Appendix B – Selected Costs of Alternative Disinfection Systems

B.1 Technologies and Costs for Control of Disinfection By-Products

Costs were developed for modifying a "base" or "typical" treatment plant to add disinfection and other technologies. The base plant is described as a conventional treatment plant using chlorine/chlorine disinfection consisting of rapid mixing, flocculation, sedimentation, chlorination, filtration, contact basin, chemical feed systems and finished water storage. This appendix contains figures and tables from *Technologies and Costs for Control of Disinfection By-Products* (USEPA, 1998), retaining the report's original figure and table numbers. Incremental costs are shown, determined by calculating the cost for the modified treatment plant and subtracting the base treatment plant cost.

The base treatment plant shown in Figure 7-1, is a basic alum coagulation and filtration plant, with chlorine disinfection. This plant was modified to meet disinfection requirements. The bases for the cost estimates are shown in Tables 7-3, 7-4, 7-5, and 7-6. The 12 flow categories for which the costs were determined are shown in Table 7-2.

Schematics and costs to add the following schemes are shown in the attached figures and tables.

- Base treatment plant - Figure 7-1 and Table 7-7.
- Move point of chlorination. This modification assumes no cost for moving the chlorine addition point, but costs for an added contact basin are shown in Table 7-8.
- Change to Chlorine/Chloramine - Figure 7-2 and Table 7-9.
- Change to Ozone/Chloramine - Figure 7-3 and Table 7-12.
- Change to Chlorine Dioxide – Table 7-13.

See USEPA, 1998 for more details and information upon the costs of other technologies.

FIGURE 7-1. ALUM COAGULATION / FILTRATION BASE PLANT

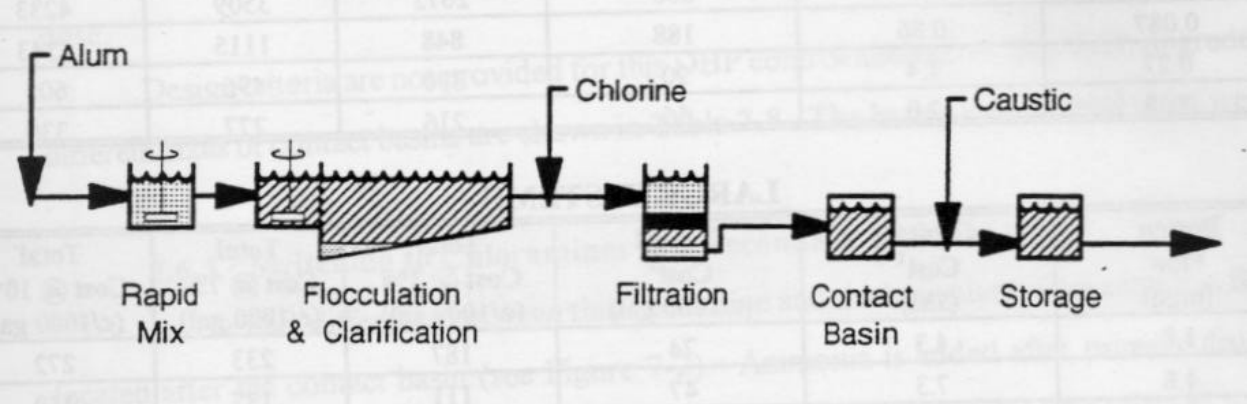

TABLE 7-2. EPA FLOW CATEGORIES

EPA FLOW CATEGORIES	POPULATION	AVERAGE FLOW mgd)	CAPACITY mgd)
1		0.0056	
2		0.024	
3		0.086	
4		0.23	
LARGE SYSTEMS - DESIGN FLOW > 1 MGD			
	5,500		1.8
	15,000		4.8
	35,000		11
	60,000		18
	88,000		26
	175,000		51
	73	120	
12		270	
12a		350	

