14-92.1

CAPACITY OF CORRUGATED METAL PIPE CULVERTS

OUTLET CONTROL - FULL FLOW - WITHOUT HEADWALLS

CIRCULAR

CUBIC FEET PER SECOND

DIAMETER INCHES	Length	Head on Pipe - Feet 0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	20 Feet	1.0	1.4	1.7	2.0	2.2	2.4	2.8	3.1	3.4	3.7	4.0	4.2	4.4	5.0	5.4	5.8	6.2
15		1.7	2.4	2.9	3.4	3.8	4.1	4.8	5.3	5.8	6.3	6.8	7.1	7.5	8.4	9.2	9.9	11
18		2.6	3.6	4.4	5.2	5.7	6.2	7.2	8.0	8.8	9.5	10	11	11	13	14	15	16
21		3.6	5.1	6.2	7.2	8.0	8.8	10	11	12	13	14	15	16	18	19	21	22
24		4.9	6.8	8.4	9.6	11	12	14	15	17	18	19	20	21	24	26	28	30
27		6.2	8.8	11	12	14	15	18	20	21	23	25	26	28	31	34	36	39
30		7.8	11	14	16	17	19	22	25	27	29	32	33	35	39	42	46	49
36		12	16	20	23	26	28	33	37	40	43	46	49	52	57	63	68	72
42		16	23	28	32	36	39	45	51	55	60	64	68	71	79	86	93	100
48		22	30	37	43	48	52	60	68	74	80	85	90	94	106	117	125	134
54		28	39	48	55	61	67	78	87	94	102	109	116	121	136	149	160	171
60		34	48	59	68	76	83	96	107	118	126	134	142	150	167	182	197	210
velocity						4		5	6		7			8	9	10		
12	40 Feet	0.8	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.0	3.2	3.4	3.6	4.0	4.4	4.8	5.1
15		1.4	1.9	2.4	2.7	3.1	3.4	3.9	4.3	4.8	5.2	5.5	5.9	6.2	6.9	7.6	8.2	8.8
18		2.1	3.0	3.7	4.3	4.8	5.2	6.0	6.8	7.4	8.0	8.6	9.0	9.6	11	12	13	14
21		3.0	4.3	5.3	6.1	6.8	7.4	8.6	9.6	11	12	12	13	14	15	17	18	19
24		4.2	5.9	7.2	8.4	9.4	10	12	13	15	16	17	18	19	21	23	25	27
27		5.5	7.8	9.6	11	12	14	16	17	19	21	22	23	25	28	30	33	35
30		7.0	9.8	12	14	16	17	20	22	24	26	28	30	31	35	38	42	44
36		10	15	18	21	24	26	30	33	36	39	42	45	47	53	58	62	66
42		15	21	26	30	33	36	42	47	51	55	59	62	66	74	80	88	93
48		20	28	35	40	45	49	56	63	69	74	80	84	89	99	109	118	127
54		26	36	45	51	57	63	72	81	89	96	103	109	115	128	140	152	163
60		32	45	55	64	72	78	90	100	110	120	128	136	143	160	175	190	202
velocity							4	5		6			7	8		9	10	
12	60 Feet	0.7	1.0	1.2	1.4	1.6	1.7	2.0	2.2	2.4	2.6	2.8	2.9	3.1	3.5	3.8	4.1	4.4
15		1.2	1.7	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.5	4.8	5.1	5.4	6.0	6.6	7.1	7.6
18		1.9	2.7	3.3	3.8	4.2	4.6	5.3	5.9	6.5	7.0	7.5	8.0	8.4	9.3	10	11	12
21		2.7	3.9	4.8	5.5	6.1	6.6	7.7	8.7	9.5	10	11	12	12	14	15	16	17
24		3.8	5.4	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	21	22	24
27		5.0	7.1	8.7	10	11	12	14	16	17	19	20	21	22	25	27	29	31
30		6.4	9.0	11	13	14	16	18	20	22	24	25	27	28	32	35	37	40
36		9.7	14	17	19	22	24	27	31	33	36	38	41	43	48	52	56	60
42		14	19	24	28	31	34	39	44	48	51	55	58	61	68	74	80	86
48		19	27	32	38	42	46	53	59	64	69	74	78	82	92	100	108	116
54		24	34	42	48	54	59	68	77	83	90	96	102	108	120	131	142	152
60		31	43	53	61	68	74	86	97	105	113	120	128	135	150	166	178	190
velocity								4		5	6			7	8	9		

