MARYLAND STATE HIGHWAY ADMINISTRATION
HIGHWAY HYDRAULICS DIVISION
707 North Calvert Street
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Design Guidelines
Culverts

Appendix 1. Service Life Estimation for Corrugated Metal Pipes

The following figures, tables and formulae are adopted from the Florida DOT Drainage Manual and are acceptable for estimating culvert service life.

Updated March 2, 2007

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FIGURE 6-1

Estimated Service Life vs. pH and Resistivity for 16 ga. Galvanized Steel

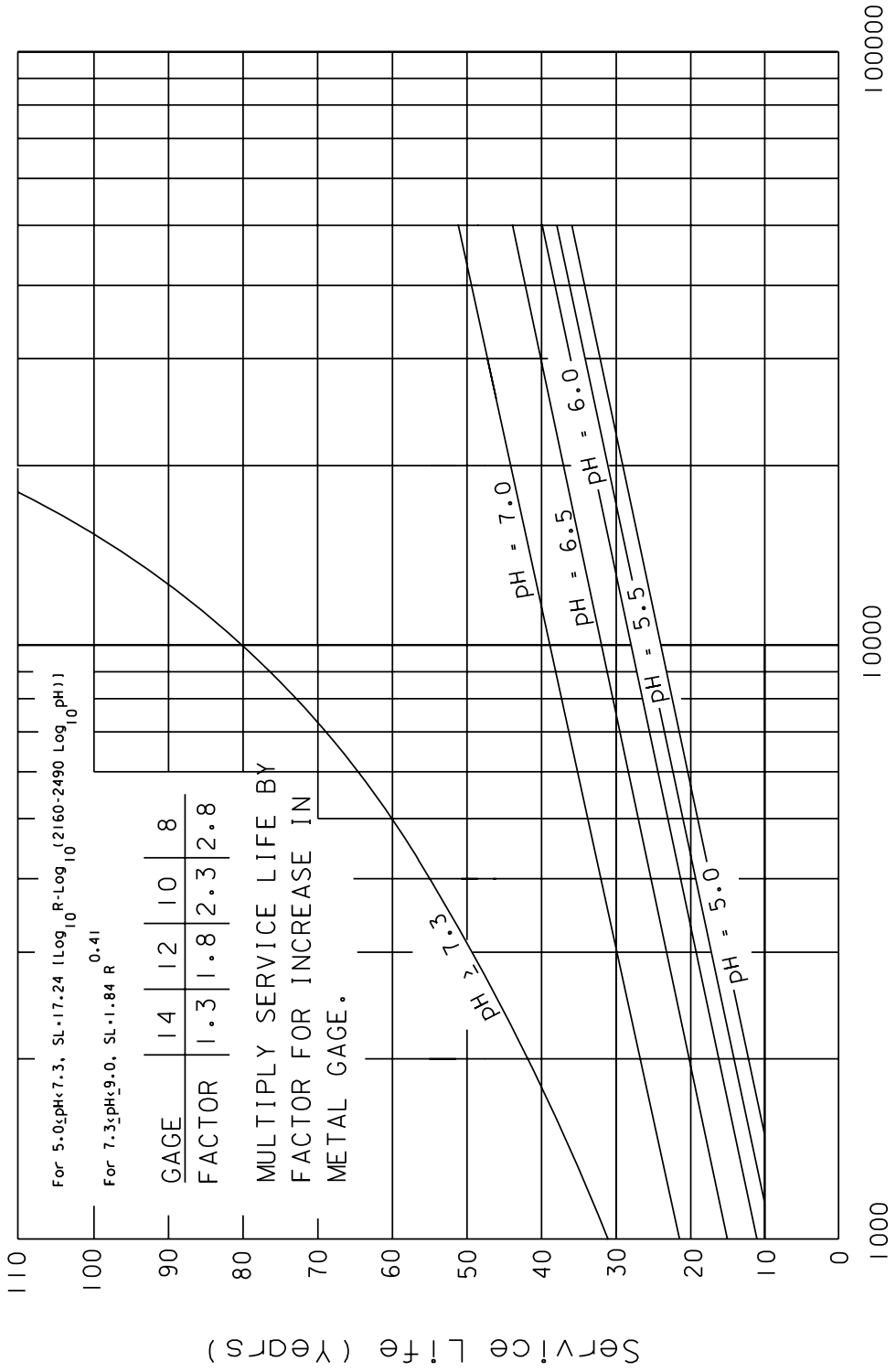


TABLE 6.2

Design Service Life vs. pH and Resistivity for 16 ga. **GALVANIZED STEEL** Culvert Pipe