TABLE 7-3. SMALL SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
Package Raw Water Pumping	Premanufactured packaged pumping station using submersible pump contained in a 20 ft deep steel pump sump. Manifold piping, sump intake valve, pump check valves, and electrical controls. Total dynamic head is 50 ft. Pump and motor efficiencies are 80 and 90%, respectively.	
Package Complete Treatment Plant	Coagulation, flocculation, sedimentation, and filtration equipment provided including tube settlers rated at 1,500 gpd/sf, mixed media filters with application rates of 2 to 5 gpm/sf and media depth of 30 in. Chemical feed facilities include storage tanks and feed pumps. Filter backwash pumps and, where applicable, surface wash water pumps. Flow measurement and control devices, pneumatic air supply (for 200 gpm or larger plants), effluent pumps, and building.	
Hypochlorite Solution	Solution tanks, mixers, and metering pumps	Sodium hypochlorite dose of 2.4 mg/L determined by WTP model.
Chlorination System	Metering pumps, PVC pipes, valves and controls are included.	
Sodium Hydroxide Feed System	Storage tanks, heater, manual transfer pump, mixers, feed tanks and metering pumps are included. PVC pipes, valves and control are also included.	
Alum Feed System	Solution tanks, mixers, and calibrated metering pumps are included. PVC pipes, valves and controls are also included.	Alum dose is determined by DBP control alternatives.

TABLE 7-3. SMALL SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
Package High Service Pump Station	Includes 2 or 3 centrifugal pumps, pressure sensing, flow control valves, instrumentation and equipment. Pumps provide a maximum output of 70 psi.	
Clearwell Storage Above Ground	Above ground, steel tanks including instrumentation and control of clearwell water level and instrumentation for turbidity and residual monitoring is provided.	Clearwell size is based on storage of 25% of the daily operating flow.
Sludge Dewatering Lagoons	Unlined lagoon and inlet, outlet structures are provided. 2 ft freeboard, 3:1 side slopes, 5 ft depth are also provided.	Sizing of lagoons is based on solids content of 5%. Sludge is thickened to a solids concentration of 30%.
Dewatered Sludge Hauling	Loading facilities including sludge conveyer, hopper, and hopper enclosure are provided. Length of haul is 20 miles one-way.	
Contact Basin		Below ground tanks without repumping are assumed. Size of basin is 60 minutes, as determined by the WTP model. The well baffled tanks are assumed to provide actual contact time of 0.7 times the theoretical according to the SWTR Guidance Manual. O&M costs were unpredictable and were assumed to be negligible.

TABLE 7-4. LARGE SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
Raw Water Pumping	Total dynamic head 100 ft Manifold piping velocity Standby pump, manifold piping, and instrumentation are provided	
Alum Feed System	Diaphragm metering pumps, steel storage hoppers with dust collector, and mechanical weight belt feeders Commercial alum density 60 lb/cu ft Dissolving tank detention time 5 min with 2 gal of water per lb of dry alum added Maximum hopper volume 6,000 cu ft with fifteen days of storage	Alum dose is determined by DBP control alternatives
Rapid Mix	Vertical shaft, variable speed turbine mixers with stainless steel shafts and paddles and TEFC motors Maximum basin capacity 2,500 cu ft Water temperature 15" C Overall mechanism efficiency 70%	G = 900/sec Detention time is 1 min at design flow
Flocculation (Horizontal Paddle)	Rectangular-shaped, reinforced concrete basins with 12 ft depth, 4:1 length to width ratio, and 12,500 cu ft individual maximum basin size Variable speed drive units requiring 15 min/day routine O&M and an oil change every 6 months requiring 4 hrs of labor Overall mechanism efficiency 60%	G = 50/sec Detention time is 30 min at design flow
Rectangular Clarifiers	Chain and flight collector with drive mechanism, sludge pumps, reinforced concrete structure, and withdraw pumps are included	Overflow rate = 1,000 gpd/sq ft

