§OH651.1004 Treatment

DESIGN GUIDE for
Practice Standard - Vegetated Treatment Area (635)

This guide will assist the designer in determining the size, dimensions, and application rates for vegetated filter areas in conformance with Standard 635, Vegetated Treatment Area, in Ohio's Field Office Technical Guide (FOTG). The design process is based on controlled hydraulic loading of diluted wastewater onto a vegetated soil surface. The wastewater is treated and assimilated by the plants and soil within the filter area. The intent is to treat the wastewater with filtering, deposition, plant uptake, evapotranspiration, solar exposure, adsorption to soil particles, and biological degradation. To accomplish this, the wastewater must be retained within the filter area. The hydraulic loading is designed so that there will be no surface discharge or leaching below the root zone beneath the filter.

The hydraulic loading criteria came from studies that showed this to be the critical factor in the success of vegetated filters. In simple terms, it means that a filter will only work if you don't overload it. The design method is based on hydraulic loading; therefore, there is no need for the accounting of nutrient accumulations. To prevent extreme nutrient build up or releases and to avoid harming the vegetation, the wastewater must be relatively dilute. Vegetated filters are not meant for undiluted or prolonged flows of manure, manure liquids, or silage leachate. These types of waste can only be accommodated if they are diluted (at least 1:1) with clean water or other wastewater such as milkhouse wastewater and barnyard runoff. The designer should consider increasing dilution and/or providing more than one filter area to provide extended rest periods for nutrient uptake and removal.

Maximum application rate is determined using the "soil group" to prevent exceeding the soil's water holding capacity. Deep well-drained soils will accept and hold more water than shallow poorly drained soils. The "soil group" and maximum application rate for the filter area can be determined from Table 1. Maximum application rate is the allowable dose volume over the entire filter area expressed both in gallons per 1,000 ft^2 and inches per dose.

Soil Groups for Vegetated Filter Area

Group 1
Soils in hydrologic group A or A/D with available water capacity greater than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

Group 2
Soils in hydrologic group A or A/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group A or A/D with available water capacity greater than 2 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group B or B/D with available water capacity greater than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group B or B/D with available water capacity greater than 4 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

Group 3

Soils in hydrologic group A or A/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group A or A/D and depth to rock or water table less than 20 inches and permeability of 2-6 inches/hour in the upper 20 inches.

or

Soils in hydrologic group B or B/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group B or B/D with available water capacity between 2 and 4 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group C or C/D with available water capacity greater than 4 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

Group 4

Soils in hydrologic group A or A/D and depth to rock or water table less than 20 inches and permeability of less than 2 inches/hour or permeability greater than 6 inches/hour.

or

Soils in hydrologic group B or B/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group B or B/D and depth to rock or water table less than 20 inches.

or

Soils in hydrologic group C or C/D with available water capacity between 2 and 4 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group C or C/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group C or C/D with available water capacity greater than 4 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group D and depth to rock or water table greater than 40 inches.

Group 5

Soils in hydrologic group C or C/D with available water capacity less than 2 inches in the upper 40 inches and depth to rock or water table greater than 40 inches.

or

Soils in hydrologic group C or C/D with available water capacity less than 4 inches in the upper 40 inches and depth to rock or water table between 20 and 40 inches.

or

Soils in hydrologic group C or C/D and depth to rock or water table less than 20 inches.

or

Soils in hydrologic group D and depth to rock or water table less than 40 inches.

- Soils with a dual hydrologic group that are not drained are lowered one group.
- Soils that are greater than 40 inches to rock and have a water table are lowered one or two groups, depending on depth to water table.
- Soils that are 20 to 40 inches to rock and have a water table less than 18 inches are lowered one group.

Table 1: Soil Groups and Maximum Application Rates[1]

	Maximum Application Rate	
Soil group	**gallons/1,000 ft^2 of filter area**	**inches/dose**
1	313	0.5
2	250	0.4
3	188	0.3
4	125	0.2
5	63	0.1

[1] The useable soil depth in the filter area should be verified on site. If there is less than 24 inches of useable soil depth, additional useable depth will have to be provided or the site is not acceptable. Useable soil depth can be increased by adding soil on the surface or by providing drainage upslope of the filter area.

