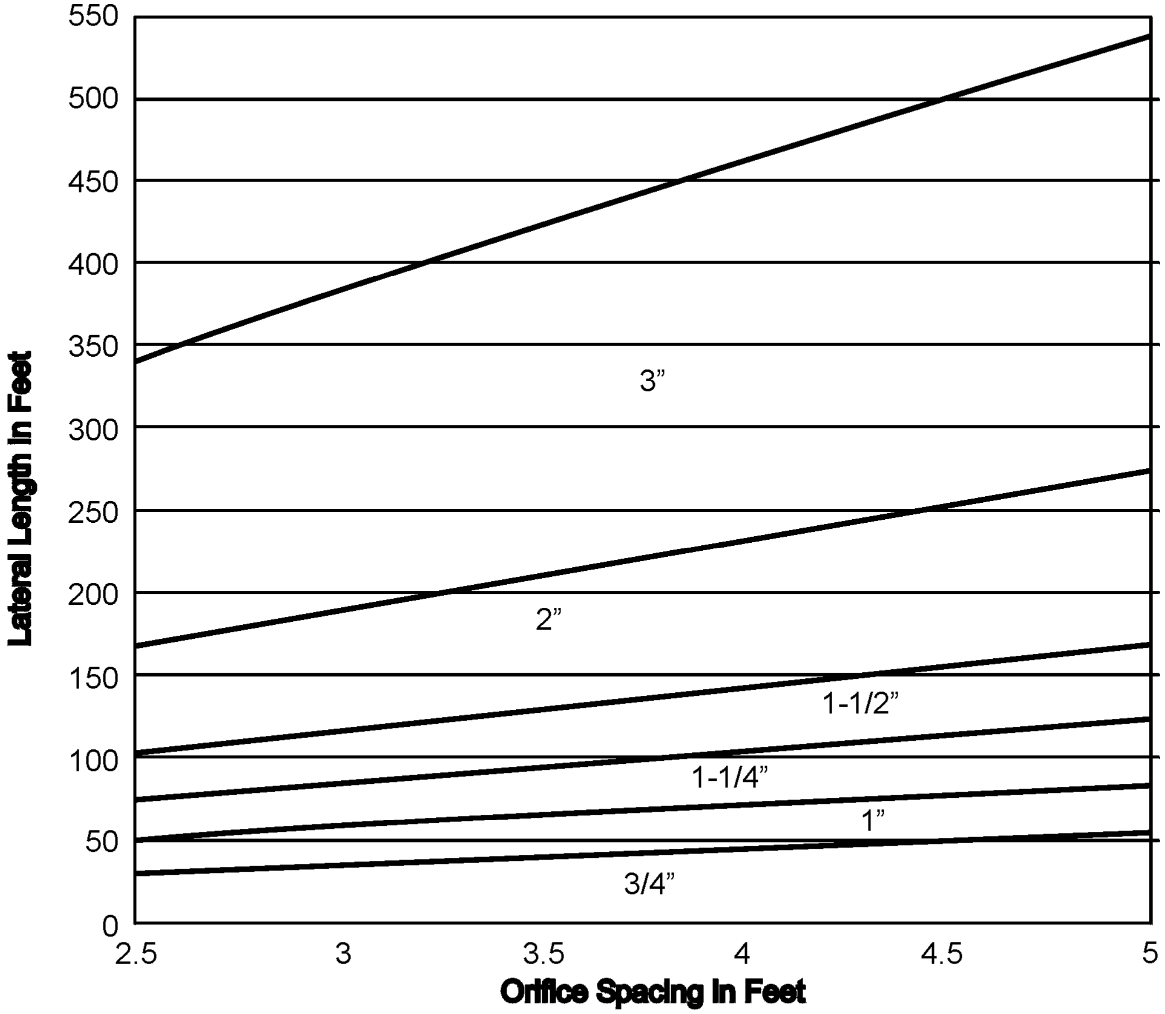

Fig. A-1b. Minimum lateral diameter based on orifice spacing for 1/8 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