TABLE 7-4. LARGE SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
	Side wall depth = 12 ft	Maximum number of units is 2 Maximum basin area = 20,000 sq ft
Gravity Filtration Systems	Filter structure, underdrains, wash water troughs, pipe gallery piping and valves, instrumentation, control panel, and filter housing are provided Filter box depth = 16 ft Maximum filter size = 1,275 sq ft	Minimum 4 filters per plant Filter loading rate = 4 gpm/sq ft
Filtration Dual Media	20 in of 1.0 to 1.2 mm effective size anthracite coal (UC = 1.7) 10 in of 0.42 to 0.52 mm effective size silica sand (UC = 1.6) 12 in underdrains. Media consisting of 4 sizes of silica gravel	
Backwash Pumping Facilities	All required pumps and motors, flow control, sequencing control, valves and backwash headers are included Pumping head = 50 ft Overall mechanism efficiency 70%	Backwash rate = 18 gpm/sq ft One filter is backwashed at a time with each filter backwashed approximately every two days
Wash Water Surge Basins	Below ground, reinforced concrete basins and level control instrumentation provided	Sized to store a 20 min volume of backwash water at design flow
Unthickened Sludge Pumping	Variable speed, centrifugal pumps, piping and valves, electrical equipment housing, dry well, and a wet well are included Pipe velocity = 5 ft/sec Total dynamic head = 30 ft	Unthickened sludge solids concentration = 1% 12 hr/day of sludge pumping

TABLE 7-4. LARGE SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
	Overall pump-motor efficiency = 65%	
Sludge Dewatering Lagoons	Unlined lagoon and inlet and outlet structures are provided 2 ft freeboard, 3:1 side slopes, and 10 ft depth are also provided	Solids production is determined by WTP model Sludge is thickened to a solids concentration of 30% Sizing of lagoons is based on a solids content of 5%
Dewatered Sludge Hauling	Loading facilities including sludge conveyor, hopper, and hopper enclosure are provided Length of haul is 20 miles one-way	Dewatered sludge has a solids content of 30%
In-plant Pumping	Constant speed, vertical turbine pumps, pump motor, wet well, and piping and valves are included Pipe velocity = 5 ft/sec	Total dynamic head = 50 ft
Chlorine Feed Facilities	Chlorinator, standby chlorinator, cylinder scales, evaporators, residual analyzers with flow proportioning device injector pumps, and housing to include 30 days of cylinder storage are provided Injector pumps deliver water at 25 psi to allow production of 3,500 mg/L solution	Chlorine dose is 2.4 mg/L as determined by WTP model
Sodium Hydroxide Feed System	Storage tanks, heater, manual transfer pump mixers, feed tanks and metering pumps are included PVC pipes, valves and controls are also included	Sodium hydroxide dose is 16 mg/L as determined by WTP model
Finished Water Pumping	Vertical turbine pumps powered by constant speed motors, electrical equipment instrumentation, valves, and manifolds are provided Total dynamic head is 300 ft	

TABLE 7-4. LARGE SYSTEMS BASIS FOR COST ESTIMATES FOR DBP CONTROL

Process	WATER Model Assumptions	Engineering Assumption
	Standby pump is also included	

TABLE 7-5. COST ALLOWANCE FACTORS

Item	Small Systems Water Model (%)	Large Systems WATERCO$T Model(%)
Site work and Interface Piping	10	15
Subsurface Considerations	10	10
Standby Power	5	5
General Contractors Overhead and Profit	12	12
Engineering	15(1)	15(2)
Legal, Fiscal and Administration fees	5 to 6(1)	9 to 11(2)

Notes:

(1)Percentages added to estimated construction cost plus estimated cost for other allowances factors.

(2)Percentages added to estimated construction cost only.

TABLE 7-6. INDICES USED IN THE ESCALATION OF COSTS

DESCRIPTION	INDEX REFERENCE	NUMERICAL VALUE	ESCALATION VALUE
Building Cost Index	ENR [1]	3391.86	1.23
Chemical & Allied Products	BLS [2]	147.2	1.19
Skilled Labor	ENR [1]	5231.35	1.178
Materials	ENR [1]	2268.57	1.328
Utility Natural Gas	BLS 055 [2]	111.3	1.679

[1] Engineering News Record (July, 1997)

[2] Bureau of Labor Statistics (March, 1997)

