PROPER GUTTER AND DOWNSPOUT SIZING

DESIGN OF ROOF DRAINAGE SYSTEMS
ROOF DRAINAGE

The roof is one of the most essential parts of a building as it protects occupants, contents, and interior of the structure from the elements. Once an architect has determined the kind of roof he intends to use, he must give equal attention to the design of the roof drainage system.

Factors to be considered in the design of roof drainage systems are the area to be drained, size of gutters, downspouts, outlets, slope of roof, type of building, and appearance.

ROOF AREA TO BE CONSIDERED

The design capacity for a roof drainage system depends on The quantity of water to be handled. The quantity of water in turn depends on the roof area, slope, and rainfall intensity.

In considering the roof area, it must be remembered that rain does not necessarily fall vertically and that maximum conditions exist only when rain falls perpendicular to a surface.
Since the roof area would increase as its pitch increases, then it would not be advisable to use the plan area of a pitched roof in the calculation of a drainage system.

Experience has taught that use of the true area of a pitched roof often leads to oversizing of gutters, downspouts, and drains. To determine the design area for a pitched roof, Table 1-1 is used.

TABLE 1-1
DESIGN AREAS FOR PITCHED ROOFS

PITCH in./ft.	PITCH mm/mm	*B
Level to 3	76/305	1.00
4 to 5	102-127/305	1.05
6 to 8	152-203/305	1.10
9 to 11	229-279/305	1.20
12	305/305	1.30

To determine the design area multiply the plan area by the factor in B column

These areas are then divided by the proper factor given in Table 1-2, thus obtaining the required area in square inches (square mm) for each downspout. From Table 1-3 select the downspout.

PROPER GUTTER AND DOWNSPOUT SIZING

RAINFALL INTENSITY - DOWNSPOUT CAPACITY

Rainfall intensity is usually given in inches per hour for a five minute duration or one hour duration based on U.S. Weather Bureau records. Table 1-2 based on records through 1978, gives five minute intensities for selected cities. New Orleans, Los Angeles, for example, may have 8 in./hr.(203 mm/hr) for a five minute duration yet record only 4.8 in. (121 mm) in an hour over a 100 year period. These rates correspond to 0.133 in./min.(3.4 mm/min.) and 0.08 in./min.(2 mm/min.). Local codes may require that drainage systems only be designed for the latter. It takes 96.15 square feet(8.93 square meters) of surface with 1 inch per hour(25 mm/hr) of water to correspond with 1 gpm (0.063 l/s) flow rate. Downspouts and gutters are sized in relation to rainfall on this basis.

Plumbing codes typically use the vertically projected roof area for drainage design and they often use a square foot allowance per square inch of downspout for 1 in./hr.(25 mm/hr) rainfall that varies with diameter, for example, 3 in.(76 mm): 911(85); 4 in.(102 mm): 1100 (102); 5 in.(127 mm): 1280 (119); 6 in.(152 mm): 1400 (130) and 8 in.(203 mm): 1750 (163) sq. ft.(sq. m). Net drainage capacity from using Table 1-1 and 1-2 should be compared with local code requirements.

DOWNSPOUT SIZING

In sizing downspouts, the following considerations apply:

1. Downspouts of less than 7.00 sq in.(4515 sq mm) cross section should not be used except for small areas such as porches and canopies.

2. The size of the downspout should be constant throughout its length.

3. Downspouts should be constructed with conductor heads every 40 ft(12.2 m) to admit air and prevent vacuum.

4. Offset of more than 10 ft(3.0 m) can affect drainage capacity.

5. The gutter outlet capacity should suit the downspout capacity.

6. The downspout size must suit the bottom width of the gutter.

TABLE 1-2 RAINFALL DATA AND DRAINAGE FACTORS

	A STORMS WHICH SHOULD BE EXCEEDED ONLY ONCE IN 10 YEARS		**B STORMS WHICH SHOULD BE EXCEEDED ONLY ONCE IN 100 YEARS**	
	Intensity lasting 5 minutes	Calculated roof area drained per downspout area	Intensity lasting 5 minutes	Calculated roof area drained per downspout area