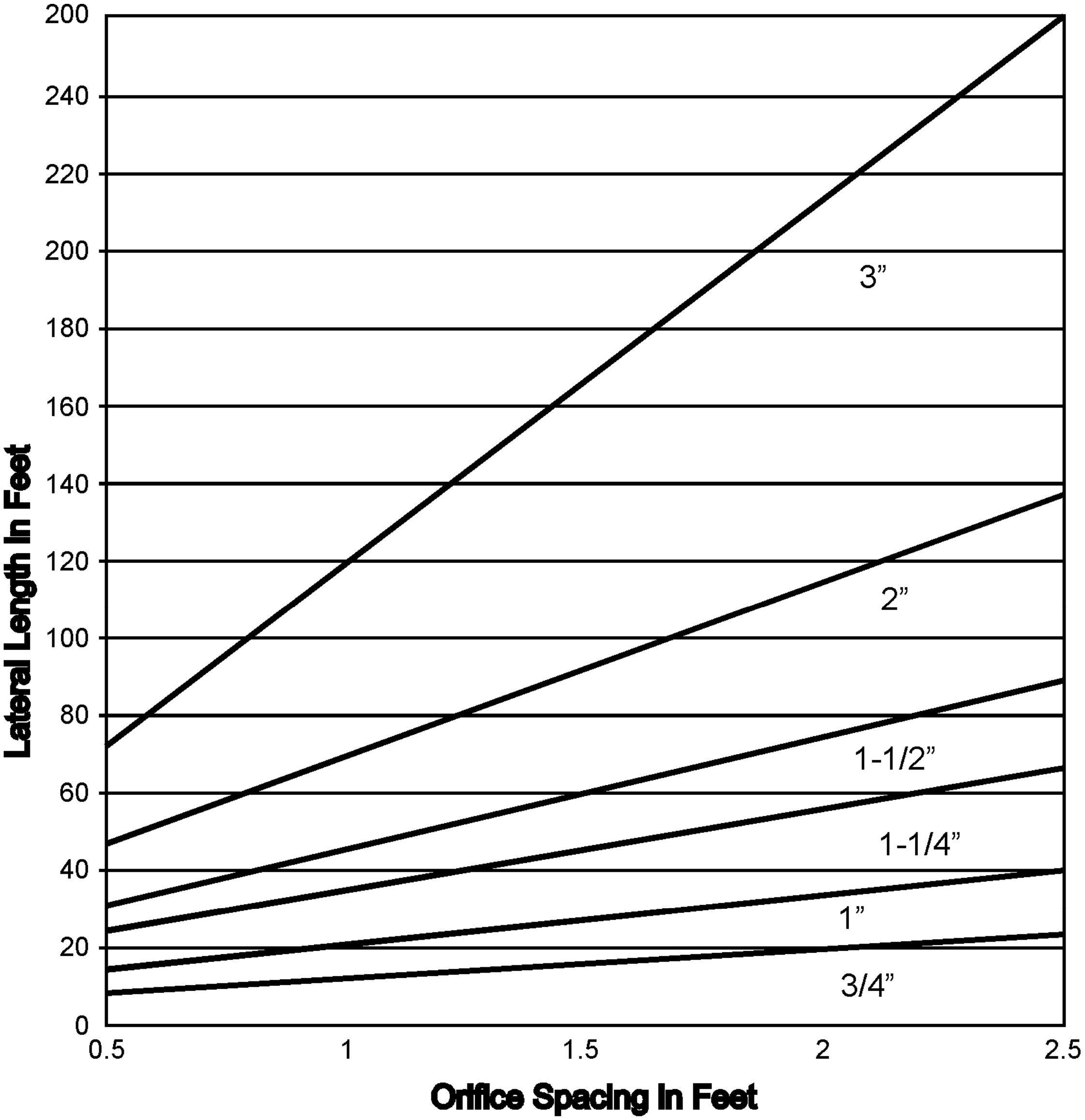

Fig. A-2a. Minimum lateral diameter based on orifice spacing for 5/32 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