TABLE 7-7. ESTIMATED BASE PLANT COSTS

SMALL SYSTEMS

Design Flow (mgd)	Capital Cost[1] ($M)	O & M Cost[2] (¢/1000 gal)	Total Cost @ 3% (¢/1000 gal)	Total Cost @ 7% (¢/1000 gal)	Total Cost @ 10% (¢/1000 gal)
0.024	0.63	600	2672	3509	4233
0.087	0.86	188	848	1115	1343
0.27	1.4	90	390	496	605
0.65	2.0	56	216	277	330

LARGE SYSTEMS

Design Flow (mgd)	Capital Cost[1] ($M)	O & M Cost[2] (¢/1000 gal)	Total Cost @ 3% (¢/1000 gal)	Total Cost @ 7% (¢/1000 gal)	Total Cost @ 10% (¢/1000 gal)
1.8	4.3	74	187	233	272
4.8	7.3	47	111	137	159
11	12	39	83	102	118
18	17	36	72	86	98
26	22	35	66	78	89
51	36	33	58	68	76
210	120	32	50	58	65
430	230	31	47	53	59
520	380	26	46	54	61

[1] 1991 Cost escalated based upon a factor of 1.23 derived from the ENR BCI

[2] 1991 Cost escalated based upon a factor of 1.19 derived from the BLS Chemical and Allied Products Index

TABLE 7-8. ESTIMATED UPGRADE COSTS FOR ADDITIONAL CONTACT BASIN SIZE (x $1000) [1]

DESIGN FLOW	Chlorine Contact Basin Time						
	30 min	60 min	120 min	180 min	240 min	300 min	360 min
0.024	14	21	26	28	38	46	55
0.087	25	34	66	76	82	84	100
0.27	52	80	103	140	180	220	234
0.65	77	112	218	251	284	317	351
1.8	197	244	335	427	519	611	702
4.8	274	396	642	887	1,132	1,376	1622
11	432	713	1,274	1,836	2,399	2,961	3521
18	611	1,070	1,990	2,909	3,828	4,748	5667
26	815	1,478	2,807	4,135	5,462	6,791	8118
51	1,454	2,755	5,360	7,965	10,569	13,175	15,778
210	5514	10,876	21,600	32,324	43,050	53,774	64,499
430	11,132	22,112	44,071	66,031	87,991	109,951	131,910
520	13,374	26,639	53,224	79,785	106,352	132,193	159,456