	in/hr mm/hr	sq/ft sq m/ sq in 100 sq mm	in/hr mm/hr	sq/ft sq m/ sq in 100 sq mm
ALABAMA:	7.5	160	10.1	120
Birmingham	191	2.30	256	1.7
Mobile	8.2	150	10.8	110
ALASKA: Fairbanks	208	2.10	274	1.6
Juneau	2.1	570	3.8	310
ARIZONA: Phoenix	53	8.30	97	4.5
Tucson	1.7	700	2.3	530
ARKANSAS:	43	10.10	57	7.60
Bentonville	5.6	220	8.8	140
Little Rock	141	3.10	224	2.00
CALIFORNIA: Los	6.1	200	9.1	130
Angeles	155	2.80	232	1.90
Sacramento	7.4	160	10.2	120
San Francisco	187	2.30	259	1.70
San Diego	7.4	160	10.0	120
COLORADO:	187	2.30	253	1.70
Denver	4.9	250	6.7	180
Boulder	124	3.50	170	2.60
CONNECTICUT:	2.5	480	3.9	310
Hartford	64	6.90	100	4.40
DISTRICT OF	2.7	450	3.7	330
COLUMBIA	68	6.4	93	4.70
FLORIDA:	2.2	540	3.1	390
Jacksonville	57	7.80	78	5.60
Miami	5.7	210	9.1	130
Tampa	146	3.00	232	1.90
GEORGIA: Atlanta	6.4	190	9.4	130
HAWAII: Honolulu	164	2.70	238	1.80
Kahului	6.2	190	8.7	140
Hilo	158	2.8	221	2.00
Lihue	7.1	170	9.7	120
IDAHO: Boise	180	2.4	247	1.80
ILLINOIS: Chicago	7.9	150	10.1	120
INDIANA:	200	2.20	256	1.70
Indianapolis	7.7	160	9.8	120
IOWA: Des Moines	195	2.20	250	1.80
KANSAS: Wichita	8.3	140	10.8	110
KENTUCKY:	212	2.10	274	1.60
Louisville	7.3	160	9.9	120
LOUISIANA: New	186	2.4	251	1.70
Orleans	8.7	140	12.0	100
MAINE: Portland	221	2.00	305	1.40
MARYLAND:	7.0	170	12.0	100
Baltimore	177	2.50	305	1.40
MASSACHUSETTS:	17.4	70	19.2	60
Boston	442	1.00	488	0.90
MICHIGAN: Detroit	10.4	110	14.4	80
MINNESOTA:	265	1.70	366	1.20
Minneapolis	1.8	660	3.3	360
MISSOURI: Kansas	46	9.50	84	5.20
City	6.8	180	9.3	130
Saint Louis	172	2.60	236	1.90
MONTANA: Helena	6.8	180	9.4	130
Missoula	173	2.50	239	1.80
NEBRASKA:	7.3	160	10.3	120
Omaha	186	2.40	262	1.70
NEVADA: Reno	7.5	160	10.5	110
Las Vegas	191	2.30	267	1.60
NEW JERSEY:	6.9	170	9.4	130
Trenton	175	2.50	238	1.80
NEW MEXICO:	8.3	140	10.9	110
Albuquerque	211	2.10	277	1.60
Santa Fe	5.4	220	7.6	160
NEW YORK: Albany	136	3.20	192	2.30
Buffalo	7.1	.170	9.7	120