The hydraulic loading rate is designed to establish sheet flow (≤0.5" deep) down the filter slope. Filter area dimensions are determined using hydraulic calculations to provide 15 minutes of retention (flow) time within the filter length, at a maximum constant flow depth of 0.5 inches throughout the length. Filter dimensions for these flow conditions are found in Table 2. (Due to infiltration, this is a conservative approach. The flow depth and velocity will actually decrease as the water flows down the slope.)

Table 2 is split into two sections that are read separately. In the top portion of the table, the slope of the filter area (%), the minimum filter length (ft) to provide 15 minute flow time, and the maximum dose rate (gal/min/ft width) per foot of filter width are related to each other. Any one of these values can be found if the other two are known.

The bottom portion of Table 2 shows the relationship among the filter slope (%) along the left side, a delivery rate (gpm) across the top, and a minimum required filter width (ft) within the body of the table. Again, any one of these values can be found based on the other two. However, the values used in the lower portion must agree with those from the top portion of the table (i.e. the same filter slope and the product of the maximum dose rate (gal/min/ft) times the minimum filter width (ft) must equal the delivery rate gpm). Minimum filter widths can be interpolated from the table for delivery rates between those listed in the table or can be calculated by dividing a desired delivery rate by the maximum dose rate (gal/min/ft of width).

The best filter area performance is achieved by intermittently dosing the filter area with a pump or siphon every three or more days. This is essential to the success of a filter area for milking center waste water and is encouraged for all types of filter areas. For a milking center filter, the pump or siphon should be selected to empty the dosing tank in 5 to 20 minutes. This will produce a dose rate that exceeds the soil infiltration rate and forces surface flow down the filter slope. A delivery rate can be initially estimated by multiplying the daily waste water volume by 3 days and dividing by 10.

A pump's delivery rate (gpm) is taken from a pump rating curve or table provided by the manufacturer. It will be a pumping capacity for the expected total dynamic head (elevation head loss plus friction losses) on the planned installation. For an automatic siphon, the manufacturer's published average discharge is used as the delivery rate in the table. For gravity flow systems, the delivery rate is the 2-year peak flow from the barnyard or a routed discharge where extra storage and a flow restricting orifice is used to limit the flow to a desired delivery rate.

The design flow depth for sheet flow through the filter area can be less than 0.5 inch to meet site constraints such as a short available slope length. This can be done using Tables 3 through 6 or Figure 1. The design flow depth must be less than or equal to 0.5 inches, regardless of the maximum application rate found in Table 1. If there are no site constraints on the dimensions of the filter area, the design flow depth should be kept at 0.5 inch to maximize surface flow down the filter slope.

Tables 3 through 6 are read in the same manner as Table 2. For a given filter slope and pump rate, Tables 3 through 6 will give shorter filter lengths, greater filter widths, and larger filter areas to provide flexibility in meeting site conditions.

Figure 1 is an alternative method to Tables 2 through 6 and yields the same results. Knowing the values for any of the three filter slopes (%), filter area length (ft), design flow depth (inches), and the maximum dose rate (gal/min/ft), the fourth value can be found. The two charts in Figure 1 are related to each other by the filter slope and the design flow depth both of which must be kept constant when reading from one chart to the other. An added step in using Figure 1 is to divide the pump rate (gpm found in the manufacturer's rating curve or table) by the dose rate (gal/min/ft) to find the minimum filter width.

As a check on the filter dimensions, the dose volume must be compared to the maximum application rate. To do this, divide the total dose volume (gal) by the filter area (ft^2) and multiply by 1,000. This value should be no higher than the maximum application rate found in Table 1 for the soil conditions on the site.