[1] 1991 Cost escalated based upon a factor of 1.23 derived from the ENR BCI

FIGURE 7-2. ALUM COAGULATION / FILTRATION SYSTEM UPGRADED WITH CHLORINE / CHLORAMINE DISINFECTION

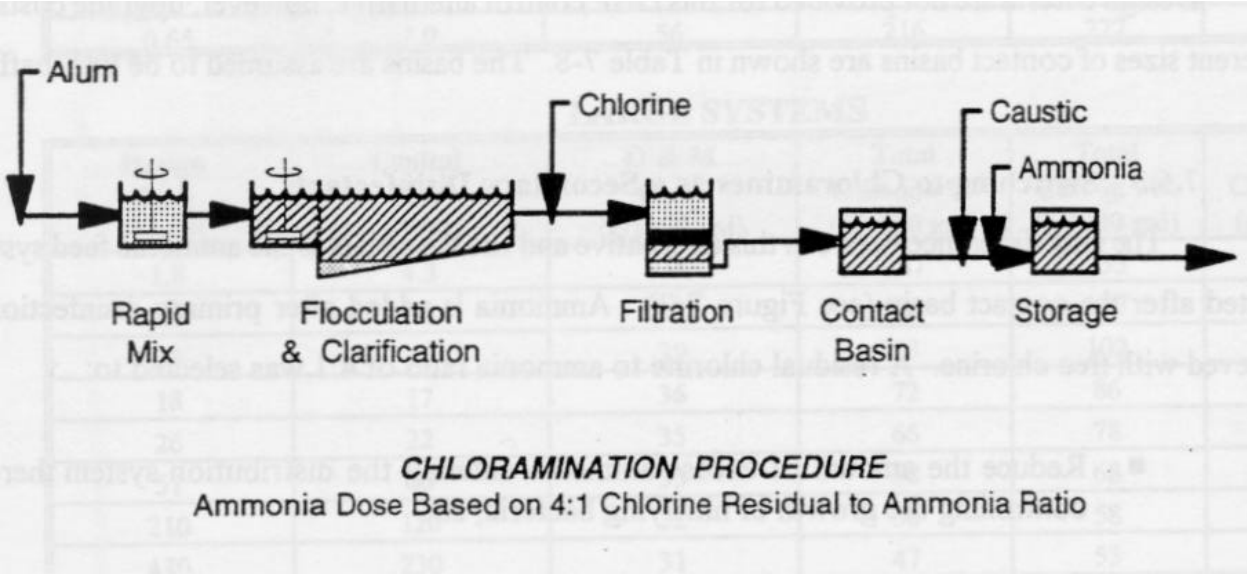

TABLE 7-9. ESTIMATED UPGRADE COSTS FOR CHLORAMINES AS SECONDARY DISINFECTANT

SMALL SYSTEMS

Design Flow (mgd)	Capital Cost[1] ($M)	O & M Cost[2] (¢/1000 gal)	Total Cost @ 3% (¢/1000 gal)	Total Cost @ 7% (¢/1000 gal)	Total Cost @ 10% (¢/1000 gal)
0.024	0.011	21	57	71	83
0.087	0.012	5.5	15	19	22
0.27	0.015	1.9	5.1	6.3	7.4
0.65	0.016	0.98	2.3	2.8	3.2

LARGE SYSTEMS

Design Flow (mgd)	Capital Cost[1] ($M)	O & M Cost[2] (¢/1000 gal)	Total Cost @ 3% (¢/1000 gal)	Total Cost @ 7% (¢/1000 gal)	Total Cost @ 10% (¢/1000 gal)
1.8	0.04	1.4	2.5	3.0	3.4
4.8	0.07	0.70	1.3	1.5	1.8
11	0.11	0.49	0.9	1.1	1.2
18	0.16	0.40	0.73	0.87	0.99
26	0.21	0.37	0.67	0.79	0.89
51	0.28	0.33	0.52	0.60	0.67
210	0.47	0.29	0.36	0.39	0.41
430	0.85	0.26	0.32	0.34	0.36
520	0.91	0.20	0.25	0.27	0.28

[1] 1991 Cost escalated based upon a factor of 1.23 derived from the ENR BCI
[2] 1991 Cost escalated based upon a factor of 1.19 derived from the BLS Chemical and Allied Products Index