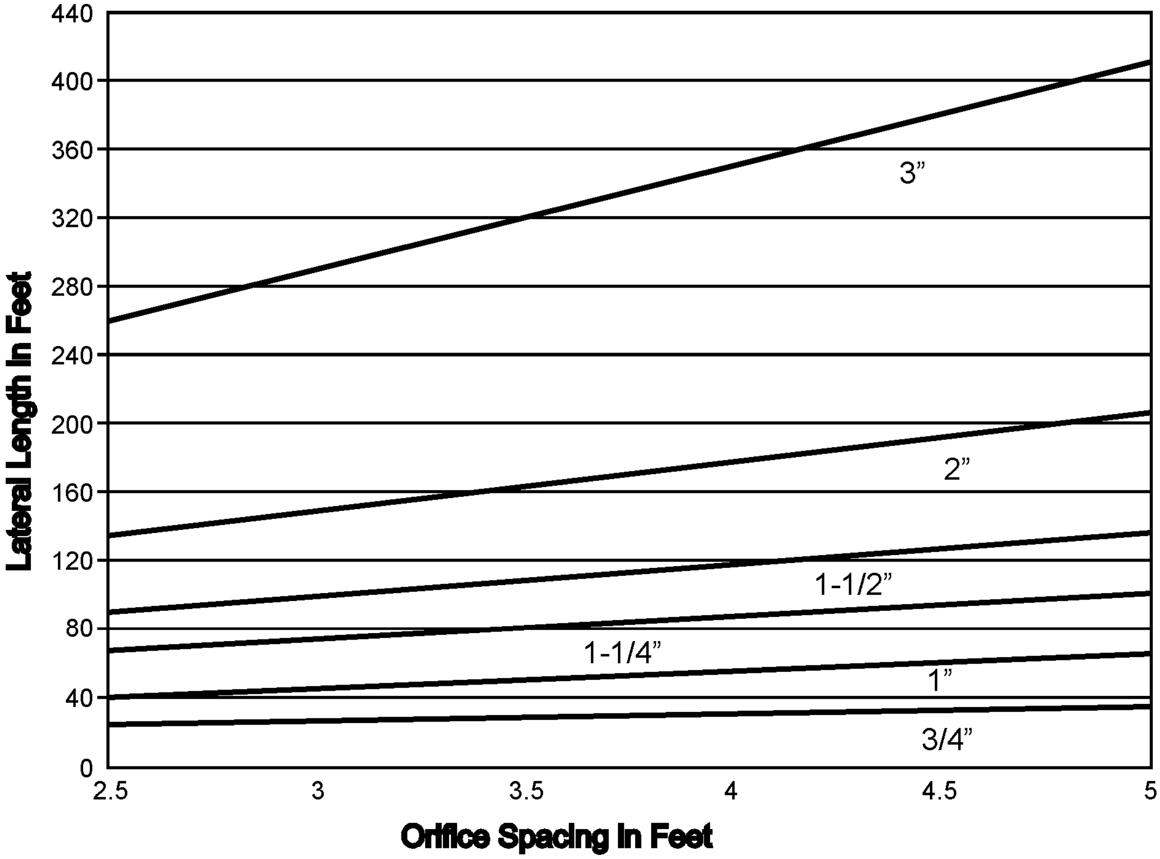

Fig. A-2b. Minimum lateral diameter based on orifice spacing for 5/32 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