New York City	181	2.40	247	1.80
NORTH	5.3	230	7.2	170
CAROLINA: Raleigh	134	3.3	183	2.40
NORTH DAKOTA:	6.4	190	8.9	140
Bismark	162	2.70	226	1.90
OHIO: Cincinnati	7.0	170	10.0	120
Cleveland	178 7.4	2.50	253	1.70
OKLAHOMA:	187	160	10.4	110
Oklahoma City	7.1	2.30	265	1.70
OREGON: Baker	181	170	9.9	120
Portland	1.8	2.40	251	1.70
PENNSYLVANIA:	46	660	3.1	390
Philadelphia	1.8	9.50	77	5.70
Pittsburgh	46	660	2.4	500
RHODE ISLAND:	7.4	9.50	61	7.20
Providence	188	160	10.5	110
SOUTH CAROLINA:	2.3	2.30	267	1.60
Charleston	57	530	4.5	270
TENNESSEE:	2.1	7.60	114	3.90
Memphis	53	570	5.2	230
Knoxville	6.7	8.3	133	3.30
TEXAS: Fort Worth	170	180	9.3	130
Dallas	4.0	2.60	236	1.90
Houston	102	300	6.7	180
San Antonio	4.5	4.30	171	2.60
UTAH: Provo	115	270	6.4	180
Salt Lake City	6.5	3.80	169	2.60
VIRGINIA: Norfolk	165	190	9.1	130
WASHINGTON:	6.0	2.70	232	1.90
Seattle	152	200	8.4	140
Spokane	6.7	2.90	213	2.10
WEST VIRGINIA:	169	180	9.2	130
Parkersburg	7.3	2.60	235	1.90
WISCONSIN:	185	160	9.8	120
Madison	6.6	2.40	250	1.80
Milwaukee	167	180	9.8	120
WYOMING:	6.8	2.60	250	1.80
Cheyenne	172	180	9.3	130
	6.3	2.50	236	1.90
	160	190	8.8	140
	7.6	2.70	223	2.00
	193	160	10.5	110
	2.2	2.30	267	1.60
	56	550	3.8	310
	2.1	7.90	97	4.50
	53	570	3.0	400
	6.8	8.30	76	5.80
	172	180	9.4	130
	6.4	2.60	238	1.80
	163	190	8.8	140
	5.6	2.70	224	2.00
	143	210	7.8	150
	7.2	3.10	198	2.20
	184	170	9.4	130
	7.4	2.40	238	1.80
	187	160	10.0	120
	6.7	2.30	253	1.70
	169	180	9.0	130
	7.6	2.60	229	1.90
	193	193	10.5	110
	7.6	160	267	1.60
	194	160	10.5	110
	8.2	2.30	267	1.60
	208	150	10.8	110
	7.6	2.10	274	1.60
	193	160	10.5	110
	3.0	2.30	267	1.60
	75	410	5.2	230
	2.8	5.80	131	3.30
	71	430	4.3	280

	7.1 181 2.1 53 2.1 53 6.6 168 6.8 172 6.6 168 5.7 146	6.20 170 2.40 570 8.30 570 8.30 180 2.60 180 2.50 180 2.60 210 3.00	108 9.5 242 3.3 84 3.5 90 9.1 230 9.5 241 9.1 232 9.9 252	4.10 130 1.80 360 5.20 340 4.90 130 1.90 130 1.80 130 1.90 120 1.70

TABLE 1-3

DIMENSIONS OF STANDARD DOWNSPOUTS

TYPE	AREA		"A" Size		Nominal Size		Actual	
	Sq in.	sq.mm.	Sq.in	sq.mm.	In.	mm.	In	mm.
Plain Round	7.07 12.57 19.63 28.27 50.24	4560 810 12661 18234 32404	5.94 11.04 17.71 25.95 47.15	3831 7120 11422 16737 30411	3 4 5 6 8	76 102 127 152 203	3 4 5 6 8	76 102 127 152 203
Corrugated Round	5.94 11.04 17.72 25.97	3831 7120 11429 16750			3 4 5 6	76 102 127 152	3 4 5 6	76 102 127 152
Plain Rectangular	3.94 6.00 12.0 20.0 24.00	2541 3870 7740 12900 15480	3.0 4.80 10.31 15.75 21.56	1935 3096 6549 10158 13906	2 3 4 5 6	51 76 102 127 152	1.75x225 44x57 2x3 51x76 3x4 76x102 3.75x4.75 95x121 4x6 102x152	
Rectangular Corrugated	3.80 7.73 11.70 18.75	2451 4985 7621 12213	3.00 6.38 10.0 16.63	1935 4155 6513 10832	2 3 4 102 5 127	51 76	1.75x2.25 44x57 2.37x3.25 60x83 2.75x4.25 70x108 3.75x5 95x127	