Figure 2 takes another approach to find the filter dimensions. Using the total dose volume (gal) and the Soil Group from Table 1, the required area (ft^2) of the filter to meet the maximum application rate can be found on the left chart in Figure 2. Reading across to the right chart, a filter width and length can be determined that meet the minimum area requirements. These dimensions do not automatically meet the minimum width or length requirements for a dose rate or 15 minute flow time. These dimensions must then be matched with a delivery rate (gal/min) that will not exceed the maximum dose rate (gal/min/ft). This can be done in Figure 1, using the length, the filter slope, and the design depth to find the maximum dose rate.

Figure 2 can also be used to check and ensure that the maximum application rate (gallons/1,000 ft^2) from Table 1 has not been exceeded. Using the total dose volume (gal) and the Soil Group from Table 1, the required area of the filter can be found at the left side of Figure 2. This area must be $\leq$ the product of the filter width and length determined from Tables 2 through 6 or Figure 1.

A final check of the filter dimensions and dose volume looks at the weekly hydraulic load on the filter area. The total allowable weekly depth, including rainfall, is 2 inches. The highest weekly average rainfall (highest monthly rainfall / 4) is subtracted from 2 inches. The result is the limiting value (in/week), which must exceed the weekly dose volume.

For a milkhouse waste filter area, the limiting value (in/week) is then multiplied by 3 days per dose, and divided by 7 days per week. This limiting value (in/dose) is then compared to the dose volume (gal/dose) multiplied by 12 in/ft, divided by the area of the filter (ft^2), and divided by 7.48 gal/ft^3. The resulting in/dose must be $\leq$ the limiting value.

For a barnyard runoff filter area, the limiting value (in/week) is compared to the barnyard runoff volume produced by the highest weekly average rainfall. The weekly rainfall is multiplied by the corresponding monthly runoff factor (taken from the AWMFH, Appendix 10C or the Ohio Nutrient Management Technical Manual, Appendix 5), then multiplied by the area of the barnyard and divided by the area of the filter. The resulting value (in) must be $\leq$ the limiting value.

For a combination milkhouse waste and barnyard runoff filter area, the total weekly wastewater volume must be less than the limiting value (in/week).

Table 7 provides orifice discharge capacities over the typical range needed to handle the 2-year peak flow from a barnyard and the small (< 1”) diameter orifice sizes used in a perforated distribution pipe. The table can be used to select the orifice size based on the desired discharge and the head at the maximum depth over the orifice. The table can also be used to determine the discharge through a trial orifice size with the design head over the orifice. Whenever possible, the design head should be 3 feet or more.

Table 8 provides discharge capacities of slotted riser pipes over the typical range needed to handle the 2-year peak flow from a barnyard. The required discharge and the maximum head over the base of the riser are used to find the open slot area needed per foot of riser pipe.

Table 2: Filter Area Dimensions for Design Flow Depth of 0.5 Inches

		Minimum Filter Width at Delivery Rate (gpm)														
		10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**	**160**	**180**	**200**
	1		15	22	29	36	43	50	58	65	72	86	100	115	129	143
F	**2**		11	16	21	26	31	36	41	46	51	61	72	82	92	102
I	**3**		9	13	17	21	25	29	34	38	42	50	58	67	75	83
L	**4**			11	15	18	22	26	29	33	36	44	51	58	65	72
T	**5**			10	13	17	20	23	26	29	33	39	45	52	58	65
E	**6**			9	12	15	18	21	24	27	30	36	41	47	53	59
R	**7**			9	11	14	17	19	22	25	28	33	38	44	49	55
	8				11	13	16	18	21	23	26	31	36	41	46	51
S	**9**				10	12	15	17	20	22	24	29	34	39	43	48
L	**10**				10	12	14	16	19	21	23	28	32	37	41	46
O	**11**				9	11	13	16	18	20	22	26	31	35	39	44
P	**12**				9	11	13	15	17	19	21	25	29	34	38	42
E	**13**					10	12	14	16	18	20	24	28	32	36	40
	14					10	12	14	16	18	20	23	27	31	35	39
(%)	**15**					10	12	13	15	17	19	23	26	30	34	37