Formula: $H = \left[\frac{2.52\,(1+K_e)}{D^4} + \frac{466.2\,n^2\,L}{D^{16/3}}\right]\left[\frac{Q}{10}\right]^2$

Using: $K_e = 0.9$, $n = 0.024$

Exhibit 14-4.1

REFERENCE
USBPR HYDRAULIC ENGR. CIRCULAR NO. 5

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING & WATERSHED PLANNING UNIT
UPPER DARBY, PENNSYLVANIA

RTSC-NE-ENG.
1411
SHEET 1 OF 3

USDA-SCS-HYATTSVILLE, MD. 1970

14-92.2

CAPACITY OF CORRUGATED METAL PIPE CULVERTS
OUTLET CONTROL - FULL FLOW - WITHOUT HEADWALLS

ARCH

SPAN AND RISE INCHES	Length	CUBIC FEET PER SECOND — Head on Pipe - Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
18x11	20 Feet	1.4	2.1	2.5	2.9	3.2	3.5	4.1	4.6	5.0	5.4	5.8	6.1	6.5	7.2	7.9	8.5	9.1
22x13		2.2	3.1	3.8	4.4	4.9	5.3	6.2	6.9	7.6	8.2	8.7	9.2	9.7	11	12	13	14
25x16		3.2	4.1	5.6	6.2	7.2	7.9	9.1	10	11	12	13	14	14	16	18	19	20
29x18		4.4	6.2	7.6	8.7	9.7	11	12	14	15	16	17	18	19	22	24	26	27
36x22		6.8	9.7	12	14	15	17	19	22	24	26	27	29	31	34	37	41	43
43x27		10	15	18	21	23	25	29	33	36	39	41	44	46	52	57	60	66
50x31		14	19	24	28	31	34	39	44	48	52	55	58	62	69	76	81	88
58x36		20	28	34	39	44	48	56	62	68	74	78	84	88	98	109	117	125
65x40		25	35	43	50	56	60	70	78	86	94	100	105	110	125	138	149	159
72x44		30	42	52	60	67	74	84	94	100	110	120	130	135	150	165	179	190
velocity						4		5		6		7		8	9	10		
18x11	40 Feet	1.2	1.7	2.0	2.4	2.7	2.9	3.4	3.8	4.1	4.5	4.8	5.0	5.3	6.0	6.6	7.0	7.6
22x13		1.8	2.6	3.2	3.6	4.1	4.5	5.1	5.7	6.3	6.8	7.2	7.6	8.0	9.0	10	11	12
25x16		2.7	3.9	4.7	5.5	6.1	6.7	7.8	8.6	9.4	10	11	12	12	14	15	16	17
29x18		3.8	5.3	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	20	22	24
36x22		6.0	8.6	11	12	14	15	17	19	21	23	24	26	27	30	33	36	39
43x27		9.4	13	16	19	21	23	27	30	33	35	37	40	42	47	51	55	59
50x31		12	17	22	25	28	31	35	40	43	47	50	53	56	63	69	74	80
58x36		18	26	32	36	40	45	51	57	62	68	72	76	80	90	99	108	115
65x40		23	33	40	46	52	57	66	72	80	86	92	98	105	115	128	139	149
72x44		28	39	48	56	62	68	80	89	97	105	110	120	125	140	155	168	180
velocity							4	5			6		7		8	9	10	
18x11	60 Feet	1.0	1.4	1.8	2.0	2.3	2.5	2.9	3.2	3.5	3.8	4.1	4.3	4.6	5.1	5.6	6.0	6.4
22x13		1.6	2.2	2.7	3.2	3.6	3.9	4.5	5.0	5.5	6.0	6.4	6.8	7.0	8.0	8.6	9.4	10
25x16		2.4	3.4	4.2	4.8	5.4	5.9	6.8	7.6	8.4	9.0	9.6	11	11	12	13	14	16
29x18		3.3	4.7	5.8	6.7	7.4	8.2	9.4	11	12	13	14	14	15	17	18	20	22
36x22		5.5	7.7	9.4	11	12	13	15	17	19	21	22	23	25	27	30	32	35
43x27		8.6	12	15	17	19	21	24	27	30	32	35	36	38	43	47	51	55
50x31		11	16	20	23	26	28	33	36	40	43	46	49	52	57	63	68	75
58x36		17	24	30	34	38	42	49	55	60	64	68	72	76	86	94	100	103
65x40		22	31	39	44	50	55	63	70	76	84	88	94	100	110	120	130	140
72x44		26	37	46	53	59	65	75	84	92	100	105	110	120	130	145	159	169
velocity							4		5		6			7	8	9		