"A" = area of 1/4 in.(6.4 mm) undersized inlet
See Figures 1-31 and 1-32 for gage

7. Assuming that using the fewest number of downspouts is desirable, their locations will be affected by

a. gutter capacity and length. To limit the effects of thermal expansion in gutters 50 ft(15.3 m) is a practical maximum length of gutter to be served by a downspout. Unless special provisions are made for flexibility in downspouts, gutters and their support systems, gutters should expand away from downspouts and downspouts should not be located near gutter expansion joints. See expansion coefficients

in Appendix A-1 and expansion allowances in Figures 1-5 to 1-10.
b. the capacity of the inlet tube. See Table 1-3 and Figure 1-33. Also, a sharp bend at the inlet may clog.
c. potential for water freezing in downspouts and gutters. Open, partially open or corrugated styles downspouts are suggested for areas subject to icing. Locating downspouts on the north side of buildings is not recommended for such areas.
d. the appearance of the downspout system and a potential need for concealment. See Figures 1-31 and 1-32.
e. the greater capacity of a pitched gutter.
f. the downspout discharge location. Water disposal at this location should be acceptable. See Figures 1-31 and 1-36.
g. the risk of gutter overflow from insufficient drainage capacity. See Figures 1-4, 1-21, and 1-23.
h. a scupper serving a designated roof area. See Figures 1-26 to 1-30.

After the number and location of downspouts have been determined, the areas to be drained by each downspout should be figured. In making this calculation for a pitched roof, the plan area should be adjusted according to recommendations given on Table 1-1.

SAMPLE PROBLEM: Select downspouts for a building in Boston, Mass. The building is 100 x 85 ft.(30.5 x 26 m) with a double pitched roof having a slope of 6 in./ft.(152 mm/m). The slope is toward the 100 ft.(30.5 m) side. Maximum rainfall conditions will be used to determine downspout size.

It is decided to drain the building with 4 downspouts located at each corner of the building. An expansion joint will be installed in each gutter between the downspouts.

The plan area of this building is 8500 sq ft.(790 sq m). Since the slope is 6 in./ft.(152 mm/m), factor 1.10 is used (Table 1-1), making the design area 9350 sq ft.(868 sq m). Thus each of the four downspouts will serve a 2338 sq ft.(217 sq m) area. From column B, Table 1-2, opposite Boston, it is found that 1 sq in.(645 sq mm) of downspout will drain 170 sq ft.(16 sq m) of roof area. Divide 2338(217) by 170(16) to determine that each downspout should have a minimum area of 13.56 sq in.(8746 sq mm).

From Table 1-3, it is found that there is a choice of; a 5 in. (127 mm) Plain Round, a 5 in.(127 mm) Corrugated Round, a 5 in.(127 mm) Rectangular Corrugated, or 5 in.(127 mm) Plain Rectangular downspout.

GUTTER SIZING

In sizing gutters, the following considerations apply for typical section lengths of 8 to 10 feet(2.41 to 3.0 m):

1. Spacing and size of outlet openings. (The gutter can never be any more effective than the outlet and downspout selected to drain it. Downspout sizes must not exceed the bottom width of the gutter.)

2. Slope of the roof. (The gutter must be of such a design and location that water from a steep pitched roof will not by its own velocity tend to overrun the front edge.)
3. Style of gutters to be used. (All gutters are not effective for their full depth and width, see Figures 1-1 and 1-4 for design data.)
4. Maximum length of gutter. (50 ft.(15.2 m) between ends or expansion joints is the limit unless the system is especially designed to accommodate the greater expansion, the larger flow and the need for special supports.)
5. Gutter support capability. (Supports should be based on full capacity of the gutter. Ice load capacity also affect the size and strength of the system.)