Table 3: Filter Area Dimensions for Design Flow Depth of 0.4 Inches

Design Flow Depth (d=0.4")															
	Filter Slope %														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Minimum Filter Length	58	82	100	116	129	142	153	163	173	183	192	200	208	216	224
gal/min/ft Width	0.96	1.36	1.66	1.92	2.15	2.35	2.54	2.72	2.88	3.04	3.19	3.33	3.46	3.6	3.72

		Minimum Filter Width at Delivery Rate (gpm)														
		10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**	**160**	**180**	**200**
	1	11	21	32	42	53	63	73	84	94	105	125	146	167	188	209
F	**2**		15	23	30	37	45	52	59	67	74	89	103	118	133	148
I	**3**		13	19	25	31	37	43	49	55	61	73	85	97	109	121
L	**4**		11	16	21	27	32	37	42	47	53	63	73	84	94	105
T	**5**			14	19	24	28	33	38	42	47	56	66	75	84	94
E	**6**			13	18	22	26	30	35	39	43	52	60	69	77	86
R	**7**			12	16	20	24	28	32	36	40	48	56	63	71	79
	8			12	15	19	23	26	30	34	37	45	52	59	67	74
S	**9**			11	14	18	21	25	28	32	35	42	49	56	63	70
L	**10**			10	14	17	20	24	27	30	33	40	47	53	60	66
O	**11**			10	13	16	19	22	26	29	32	38	44	51	57	63
P	**12**			10	13	16	19	22	25	28	31	37	43	49	55	61
E	**13**			9	12	15	18	21	24	27	29	35	41	47	53	58
	14			9	12	14	17	20	23	25	28	34	39	45	50	56
(%)	**15**			9	11	14	17	19	22	25	27	33	38	44	49	54

Table 4: Filter Area Dimensions for Design Flow Depth of 0.3 Inches

	Design Flow Depth (d=0.3")														
	Filter Slope (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	48	68	83	96	107	117	126	135	143	151	158	165	172	179	185
gal/min/ft Width	0.6	0.84	1.03	1.19	1.33	1.46	1.57	1.68	1.79	1.88	1.97	2.06	2.14	2.22	2.3

		Minimum Filter Width at Delivery Rate (gpm)														
		10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**	**160**	**180**	**200**
	1	17	34	50	67	84	100	117	134	150	167	200	234	267	300	
F	**2**	12	24	36	48	60	72	84	96	108	120	143	167	191	215	239
I	**3**	10	20	30	39	49	59	68	78	88	98	117	136	156	175	195
L	**4**	9	29	26	34	43	51	59	68	76	85	101	118	135	152	169
T	**5**		19	23	31	38	46	53	61	68	76	91	106	121	136	151
E	**6**		14	21	28	35	42	48	55	62	69	83	96	110	124	137
R	**7**		19	20	26	32	39	45	51	58	64	77	90	102	115	128
	8		12	18	24	30	36	42	48	54	60	72	84	96	108	120
S	**9**		12	17	23	28	34	40	45	51	56	68	79	90	101	112
L	**10**		11	16	22	27	32	38	43	48	54	64	75	86	96	107
O	**11**		11	16	21	26	31	36	41	46	51	61	72	82	92	102
P	**12**		10	15	20	25	30	34	39	44	49	59	68	78	88	98
E	**13**		10	15	19	24	29	33	38	43	47	57	66	75	85	94
	14		10	14	19	23	28	32	37	41	46	55	64	73	82	91
(%)	**15**		9	14	18	22	27	31	35	40	44	53	61	70	79	87

[1] **There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.**

Table 5: Filter Area Dimensions for Design Flow Depth of 0.2 Inches

	Design Flow Depth (d=0.2")														
	Filter Slope (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	37	52	63	73	82	89	97	103	109	115	121	126	131	136	141
gal/min/ft width	0.3	0.43	0.52	0.61	0.68	0.74	0.8	0.86	0.91	0.96	1	1.05	1.09	1.13	1.17