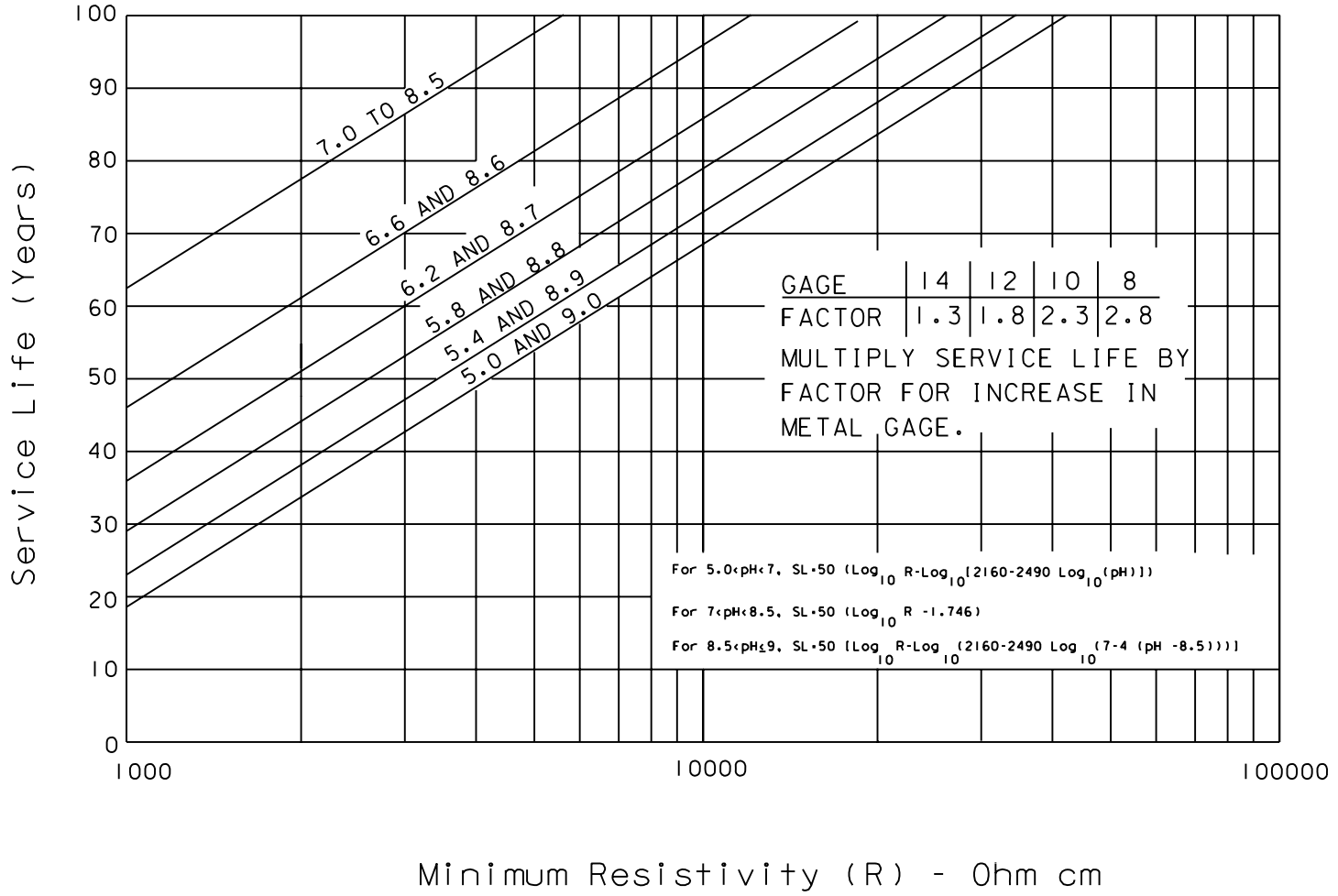
	Resistivity												
pH	1000	1500	2000	3000	4000	5000	7000	10000	15000	20000	30000	40000	∃50000
5.0	7	10	12	15	17	19	21	24	27	29	32	34	36
5.1	7	10	12	15	17	19	21	24	27	29	32	34	36
5.2	8	10	13	16	18	19	22	25	28	30	33	35	37
5.3	8	11	13	16	18	20	22	25	28	30	33	35	37
5.4	8	11	13	16	19	20	23	25	28	31	34	36	37
5.5	9	12	14	17	19	21	23	26	29	31	34	36	38
5.6	9	12	14	17	19	21	24	26	29	32	35	37	38
5.7	10	13	15	18	20	22	24	27	30	32	35	37	39
5.8	10	13	15	18	21	22	25	27	30	32	36	38	39
5.9	11	14	16	19	21	23	25	28	31	33	36	38	40
6.0	11	14	16	20	22	23	26	28	32	34	37	39	41
6.1	12	15	17	20	22	24	26	29	32	34	37	40	41
6.2	13	16	18	21	23	25	27	30	33	35	38	40	42
6.3	13	16	19	22	24	25	28	31	34	36	39	41	43
6.4	14	17	19	22	24	26	29	31	34	36	40	42	43
6.5	15	18	20	23	25	27	30	32	35	37	40	43	44
6.6	16	19	21	24	26	28	31	33	36	38	41	44	45
6.7	17	20	22	25	27	29	32	34	37	39	42	45	46
6.8	18	21	23	26	29	30	33	36	39	41	44	46	48
6.9	20	23	25	28	30	32	34	37	40	42	45	47	49
7.0	22	25	27	30	32	34	36	39	42	44	47	49	51
7.1	24	27	29	32	34	36	39	41	44	46	50	52	53
7.2	28	31	33	36	38	40	42	45	48	50	53	55	57
7.3	34	37	39	42	45	46	49	52	54	57	60	61	64
7.4 - 9.0	34	37	42	49	55	60	69	80	95	107	126	142	155