FIGURE 7-3. ALUM COAGULATION / FILTRATION SYSTEMS UPGRADED WITH OZONE / CHLORAMINE DISINFECTION

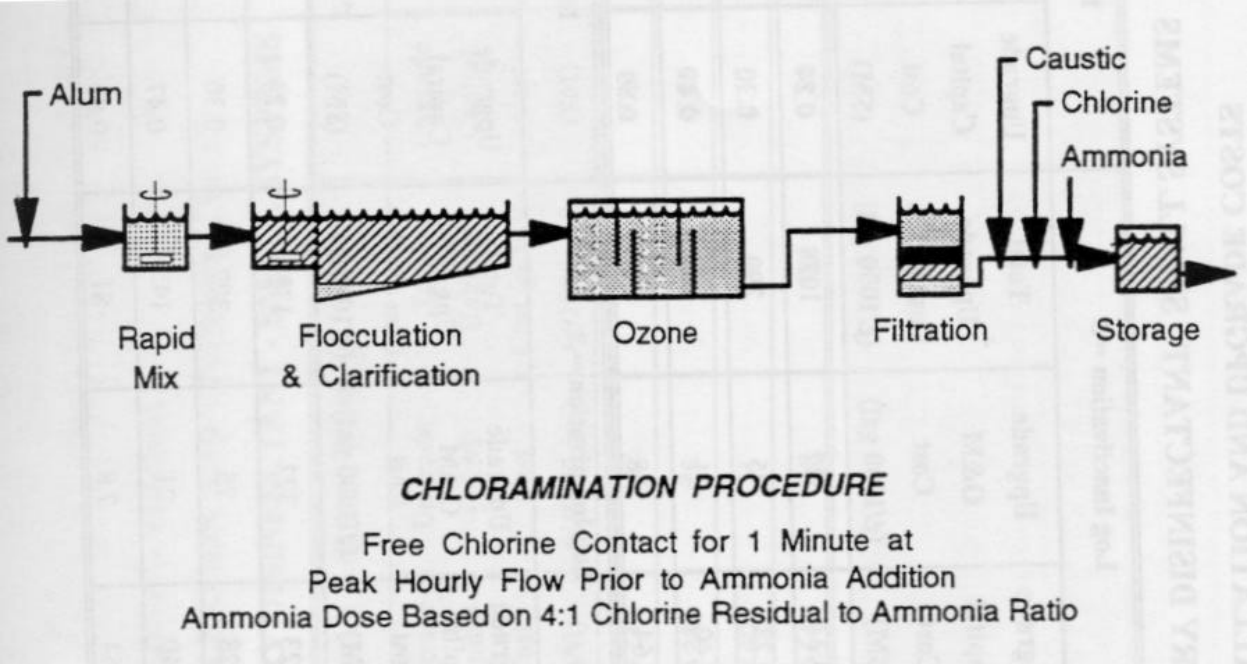

TABLE 7- 12. ESTIMATED INSTALLATION AND UPGRADE COSTS FOR OZONE AS PRIMARY DISINFECTANT - SMALL SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 3% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 3% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 3% (¢/1000 gal)
0.024	0.22	161	885	0.23	322	1078	0.24	644	1433
0.086	0.24	38	222	0.28	75	290	0.30	150	380
0.27	0.29	10	72	0.40	21	107	0.47	42	143
0.65	0.39	3.9	35	0.64	7.8	59	0.80	16	80
Design Flow (mgd)	**Log Inactivation = 1**			**Log Inactivation = 3**			**Log Inactivation = 5**		
	Upgrade Capital Cost ($M)	**Upgrade O&M Cost (¢/1000 gal)**	**Total Upgrade Cost @ 7% (¢/1000 gal)**	**Upgrade Capital Cost ($M)**	**Upgrade O&M Cost (¢/1000 gal)**	**Total Upgrade Cost @ 7% (¢/1000 gal)**	**Upgrade Capital Cost ($M)**	**Upgrade O&M Cost (¢/1000 gal)**	**Total Upgrade Cost @ 7% (¢/1000 gal)**
0.024	0.22	161	1177	0.23	322	1384	0.24	644	1752
0.086	0.24	38	297	0.28	75	377	0.30	150	473
0.27	0.29	10	97	0.40	21	145	0.47	42	183
0.65	0.39	3.9	48	0.64	7.8	81	0.80	16	106

TABLE 7- 12 (cont)

ESTIMATED INSTALLATION AND UPGRADE COSTS FOR OZONE AS PRIMARY DISINFECTANT - SMALL SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)
0.024	0.22	161	1442	0.23	322	1661	0.24	644	2023
0.086	0.24	38	361	0.28	75	445	0.30	150	551
0.27	0.29	10	119	0.40	21	170	0.47	42	217
0.65	0.39	3.9	59	0.64	7.8	98	0.80	16	128

TABLE 7- 12 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS FOR OZONE AS PRIMARY DISINFECTANT - LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @3% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 3% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 3% (¢/1000 gal)
1.8	0.89	1.8	25	1.5	4.4	44	1.4	6.3	43
4.8	1.5	1.8	15	1.9	4.4	21	2.0	6.3	24
11	1.9	1.8	9.0	2.6	4.4	14	2.8	6.3	17
18	2.4	1.8	7.0	3.0	4.4	11	3.7	6.3	14
26	2.6	1.8	5.5	3.9	4.4	9.9	4.8	6.3	13
51	3.8	1.8	4.4	6.2	4.4	8.6	7.4	6.3	11
210	9.2	1.8	3.2	18	4.4	7.2	24	6.3	10
430	16.5	1.8	2.9	35	4.4	6.8	47	6.3	9.5
520	20	1.8	2.9	42	4.4	6.6	57	6.3	9.3