		Minimum Filter Width at Delivery Rate (gpm)														
		10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**	**160**	**180**	**200**
	1	34	67	100	134	167	200	234	267	300						
F	**2**	24	47	70	94	117	140	163	187	210	233	280				
I	**3**	20	39	58	77	97	116	135	154	174	193	231	270			
L	**4**	17	33	50	66	82	99	115	132	148	164	197	230	263	296	
T	**5**	15	30	45	59	74	89	103	118	133	148	177	206	236	265	
E	**6**	14	27	41	55	68	82	95	109	122	136	163	190	217	244	295
R	**7**	13	25	38	50	63	75	88	100	113	125	150	175	200	225	271
	8	12	24	35	47	59	70	82	94	105	117	140	163	187	210	250
S	**9**	11	22	33	44	55	66	77	88	99	110	132	154	176	198	233
L	**10**	11	21	32	42	53	63	73	84	94	105	125	146	167	188	220
O	**11**	10	20	30	40	50	60	70	80	90	100	120	140	160	180	209
P	**12**	10	20	29	39	48	58	67	77	86	96	115	134	153	172	200
E	**13**	10	19	28	37	46	56	65	74	83	92	111	129	147	166	191
	14	9	18	27	36	45	54	62	71	80	89	107	124	142	160	184
(%)	**15**	9	18	26	35	43	52	60	69	77	86	103	120	137	154	177
																171

[1]There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.

Table 6: Filter Area Dimensions for Design Flow Depth of 0.1 Inches

Design Flow Depth (d=0.1")															
	Filter Slope (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	23	32	40	46	51	56	61	65	69	73	76	79	83	86	89
gal/min/ft Width	0.1	0.13	0.16	0.19	0.21	0.23	0.25	0.27	0.29	0.3	0.32	0.33	0.34	0.36	0.37

		Minimum Filter Width at Delivery Rate (gpm)														
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
	1	100	200	300												
F	2	77	154	231												
I	3	63	125	188	250											
L	4	53	106	158	211	264										
T	5	48	96	143	191	239	286									
E	6	44	87	131	174	218	261									
R	7	40	80	120	160	200	240	280								
	8	38	75	112	149	186	223	260	297							
S	9	35	69	104	138	173	207	242	276							
L	10	34	67	100	134	167	200	234	267	300						
O	11	32	63	94	125	157	188	219	250	282						
P	12	31	61	91	122	152	182	213	243	273						
E	13	30	59	89	118	148	177	206	236	265	295					
	14	28	56	84	112	139	167	195	223	250	278					
(%)	15	28	55	82	109	136	163	190	217	244	271					

[1] There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.