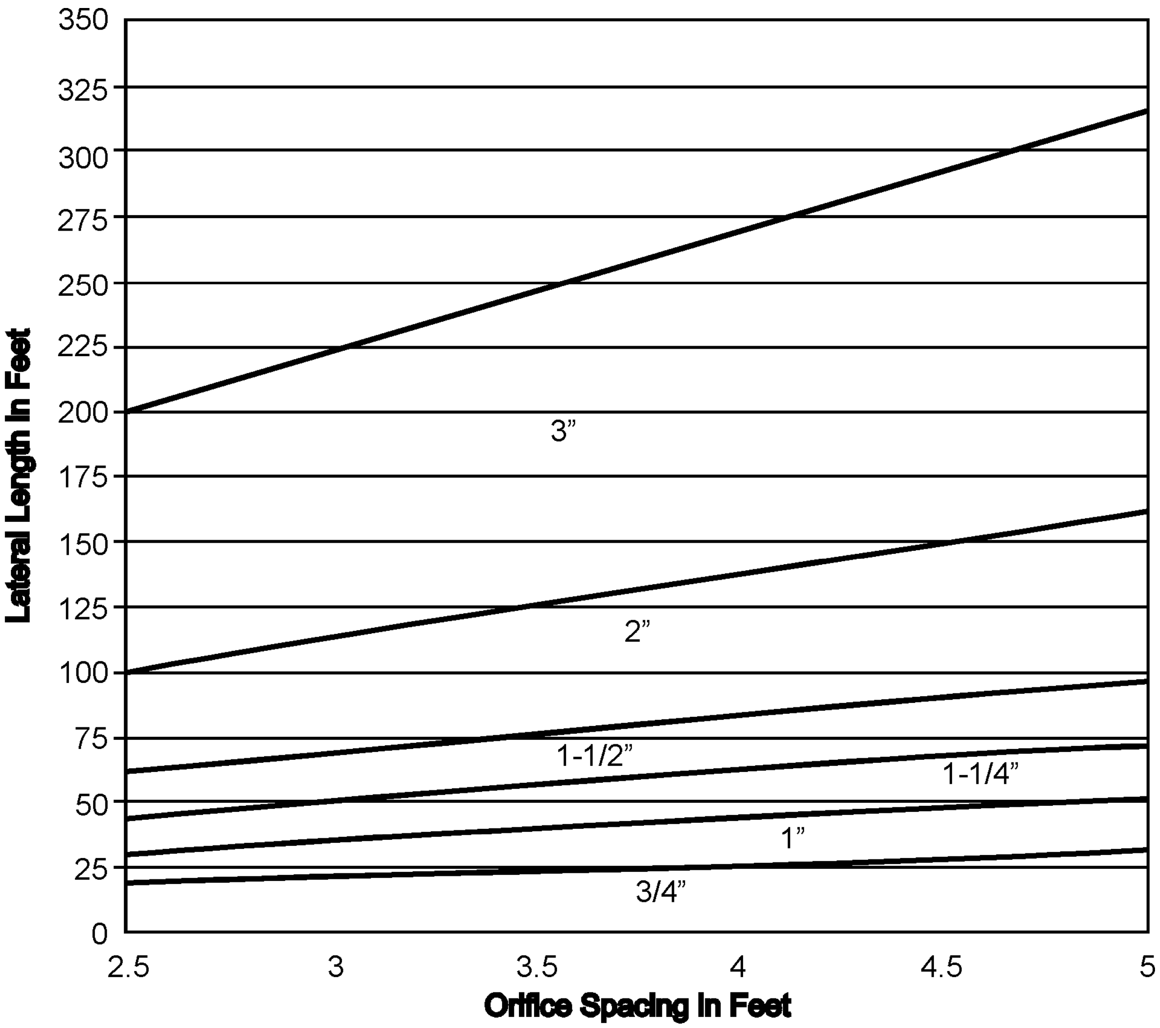

Fig. A-3a. Minimum lateral diameter based on orifice spacing for 3/16 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