TABLE 7- 12 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS FOR OZONE AS PRIMARY DISINFECTANT - LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 7% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 7% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 7% (¢/1000 gal)
1.8	0.89	1.8	35	1.5	4.4	58	1.4	6.3	56
4.8	1.5	1.8	21	1.9	4.4	28	2.0	6.3	31
11	1.9	1.8	12	2.6	4.4	17	2.8	6.3	21
18	2.4	1.8	8.9	3.0	4.4	13	3.7	6.3	17
26	2.6	1.8	7.2	3.9	4.4	12	4.8	6.3	15
51	3.8	1.8	5.6	6.2	4.4	10	7.4	6.3	13
210	9.2	1.8	4.0	18	4.4	7.8	24	6.3	11
430	16.5	1.8	3.6	35	4.4	7.4	47	6.3	11
520	20	1.8	3.4	42	4.4	6.1	57	6.3	10

TABLE 7- 12 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR OZONE AS PRIMARY DISINFECTANT
LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)	Upgrade Capital Cost ($M)	Upgrade O&M Cost (¢/1000 gal)	Total Upgrade Cost @ 10% (¢/1000 gal)
1.8	0.89	1.8	43	1.5	4.4	72	1.4	6.3	69
4.8	1.5	1.8	26	1.9	4.4	34	2.0	6.3	37
11	1.9	1.8	14	2.6	4.4	21	2.8	6.3	24
18	2.4	1.8	11	3.0	4.4	15	3.7	6.3	20
26	2.6	1.8	8.4	3.9	4.4	14	4.8	6.3	18
51	3.8	1.8	6.5	6.2	4.4	11	7.4	6.3	15
210	9.2	1.8	4.5	18	4.4	8.7	24	6.3	12
430	16	1.8	4.0	35	4.4	8.2	47	6.3	12
520	20	1.8	3.6	42	4.4	8.2	57	6.3	10

TABLE 7-13 ESTIMATED INSTALLATION AND UPGRADE COSTS FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT (MANUAL GENERATOR) SMALL SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)
0.024	0.10	1929	2258	0.10	1934	2263	0.13	1934	2362
0.087	0.10	452	529	0.10	456	533	0.15	456	571
0.27	0.10	128	149	0.10	132	153	0.22	132	179
0.65	0.10	49	57	0.10	52	60	0.28	52	74
Design Flow (mgd)	**Log Inactivation = 1**			**Log Inactivation = 3**			**Log Inactivation = 5**		
	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)
0.024	0.10	1929	2391	0.10	1934	2396	0.13	1934	2534
0.087	0.10	452	560	0.10	456	564	0.15	456	618
0.27	0.10	128	158	0.10	132	162	0.22	132	198
0.65	0.10	49	60	0.10	52	63	0.28	52	63

TABLE 7-13 (cont)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(MANUAL GENERATOR)
SMALL SYSTEMS

Design Flow (mgd)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10 % (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)
0.024	0.10	1929	2455	0.10	1934	2460	0.13	1934	2659
0.087	0.10	452	575	0.10	456	579	0.15	456	654
0.27	0.10	128	162	0.10	132	166	0.22	132	215
0.65	0.10	49	62	0.10	52	65	0.28	52	91

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(AUTOMATIC GENERATOR)
SMALL SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)
0.024	0.33	1548	2633	0.33	1552	2637	0.37	1552	2769
0.087	0.33	364	617	0.33	367	620	0.39	367	666
0.27	0.33	104	175	0.33	107	178	0.47	107	208
0.65	0.33	40	66	0.33	43	69	0.52	43	85
Design Flow (mgd)	**Log Inactivation = 1**			**Log Inactivation = 3**			**Log Inactivation = 5**		
	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)
0.024	0.33	1548	3072	0.33	1552	3076	0.37	1552	3261
0.087	0.33	364	720	0.33	367	723	0.39	367	787
0.27	0.33	104	203	0.33	107	206	0.47	107	248
0.65	0.33	40	77	0.33	43	80	0.52	43	101

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(AUTOMATIC GENERATOR)
SMALL SYSTEMS