Figure 1: Filter Area Dimensions for Design Flow Depths from 0.1 to 0.5 Inches

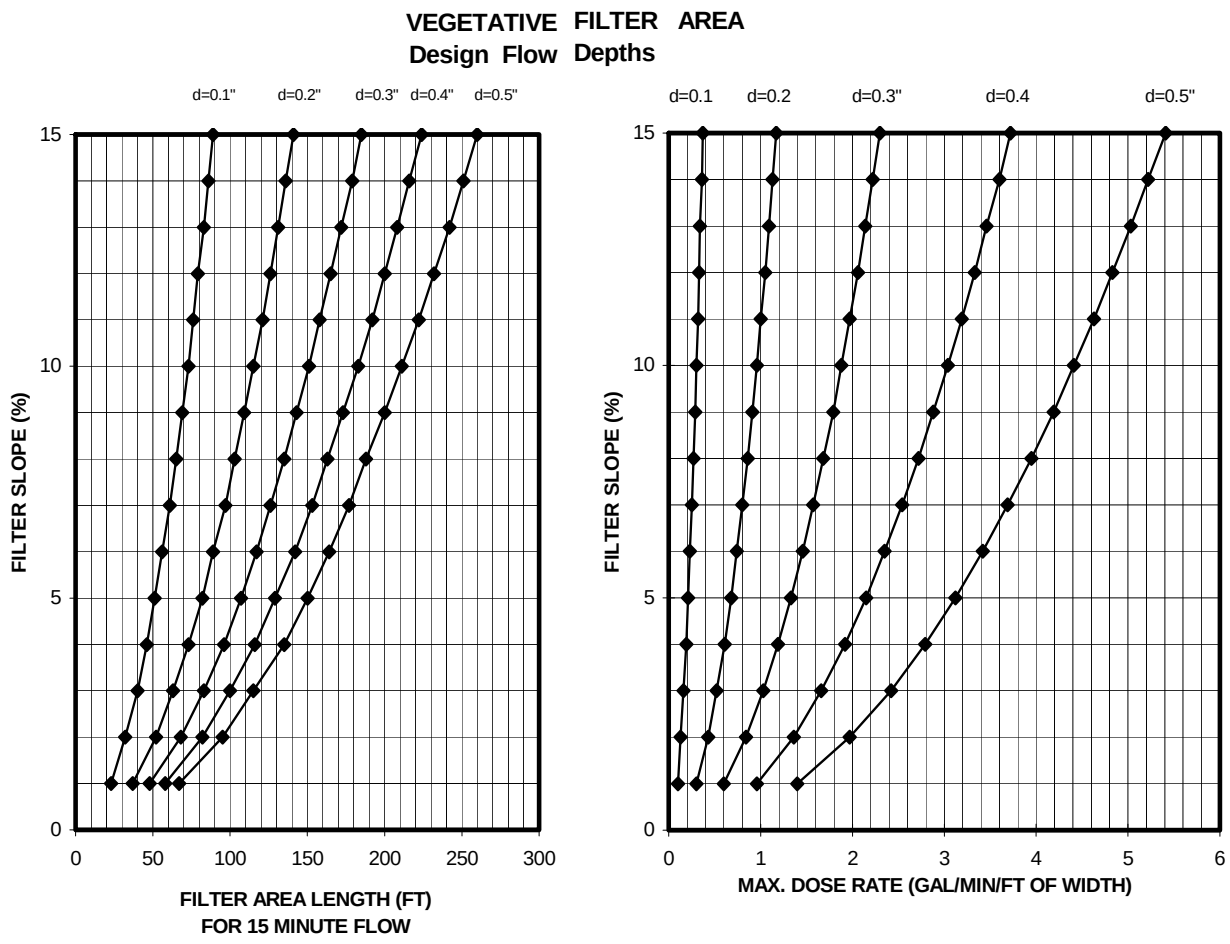
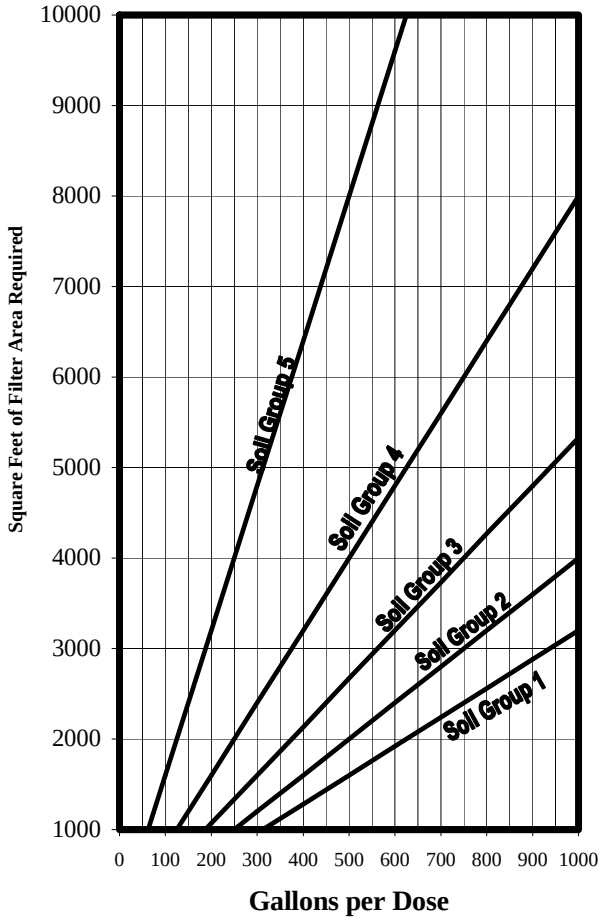