Estimated Service Life: $(SL) = 17.24\{Log_{10}R - Log_{10}[2160 - 2490(Log_{10}pH)]\}$ for $5 \leq pH \leq 7.3$

$(SL) = 1.84\ R^{0.41}$ for $7.3 \leq pH \leq 9$

FIGURE 6-2

Estimated Service Life vs. pH and Resistivity for 16 ga. Aluminized Steel Type II



Minimum Resistivity (R) - Ohm cm

TABLE 6.3

Estimated Service Life vs. pH and Resistivity for 16 ga. **ALUMINIZED STEEL** Culvert Pipe

	Resistivity												
pH	1000	1500	2000	3000	4000	5000	7000	10000	15000	20000	30000	40000	□50000
5.0	19	28	34	43	49	54	61	69	78	84	93	99	104
5.1	20	29	35	44	50	55	62	70	79	85	94	100	105
5.2	21	30	36	45	51	56	63	71	80	86	95	101	106
5.3	22	31	37	46	52	57	65	72	81	87	96	102	107
5.4	24	32	39	48	54	59	66	74	82	89	98	104	109
5.5	25	34	40	49	55	60	67	75	84	90	99	105	110
5.6	26	35	41	50	56	61	69	76	85	91	100	106	111
5.7	28	37	43	52	58	63	70	78	87	93	102	108	113
5.8	29	38	44	53	59	64	72	79	88	94	103	109	114
5.9	31	40	46	55	61	66	73	81	90	96	105	111	116
6.0	33	41	48	56	63	68	75	83	91	98	106	113	118
6.1	34	43	50	58	65	69	77	84	93	100	108	115	119
6.2	36	45	51	60	67	71	79	86	95	101	110	116	121
6.3	38	47	54	62	69	73	81	88	97	104	112	119	123
6.4	41	50	56	65	71	76	83	91	100	106	115	121	126
6.5	43	52	58	67	73	78	86	93	102	108	117	123	128
6.6	46	55	61	70	76	81	88	96	105	111	120	126	131
6.7	49	58	64	73	79	84	92	99	108	114	123	129	134
6.8	53	62	68	77	83	88	95	103	112	118	127	133	138
6.9	57	66	72	81	87	92	100	107	116	122	131	137	142
7.0 to 8.5	63	72	78	87	93	98	105	113	122	128	137	143	148
8.6	46	55	61	70	76	81	88	96	105	111	120	126	131
8.7	36	45	51	60	67	71	79	86	95	101	110	116	121
8.8	29	38	44	53	59	64	72	79	88	94	103	109	114
8.9	24	32	39	48	54	59	66	74	82	89	98	104	109
9.0	19	28	34	43	49	54	61	69	78	84	93	99	104