Level gutters may be sized by Charts 1-1, 1-2, or 1-3. Sloped gutters may be sized by Chart 1-3. Formulae for flow in gutters with different pitch are not available. The capacity of a gutter with 1/16 in./ft.(5.21 mm/m) or less pitch is taken as that of a level gutter even though it is somewhat greater.

RECTANGULAR GUTTER SIZING

The size of rectangular gutters depends upon these factors:
1. Area to be drained. (A, Chart 1-1)
2. Rainfall intensity per hour. (I, Chart 1-1)
3. Length of gutter in ft.(m) (L, Chart 1-1)
4. Ratio of depth to width of gutter. (M, Chart 1-1)
Chart 1-1 is based on level gutter capacity as experimentally determined by the National Institute of Standards and Technology (NIST) formerly National Bureau of Standards. It is plotted from W = 0.0106 M-4/7 L3/28(1A)5/14 with W in feet(m).
IRREGULAR CROSS SECTION GUTTER SIZING
The required sizes of gutters other than rectangular or round can be determined by finding the semicircle or rectangular area that most closely fits the irregular cross section.

HALF ROUND GUTTER SIZING

Chart 1-2 is based on level gutter capacity as determined by NIST. It is based on W = 0.0182 (lA)2/5. W is the width in in.(mm). I denotes rainfall intensity (Table 1-2) and A is the roof area in square feet(sq m) (Table 1-1).

SAMPLE PROBLEM: To size rectangular gutter for a building 120 x 30 ft.(35.6 x 9.1 m) located in Buffalo, NY. This building has a flat roof with a raised roof edge on three sides.
A gutter is to be located on one of the 120 ft.(35.6 m) sides. So that each section of gutter will not exceed 50 ft.(15.2 m), three downspouts will be used with 2 gutter expansion joints.
The area to be drained by each section of gutter will be 1200 sq ft.(111.5 sq m), the rainfall intensity from Table 1-2, col A is 6 in/hr(152 mm/hr), the length of each gutter section is 40 ft.(12.2 m), and the ratio of gutter depth to width is 0.75. On Chart 1-1 find the vertical line representing L = 40(12.2 m). Proceed vertically along this line to its intersection with