Figure 2: Minimum Filter Area Requirements
(To meet maximum application rate limitations for soil groups)



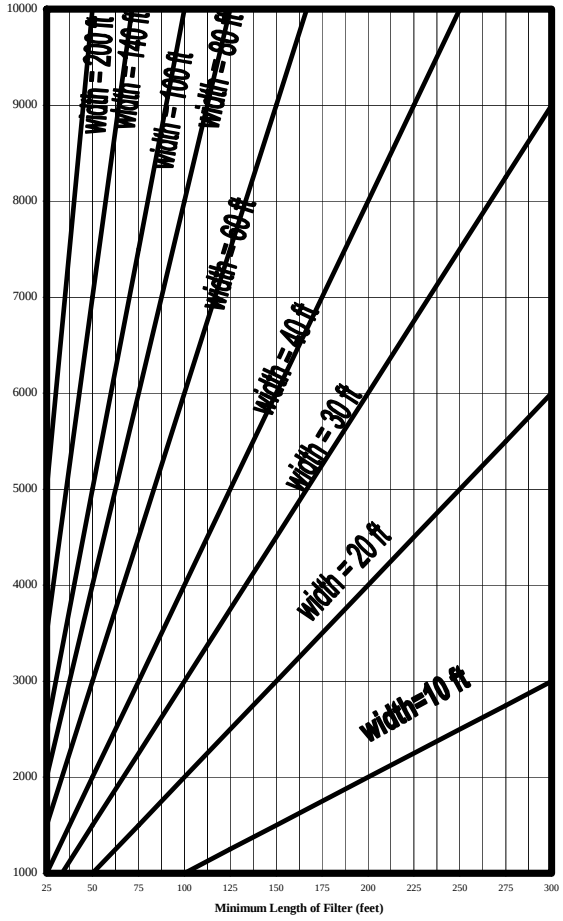


Table 7: Orifice Discharge Capacity

For orifices to control flow rate through riser, or distribution manifold.
Based on:
$Q = (C)\ (A)\ (2gh)^{0.5}$ in cfs
C = orifice constant; assumed to be 0.61 ft. The actual value varies with the type of orifice.
The assumed value is conservative.
A = orifice area, ft^2
g = 32.174 ft/sec^2
h = head of orifice, ft

Diameter in	Area ft^2	Head, ft							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		- - - - - - - - - - - - - - - - Flow Rate, cfs - - - - - - - - - - - - - - - -							
0.50	**0.0014**	0.005	0.007	0.008	0.009	0.010	0.012	0.013	0.014
0.75	**0.0031**	0.011	0.015	0.018	0.021	0.024	0.026	0.028	0.030
1.00	**0.005**	0.017	0.027	0.033	0.038	0.042	0.046	0.050	0.053
1.25	**0.009**	0.031	0.042	0.051	0.059	0.066	0.072	0.078	0.083
1.50	**0.012**	0.042	0.060	0.074	0.085	0.095	0.104	0.112	0.120
1.75	**0.017**	0.059	0.082	0.100	0.116	0.129	0.142	0.153	0.163
2.00	**0.022**	0.076	0.107	0.131	0.151	0.169	0.185	0.200	0.214
2.25	**0.028**	0.097	0.135	0.165	0.191	0.214	0.234	0.253	0.270
2.50	**0.034**	0.118	0.167	0.204	0.236	0.264	0.289	0.312	0.334
2.75	**0.041**	0.142	0.202	0.247	0.285	0.319	0.350	0.378	0.404
3.00	**0.049**	0.170	0.240	0.294	0.340	0.380	0.416	0.449	0.480
3.25	**0.058**	0.201	0.282	0.345	0.399	0.446	0.488	0.527	0.564
3.50	**0.067**	0.232	0.327	0.400	0.462	0.517	0.566	0.612	0.654
3.75	**0.077**	0.266	0.375	0.460	0.531	0.593	0.650	0.702	0.751
4.00	**0.087**	0.301	0.427	0.523	0.604	0.675	0.740	0.799	0.854
4.25	**0.099**	0.343	0.482	0.590	0.682	0.762	0.835	0.902	0.964
4.50	**0.110**	0.381	0.540	0.662	0.764	0.855	0.936	1.011	1.081
4.75	**0.123**	0.426	0.602	0.737	0.852	0.952	1.043	1.127	1.204
5.00	**0.136**	0.471	0.667	0.817	0.944	1.055	1.156	1.248	1.334
5.25	**0.150**	0.519	0.736	0.901	1.040	1.163	1.274	1.376	1.471
5.50	**0.165**	0.571	0.807	0.989	1.142	1.276	1.398	1.510	1.615
5.75	**0.180**	0.623	0.882	1.081	1.248	1.395	1.528	1.651	1.765
6.00	**0.196**	0.678	0.961	1.177	1.359	1.519	1.664	1.797	1.922
6.25	**0.213**	0.737	1.043	1.277	1.474	1.648	1.806	1.950	2.085
6.50	**0.230**	0.796	1.128	1.381	1.595	1.783	1.953	2.110	2.255
6.75	**0.249**	0.862	1.216	1.489	1.720	1.923	2.106	2.275	2.432
7.00	**0.267**	0.924	1.308	1.602	1.849	2.068	2.265	2.447	2.615
7.25	**0.287**	0.993	1.403	1.718	1.984	2.218	2.430	2.624	2.806
7.50	**0.307**	1.062	1.501	1.839	2.123	2.374	2.600	2.890	3.002
7.75	**0.328**	1.135	1.603	1.963	2.267	2.535	2.776	2.999	3.206
8.00	**0.349**	1.208	1.708	2.092	2.416	2.701	2.958	3.195	3.416