Estimated Service Life

$(SL) = 50\{Log_{10}R - Log_{10}[2160 - 2490(Log_{10}pH)]\}$ for $5.0 \leq pH < 7.0$

$(SL) = 50(Log_{10}R - 1.746)$ for $7.0 \leq pH \leq 8.5$

$(SL) = 50\{Log_{10}R - Log_{10}\{2160 - 2490\ Log_{10}[7 - 4(pH - 8.5)]\}\}$ for $8.5 < pH \leq 9.0$

FIGURE 6-3

Estimated Service Life vs. pH and Resistivity for Aluminum

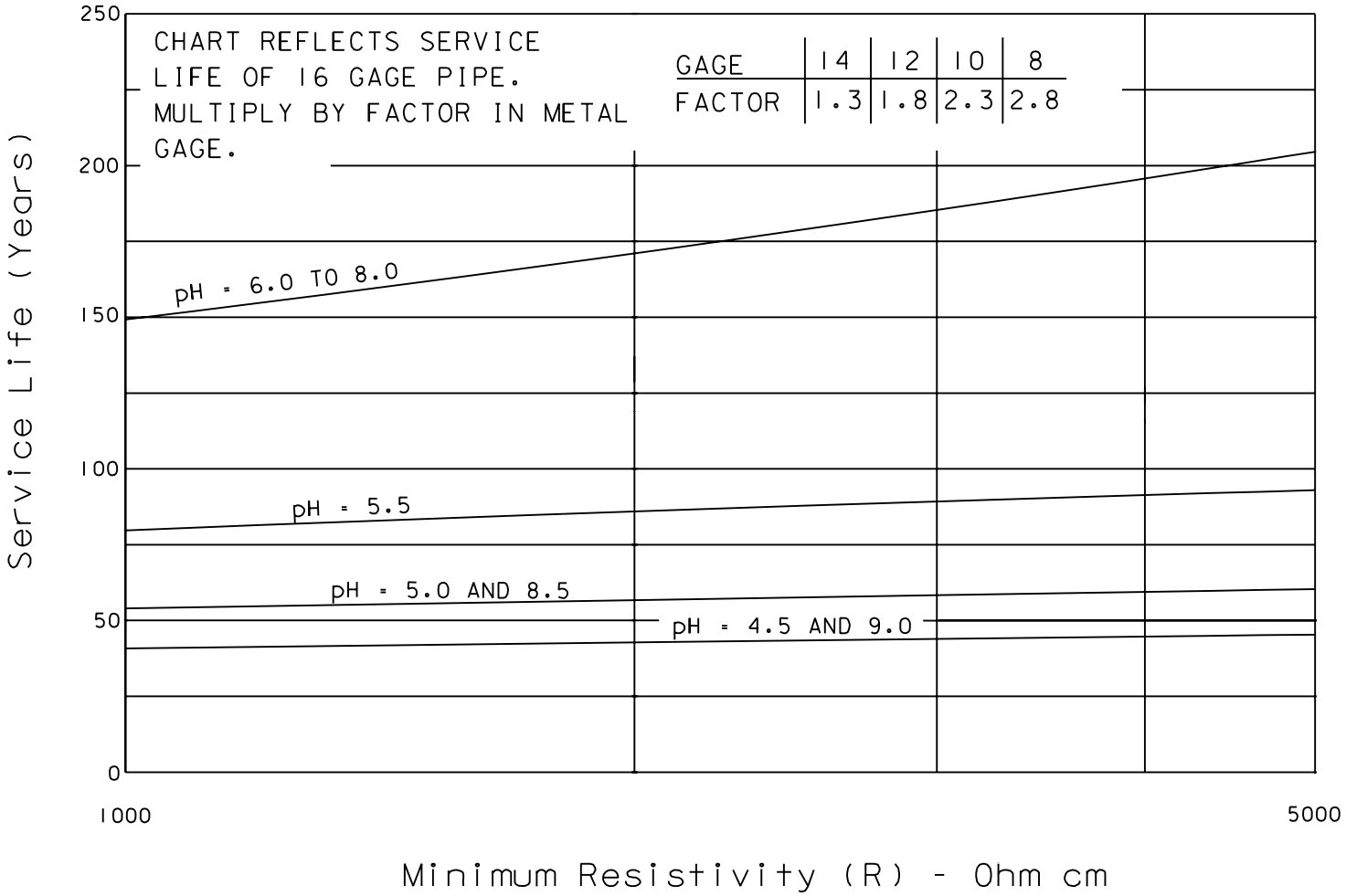


TABLE 6.4

Estimated Service Life vs. pH and Resistivity for 16 ga. **ALUMINUM** Culvert Pipe