$$H = \left[\frac{2.460\,(1+k_e)}{(BD)^2} + \frac{350.7\,n^2\,L}{(BD)^2\,D^{4/3}}\right]\left[\frac{Q}{10}\right]^2$$

$n = 0.024 \quad k_e = 0.9$

Exhibit 14-4.1

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	RTSC-NE-ENG. 1411 SHEET 2 OF 3

USDA-SCS-HYATTSVILLE, MD. 1970

14-92.3

CAPACITY OF CONCRETE PIPE CULVERTS

OUTLET CONTROL-FULL FLOW-WITHOUT HEADWALLS-SOCKET END UPSTREAM

DIAMETER INCHES	Length	CUBIC FEET PER SECOND Head on Pipe - Feet 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
12	20 Feet	3	5	6	7	8	8	9	10
18		8	12	14	16	18	20	22	23
24		15	21	26	30	34	37	40	42
30		24	34	41	48	53	59	63	68
36		35	49	60	70	78	85	92	99
42		48	68	83	96	107	117	127	135
48		63	89	109	126	141	154	166	178
54		80	113	138	160	179	196	212	226
60		99	140	172	198	222	243	262	282
velocity		4 5	6 7	8	10		12		
12	30 Feet	3	4	5	6	7	8	8	9
18		8	11	13	16	17	19	21	22
24		14	20	25	29	32	35	38	41
30		23	33	40	46	52	57	61	66
36		34	48	59	68	76	83	90	96
42		47	66	81	94	105	115	124	133
48		62	88	107	124	138	152	164	175
54		79	112	137	158	176	193	209	223
60		98	138	170	196	219	240	259	277
velocity		4 5	6 7	8	10		12		
12	40 Feet	3	4	5	6	7	7	8	8
18		7	10	13	15	17	18	20	21
24		14	20	24	28	31	34	37	40
30		23	32	39	45	51	55	60	64
36		33	47	58	67	75	82	88	94
42		46	65	80	92	103	113	122	130
48		61	86	106	122	136	149	161	172
54		78	110	135	156	174	191	206	220
60		97	137	168	194	216	237	256	274
velocity		4 5	6 7	8		10	12		
12	50 Feet	3	4	5	6	6	7	7	8
18		7	10	12	14	16	17	19	20
24		14	19	23	27	30	33	36	38
30		22	31	38	44	49	54	58	62
36		33	46	57	65	73	80	86	92
42		45	64	78	91	101	111	120	128
48		60	85	104	120	134	147	159	170
54		77	109	133	154	172	188	203	217
60		96	135	166	191	214	234	253	270
velocity		4 5	6 7	8		10		12	

Exhibit 14-4.1

REFERENCE

$$H = \left[\frac{2.520(1-k_e)}{D^4} + \frac{466.2\,n^2 L}{D^{16/3}}\right]\left[\frac{Q}{10}\right]^2$$