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Table 8: Riser Pipe Outlet Design.

For settling basins.

Based on:
$Q = (C)(A)(2gh)^{0.5}$ in cfs

C = slot constant; assumed to be 0.61. The actual value varies with the type of slot.
The assumed value is conservative.
A = open slot area, ft^2

$g = 32.174$ ft/sec^2

h = head on openings, ft. The pipe height was divided into 0.5 ft increment.

The head on all the slots in the first 0.5 ft increment assumed to be 0.25 ft.

The head on the subsequent 0.5 ft pipe increments increase at 0.5 ft increments.
Open slot area
Per foot of pipe height in^2/ft

	Head, ft							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
	- - - - - - - - - - - - - - - - -Flow rate, cfs - - - - - - - - - - - - - - - - - -							
4	0.034	0.093	0.169	0.259	0.361	0.473	0.596	0.728
6	0.051	0.139	0.253	0.388	0.541	0.710	0.894	1.091
8	0.068	0.186	0.338	0.518	0.721	0.947	1.192	1.455
10	0.085	0.232	0.422	0.647	0.902	1.183	1.480	1.819
12	0.102	0.279	0.507	0.776	1.082	1.420	1.788	2.183
14	0.119	0.325	0.591	0.906	1.262	1.657	2.086	2.546
16	0.136	0.371	0.675	1.035	1.443	1.894	2.384	2.910
18	0.153	0.418	0.760	1.164	1.623	2.130	2.682	3.274
20	0.170	0.464	0.844	1.294	1.803	2.367	3.980	3.638
22	0.187	0.511	0.929	1.423	1.984	2.604	3.277	4.001
24	0.204	0.557	1.013	1.542	2.164	2.840	3.575	4.365
26	0.221	0.603	1.097	1.682	2.344	3.077	3.873	4.729
28	0.238	0.650	1.182	1.811	2.525	3.314	4.171	5.093
30	0.255	0.696	1.266	1.940	2.705	3.550	4.469	5.456
32	0.272	0.743	1.351	2.070	2.885	3.787	4.767	5.820
34	0.289	0.789	1.435	2.199	3.066	4.024	5.065	6.184
36	0.306	0.836	1.519	2.329	3.246	4.260	5.363	6.548
38	0.323	0.882	1.604	2.458	3.426	4.497	5.661	6.911
40	0.340	0.928	1.688	2.587	3.607	4.734	5.959	7.275