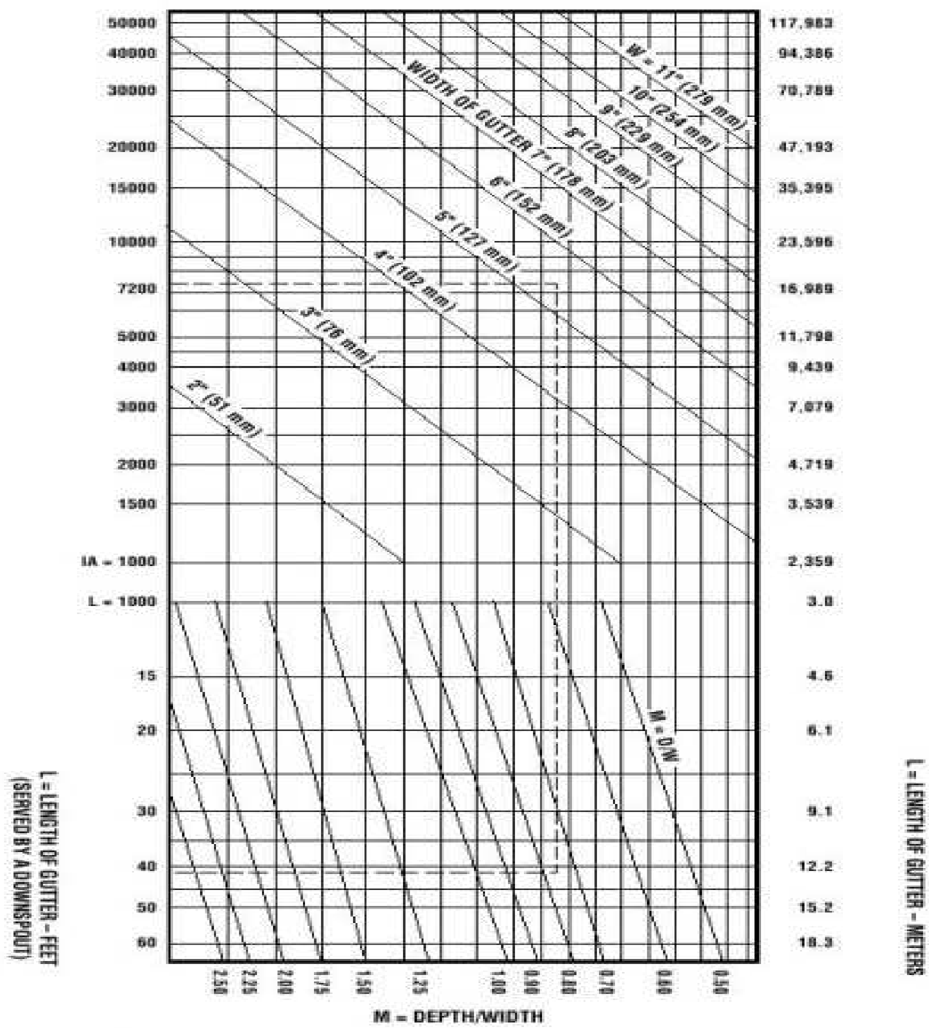
the oblique line representing M = 0.75. Pass to B vertically to the intersect the horizontal line representing IA = 7200(16948). The point of intersection occurs between the oblique line representing gutter widths of 5 and 6 in.(127 and 152 mm). The required width of gutter is, therefore, 6 in.(152 mm) and its depth need be only 4.5 in.(114 mm).in.

SAMPLE PROBLEM: To size a half round gutter for a building,
located in Kansas City, Mo., with a flat roof 80 x 40 ft.(24.4 x 12.2 m). This building has a parapet wall on three sides and a gutter to be located on an 80 ft.(24.4 m) side. Column A, Table 1-2, was used to determine rainfall conditions.
Since the gutter run will exceed 50 ft.(15.2 m), two downspouts will be used with an expansion joint between.

The area of the building is 3200 sq ft. (297 sq m). Thus each
of the downspouts will serve an area of 1600 sq ft. (149 sq m). From column A, Table 1-2, opposite Kansas City, Mo., it
is found that 1 sq in.(100 sq mm) of downspout will drain 160 sq ft.(2.3 sq m/100 sq mm) of roof area. Divide 1600 sq
ft. (149 sq m) by 160 sq ft/sq in. (2.3 sq m/100 sq mm) to determine that each downspout should have a minimum area
of 10 sq in. (6470 sq mm). From Table 1-3 it is found that a4
in. (102 mm) downspout is required. From Chart 1-2 it is determined that a 9.5 in. (241 mm) half round gutter should be used. Area and flow in Table 1-4 are based on 1 in. (25 mm) of rainfall per hour; divide these areas by the local rainfall
rate in inches per hour to determine the actual roof area to be served by the gutter diameter. “The capacity of a sloped
rectangular gutter may be approximated by using a gutter cross section area not less than that of a semicircular gutter
and a depth to width ratio of at least 0.75.