$n = 0.012 \quad k_e = 0.2$

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING & WATERSHED PLANNING UNIT
UPPER DARBY, PENNSYLVANIA

RTSC-NE-ENG.
1411
SHEET 3 OF 3

USDA-SCS HYATTSVILLE, MD. 1970

14-92.4

CAPACITY OF CULVERTS
INLET CONTROL - WITHOUT HEADWALLS

CIRCULAR CORRUGATED METAL PIPE

Diameter	Cubic Feet Per Second												
	Head on Pipe Inlet - Feet												
Inches	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
12	2.0	3.2	4.1	4.7	5.3	5.8	6.3	6.7	7.2	7.5	8.0		
15	2.6	4.5	6.0	7.2	8.0	8.9	9.5	10	11	11	12	12	13
18	3.1	5.5	8.0	9.8	11	12	13	14	15	16	17	18	18
21	3.4	6.8	10	13	15	17	18	19	20	22	23	24	25
24	3.8	7.5	11	15	18	21	23	25	26	28	29	31	32
27		8.5	13	18	22	25	28	31	33	35	37	39	40
30		9.0	15	20	26	30	33	37	40	42	45	47	50
36		10	17	24	31	38	45	50	55	60	64	67	70
42			19	28	37	46	55	63	70	76	81	86	91
48			21	32	42	54	62	77	86	92	101	110	115
54				33	47	60	73	86	99	111	122	131	140
60				37	51	66	82	96	110	130	142	155	165

CIRCULAR CONCRETE PIPE - SOCKET END UPSTREAM

Diameter	Cubic Feet Per Second												
	Head on Pipe Inlet - Feet												
Inches	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
12	2.5	4.0	5.2	6.0	6.8	7.4	8.0	8.6	9.1	9.6	10		
15	3.1	5.6	7.5	9.0	10	11	12	13	14	15	16	16	17
18	3.5	7.0	9.0	12	14	15	17	18	20	21	22	23	24
21	4.0	8.0	12	15	18	20	22	24	26	27	29	30	32
24	4.3	9.1	14	19	22	26	29	31	33	35	38	40	42
27		9.8	16	22	27	32	35	38	40	43	46	48	52
30		10	17	25	32	37	42	46	50	53	56	59	62
36		12	20	29	38	47	55	62	68	72	79	82	85
42			22	33	44	57	67	76	85	93	100	107	113
48			24	38	50	65	80	92	105	115	125	135	145
54				38	55	73	90	105	120	135	150	162	175
60				42	58	78	95	115	135	155	172	190	202

PIPE ARCH - CORRUGATED METAL PIPE

Span and Rise	Cubic Feet Per Second												
	Head on Pipe Inlet - Feet												
Inches	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
18x11	3.2	4.8	6.0	6.8	7.5	8.2							
22x13	4.0	6.5	8.0	9.5	11	12	13						
25x16	4.7	8.0	11	13	15	16	17	18					
29x18	5.5	10	13	16	19	21	22	24	26	27	28		
36x22	6.7	12	18	22	26	30	33	35	38	40	43	45	47
43x27	7.8	15	22	30	37	42	46	51	55	58	61	65	67
50x31	9.4	17	26	36	45	53	59	66	71	76	80	84	88
58x36		20	31	43	55	65	75	83	90	98	105	111	116
65x40		21	34	47	62	75	87	98	108	118	125	133	141
72x44		24	38	53	70	85	100	115	128	138	150	160	170

Exhibit 14-4.2

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC-NE-ENG.
USBPR HYDRAULIC ENGR. CIRCULAR NO. 5	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1412 SHEET 1 OF 1

USDA-SCS-HYATTSVILLE, MD. 1970

14-92.6

MINIMUM GAGE [1] CORRUGATED IRON AND STEEL PIPE

ARCH

CULVERTS

Span in.	Rise in.	Area sq.ft.	Height of Fill -- ft. [2]			
			1-2	3-10	11-15	16-20
18	11	1.1	16	16	16	16
22	13	1.6	16	16	16	16
25	16	2.2	16	16	16	16
29	18	2.8	14	14	14	14
36	22	4.4	14	14	14	14
43	27	6.4	12	12	12	12
50	31	8.7	12	12	12	10
58	36	11.4	10	12	10	10
65	40	14.3	10	12	10	8
72	44	17.6	8	12	8	--

1/ Minimum thickness of metal U.S. standard gage.
2/ Height of fill measured from top of culvert.