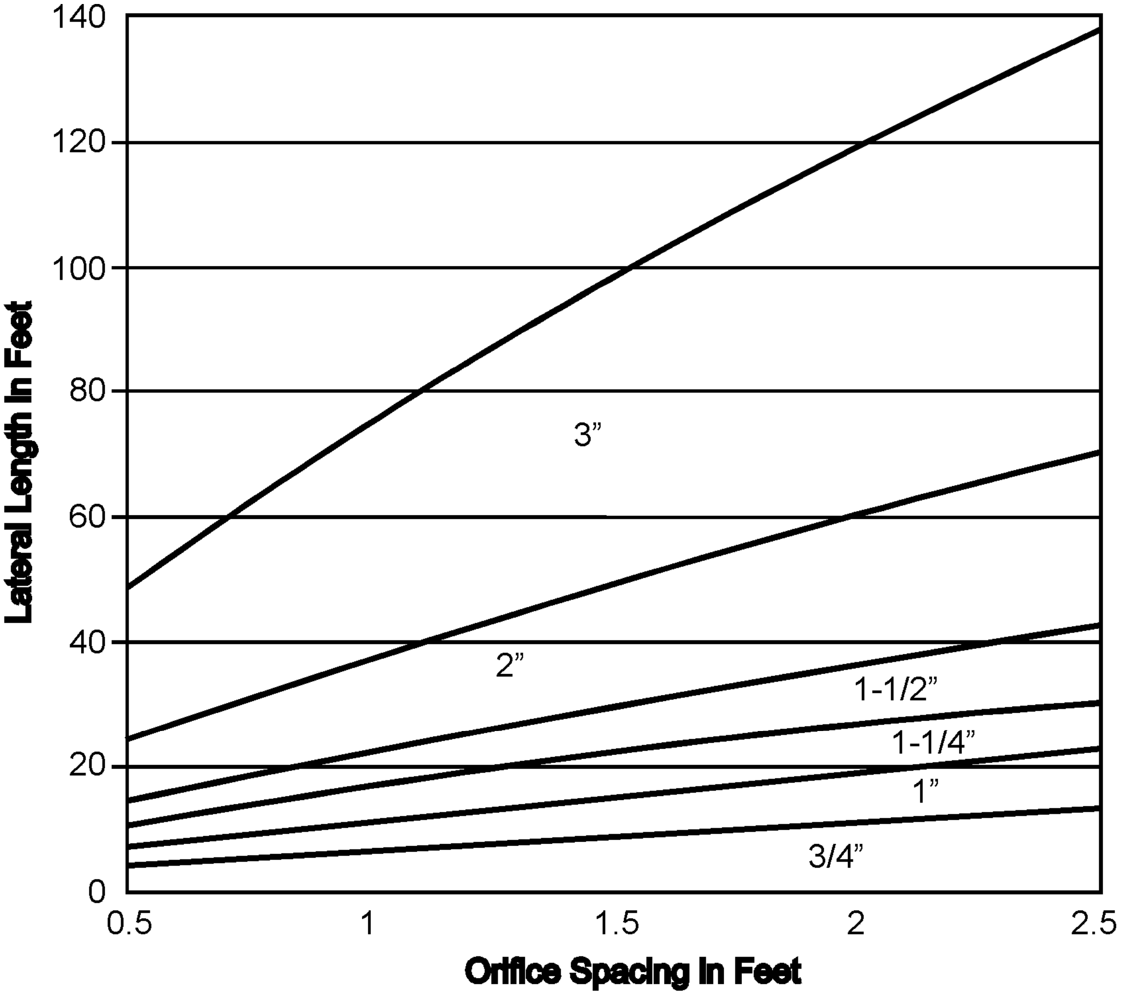

Fig. A-3b. Minimum lateral diameter based on orifice spacing for 3/16 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