	Resistivity															
pH	≥200	400	600	800	1000	1200	1400	1600	1800	2000	2300	2700	3200	3800	4500	≤5000
4.5 & 9.0	36	39	40	41	41	42	42	42	43	43	43	43	44	44	44	45
4.6 & 8.9	38	41	42	43	43	44	44	45	45	45	45	46	46	47	47	48
4.7 & 8.8	40	43	44	45	46	46	47	47	47	48	48	48	49	49	50	51
4.8 & 8.7	42	45	46	48	48	49	49	50	50	50	51	51	52	52	53	54
4.9 & 8.6	44	48	49	50	51	52	52	53	53	54	54	55	55	56	56	57
5.0 & 8.5	46	50	52	53	54	55	56	56	57	57	58	58	59	59	60	61
5.1	49	53	56	57	58	59	60	60	61	61	62	62	63	64	65	66
5.2 & 8.4	52	57	59	61	62	63	64	65	65	66	67	67	68	69	70	71
5.3	55	61	64	66	67	68	69	70	71	71	72	73	74	75	76	77
5.4 & 8.3	59	66	69	71	73	74	75	76	77	78	79	80	81	82	83	84
5.5	63	71	75	78	80	81	83	84	85	86	87	88	90	91	92	93
5.6 & 8.2	68	78	82	85	88	90	91	93	94	95	97	98	100	102	104	105
5.7	74	85	91	95	98	100	102	104	106	107	109	111	113	116	118	119
5.8 & 8.1	81	95	102	107	110	114	116	119	121	122	125	128	131	134	137	138
5.9	89	107	115	122	127	131	134	138	140	143	146	150	154	158	163	165
≥6.0 & ≤8.0	100	122	133	142	149	154	159	164	168	171	176	182	188	194	200	204

Service Life (SL) = $T_p / (R_{pH} + R_r)$

Where:

SL = Years to first perforation

T_p = Thickness of pipe (inches)

R_{pH} = Corrosion rate for pH (inches/year)

R_r = Corrosion rate for resistivity (inches/year)