Notes:

1. Use of chart limited to culverts with maximum hydraulic head of 10 feet.
2. Gages based upon H-20 live load plus dead load -- projection condition.
3. Annular or helical corrugations of 2-2/3 x 1/2 inches.

Exhibit 14-4.4

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC-NE-ENG.
MICHIGAN ENGINEERING EXPERIMENT STATION BULLETIN 109, 1951, P. 62	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1414 SHEET 1 OF 1

USDA-SCS-HYATTSVILLE, MD. 1970

MINIMUM U.S. STANDARD GAGE - CORRUGATED IRON AND STEEL PIPE ANNULAR OR HELICAL CORRUGATIONS 2 2/3 x 1/2 INCHES — ROUND

Diameter in.	Area sq. ft.	CULVERTS Height of Fill ft. 1/	PRINCIPAL SPILLWAYS Height of Fill - ft. 1/																	
		2-20	2-10	11-14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
8	0.35	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
10	0.55	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
12	0.78	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
15	1.23	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
18	1.77	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
21	2.41	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	14	14	14	14
24	3.14	16	16	16	16	16	16	16	16	16	16	14	14	12	12	12	12	12	12	10
30	4.91	16	16	16	14	14	14	14	12	12	10	10	10	10	8	8	8			
36	7.07	16	16	16	14	12	12	10	10	8										
42	9.62	16	16	14	12	10	8	8												
48	12.57	16																		
54	15.90	14																		
60	19.63	12																		
66	23.76	12																		
72	28.27	10																		

1/ Height of fill as measured from top of conduit.

Design Criteria: Minimum cover of 2 feet, culverts and spillways.
Culverts - maximum allowable deflection, 5 percent of diameter.
Principal spillways - maximum allowable deflection, 3 percent of diameter.

Deflection formula: $D_x = \frac{D_1 K W_c R^3}{EI + 0.061 E' R^3}$ where $D_1 = 1.5$; $K = 0.1$; $E = 30 \times 10^6$; $E' = 700$ psi.

Ring compression: FS = 4, for seam strength. Buckling of wall: FS = 2. Handling and installation: FF = 0.0433.

Exhibit 14-4.3

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC - NE - ENG.
HANDBOOK OF STEEL DRAINAGE AND HIGHWAY CONSTRUCTION PRODUCTS 1967	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1413 SHEET 1 OF 1

USDA-SCS-HYATTSVILLE MD. 1970

14-92.7

MINIMUM GAGE 1/ -- CORRUGATED ALUMINUM PIPE
RIVETED, ANNULAR, OR HELICAL FABR., 2⅔" x ½" DEPTH CORR.

ROUND

Diameter in.	Area sq.ft.	Height of Fill -- ft. 2/		
		1-10	11-15	16-20
8	0.35	16	16	16
10	0.55	16	16	16
12	0.78	16	16	16
15	1.23	16	16	16
18	1.77	16	16	16
21	2.41	16	16	16
24	3.14	16	14	14
30	4.91	14	14	12
36	7.07	14	12	10

1/ Minimum thickness of metal U.S. standard gage.
2/ Measured from top of conduit.

Limitations for use:

1. The diameter shall not exceed 36 inches.
2. Do not use in soils that have a pH greater than 9 or less than 4, or in which excessive corrosion of similar material is known to have occurred.
3. The maximum pressure in the culvert barrel must not exceed 15 feet of head.

Exhibit 14-4.5

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC-NE-ENG.
FED. SPEC. WW-P-402	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1415 SHEET 1 OF 1

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