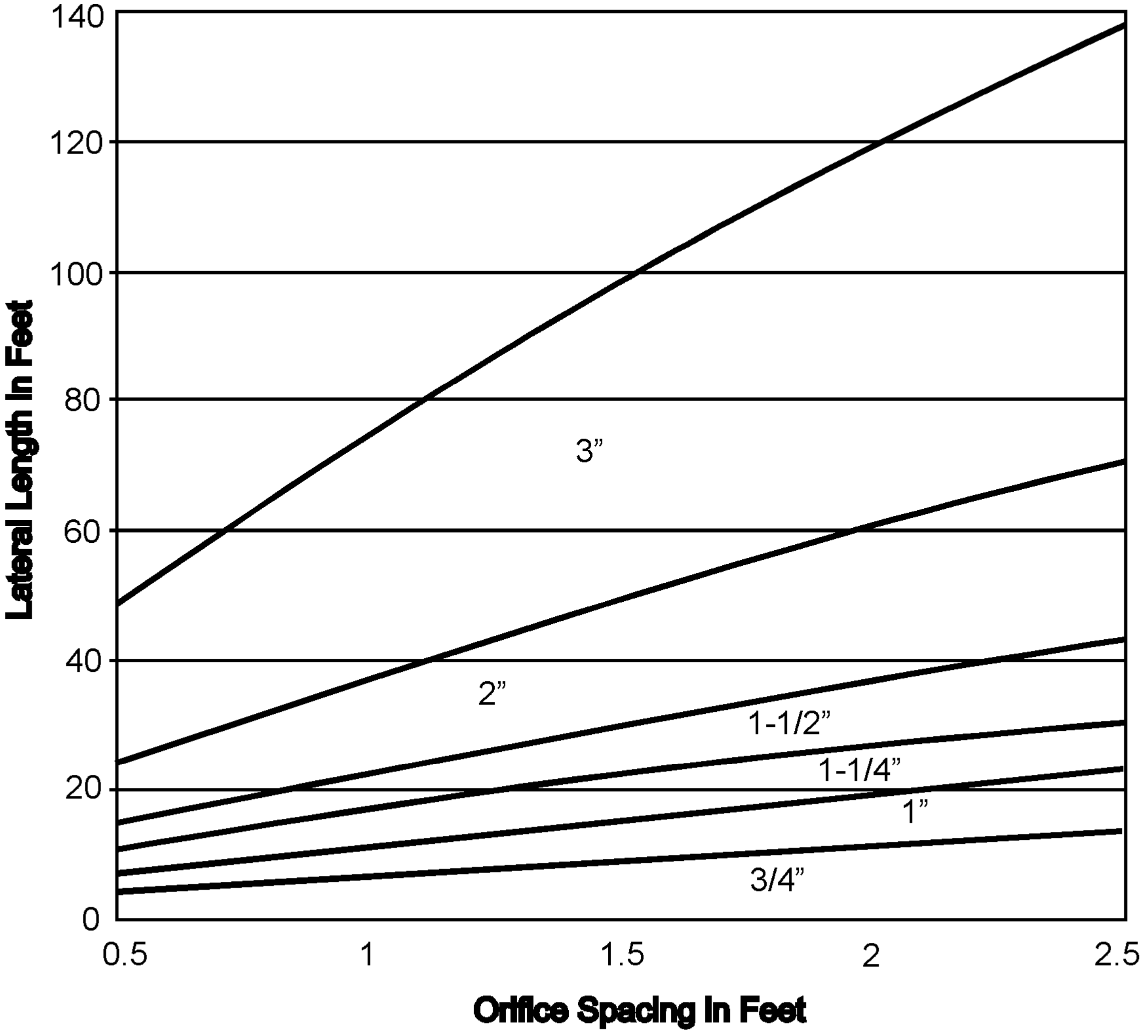

Fig. A-4a. Minimum lateral diameter based on orifice spacing for 1/4 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