FIGURE 6-4

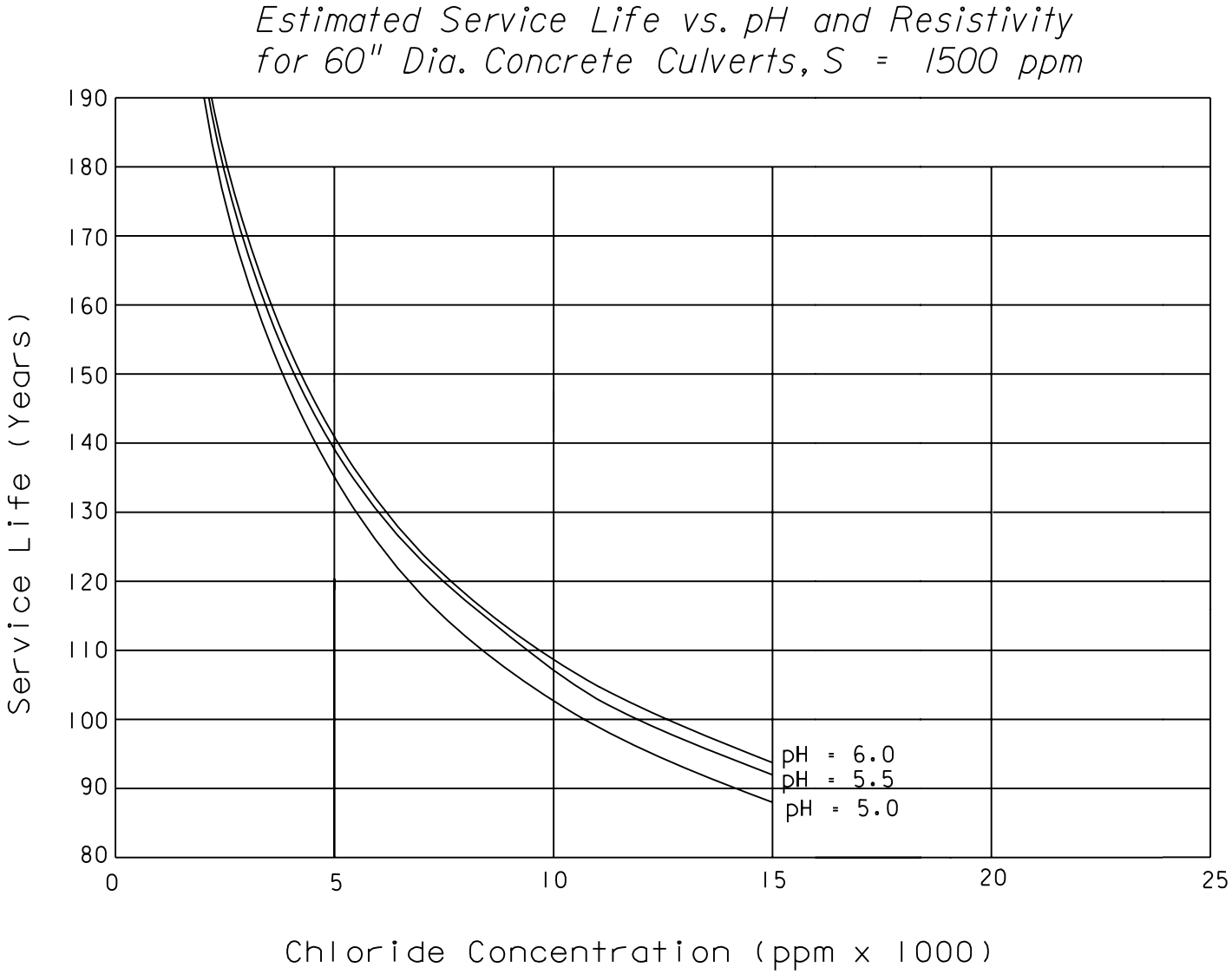

Estimated Service Life vs. pH and Resistivity
for 60" Dia. Concrete Culverts, S = 1500 ppm
Service Life (Years)
190
180
170
160
150
140
130
120
110
100
90
80
0
5
10
15
20
25
pH = 6.0
pH = 5.5
pH = 5.0
Chloride Concentration (ppm x 1000)

TABLE 6.5

Estimated Service Life vs. pH and Chlorides for 60" Dia. **REINFORCED CONCRETE** Culverts at 1500 ppm Sulfate Concentration

	Chlorides											
pH	15000	13000	11000	9000	7000	5000	3000	2000	1000	750	500	250
5.0	88	93	99	107	118	135	164	192	250	278	324	360
5.1	89	94	101	109	119	136	165	193	251	279	325	360
5.2	90	95	102	110	121	137	167	194	252	281	327	360
5.3	91	96	102	111	122	138	167	195	253	282	327	360
5.4	92	97	103	111	122	139	168	196	253	282	328	360
5.5	92	97	103	112	123	139	168	196	254	282	328	360
5.6	93	98	104	112	123	140	169	196	254	283	329	360
5.7	93	98	104	112	123	140	169	197	254	283	329	360
5.8	93	98	104	113	124	140	169	197	255	283	329	360
5.9	93	98	105	113	124	140	170	197	255	284	330	360
≥6.0	94	99	105	113	124	141	170	197	255	284	330	360

Conversion Factors for Different Size Culverts			
Pipe Dia.	Mult. By	Pipe Dia.	Mult. By
12”	.36	48”	.76
18”	.36	60”	1
24”	.41	72”	1.25
30”	.48	84”	1.51
36”	.54	96”	1.77
42”	.65	108”	2.04

SL Reduction Factors for Sulfates

Sulfate Content	Subtract from SL
1500	0
3200	5
4900	10
6600	15
8300	20
10000	25

Note: Sulfate derating not applicable When Type V cement is used.

$$\text{Service Life (SL)} = 1000(1.107^{C}C^{0.717}D^{1.22}K^{-0.37}W^{-0.631})-4.22\times10^{10}(pH^{-14.1})-2.94\times10^{-3}(S)+4.41$$

Where: C = Sacks of cement per cubic yard D = Steel depth in concrete K = Environmental chloride concentration in ppm
W = Total percentage of water in the mix S = Environmental sulfate content in ppm