PROPER GUTTER AND DOWNSPOUT SIZING

CHART 1-1
WIDTH OF RECTANGULAR GUTTERS FOR GIVEN ROOF AREAS AND RAINFALL INTENSITIES



IA = RAINFALL INTENSITY x AREA (AREA FROM TABLE 1-1 THAT RELATES TO L)

PROPER GUTTER AND DOWNSPOUT SIZING

CHART 1-2
HALF ROUND GUTTER SELECTION
Width required for given roof areas and rainfall intensities

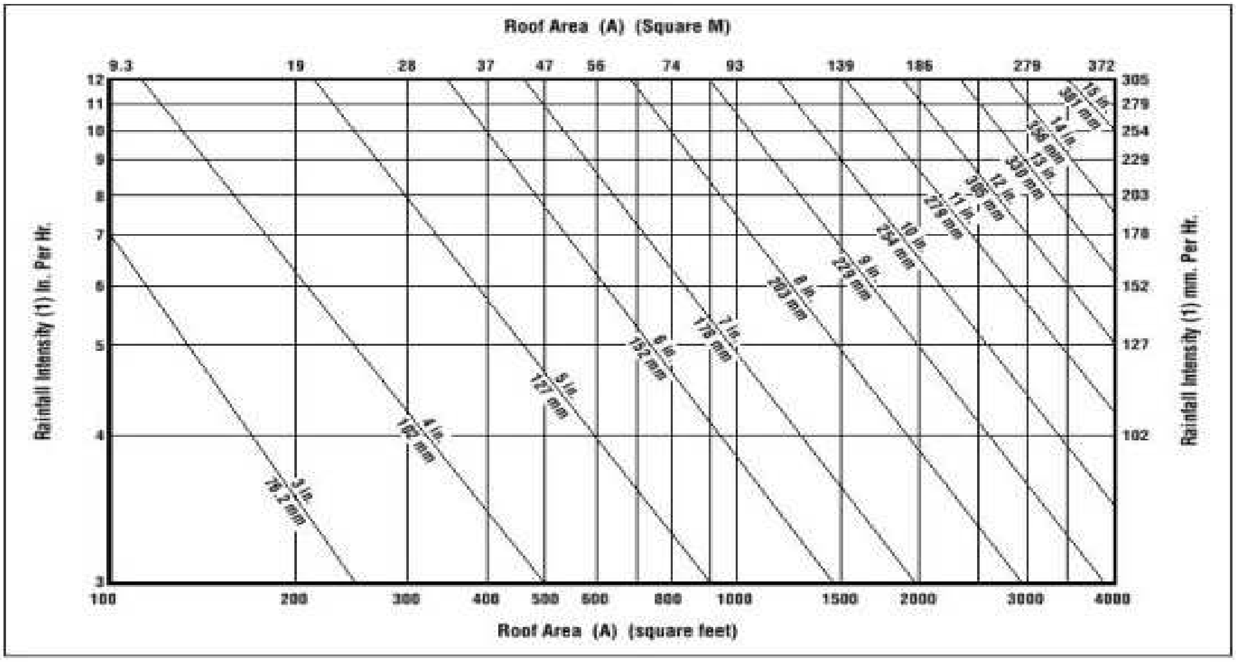


TABLE 1-4
SLOPED ROOF GUTTERS
Maximum Roof Area for Gutters

Diameter of gutter		C.S. Area		Level		Level		1/8 in per ft slope (3.2 mm/.3 m)				1/4 in per ft slope (6.4 mm/.3 m)			
in	mm	sq in	sq mm	sq ft	sq m	gpm	l/s	sq ft	sq m	gpm	l/s	sq ft	sq m	gpm	l/s
3	76	3.5	2258	680	63	7	0.44	960	89	10	0.63	1360	126	14	0.88
4	102	6.3	4064	1440	134	15	0.95	2040	190	21	1.33	2880	268	30	2.08
5	127	9.8	6321	2500	232	26	1.64	3520	327	37	2.33	5000	465	52	3.28
6	152	14.1	9095	3840	357	40	2.52	5440	505	57	3.60	7680	713	80	5.05
7	178			5520	513	57	3.60	7800	725	81	5.11	11040	1030	115	7.26
8	203	25.1	16190	7960	739	83	5.24	11200	1040	116.	7.32	14400	1338	165	10.4
10	254	39.1	25220	14400	1338	150	9.47	20400	1895	212	13.4	28800	2676	299	18.9