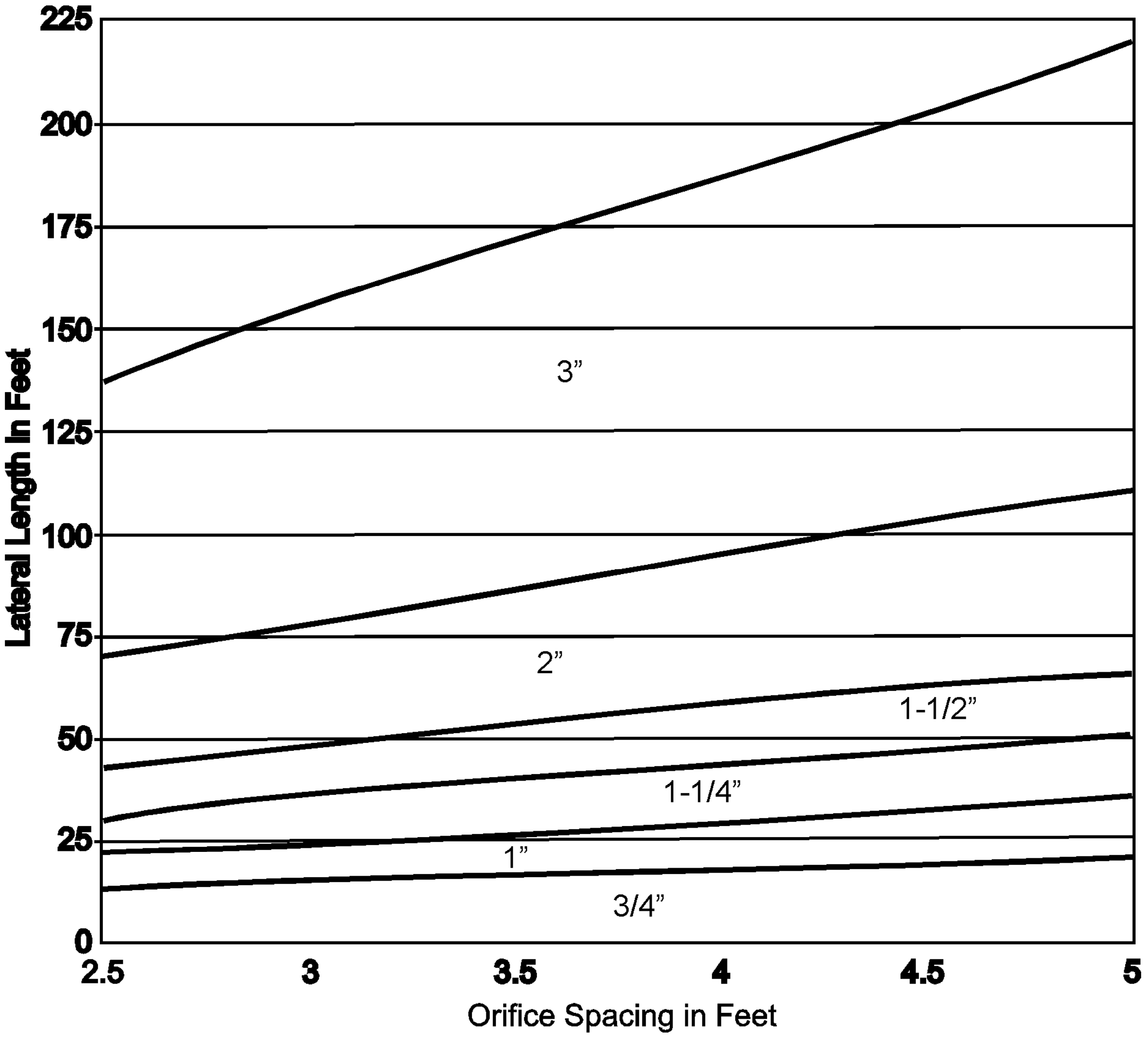

Fig. A-4b. Minimum lateral diameter based on orifice spacing for 1/4 in. diameter orifices (Wisc. Dept. Of Commerce, 1999)

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