Design Flow (mgd)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)
0.024	0.33	1548	3459	0.33	1552	3462	0.37	1552	3662
0.087	0.33	364	810	0.33	367	813	0.39	367	888
0.27	0.33	104	228	0.33	107	231	0.47	107	280
0.65	0.33	40	87	0.33	43	90	0.52	43	115

(1) Cost were adjusted to account for an increase in basin contact time from the information reported in Table 7-10

TABLE 7-13 (cont.) ESTIMATED INSTALLATION AND UPGRADE COSTS FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT (MANUAL GENERATOR)

LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)
1.8	0.10	18	20.6	0.10	20	22.6	0.50	20	33
4.8	0.10	7.4	8.3	0.10	9.6	10.5	0.75	9.6	16
11	0.10	4.3	4.7	0.10	6.5	6.9	1.3	6.5	11.3
18	0.20	3.8	4.2	0.20	5.8	6.2	3.7	5.8	13.5
26	0.20	3.2	3.5	0.20	5.1	5.4	5.1	5.1	12.3
51	0.28	2.4	2.6	0.28	4.6	4.8	9.4	4.6	11
210	0.29	1.8	1.8	0.29	3.6	3.6	36	3.6	9.1
430	0.35	1.6	1.6	0.35	3.2	3.2	73	3.2	8.2
520	0.35	1.4	1.4	0.35	2.4	2.4	89	2.	7.1

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(MANUAL GENERATOR)
LARGE SYSTEMS

	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
Design Flow (mgd)	**Upgrade Capital Cost[(1)] ($M)**	**Upgrade O&M Cost (¢/1000gal)**	**Total Upgrade Cost @ 7% (¢/1000gal)**	**Upgrade Capital Cost[(1)] ($M)**	**Upgrade O&M Cost (¢/1000gal)**	**Total Upgrade Cost @ 7% (¢/1000gal)**	**Upgrade Capital Cost[(1)] ($M)**	**Upgrade O&M Cost (¢/1000gal)**	**Total Upgrade Cost @ 7% (¢/1000gal)**
1.8	0.10	18	22	0.10	20	24	0.50	20	38
4.8	0.10	7.4	8.2	0.10	9.6	11	0.75	9.6	19
11	0.10	4.3	4.5	0.10	6.5	6.5	1.3	6.5	13
18	0.20	3.8	4.6	0.20	5.8	6.6	3.7	5.8	17
26	0.20	3.2	3.4	0.20	5.1	5.4	5.1	5.1	15
51	0.28	2.4	2.3	0.28	4.6	4.3	9.4	4.6	13
210	0.29	1.8	2.1	0.29	3.6	4.1	36	3.6	12
430	0.35	1.6	2.0	0.35	3.2	3.0	73	3.2	10
520	0.35	1.4	1.4	0.35	2.4	2.5	89	2.4	9.0

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(MANUAL GENERATOR)

LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)
1.8	0.10	18	22	0.10	20	25	0.50	20	43
4.8	0.10	7.4	8.8	0.10	10	11	0.75	10	21
11	0.10	4.3	4.9	0.10	6.5	7.1	1.3	6.5	15
18	0.20	3.8	4.5	0.20	5.8	6.5	3.7	5.8	19
26	0.20	3.2	3.7	0.20	5.1	5.6	5.1	5.1	18
51	0.28	2.4	2.8	0.28	4.3	4.6	9.4	4.3	15
210	0.29	1.8	1.9	0.29	3.5	3.6	36	3.5	13
430	0.35	1.6	1.7	0.35	3.2	3.2	73	3.2	12
520	0.35	1.4	1.4	0.35	2.4	2.5	89	2.4	11

(1) Cost were adjusted to account for an increase in basin contact time from the information reported in Table 7-10

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(AUTOMATIC GENERATOR)

LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)	Upgrade Capital Cost[1] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 3% (¢/1000gal)
1.8	0.33	15	24	0.33	17	26	0.74	17	37
4.8	0.33	6.3	9.2	0.33	8.6	12	0.99	8.6	17
11	0.33	3.9	5.1	0.33	6.0	7.2	1.5	6.0	12
18	0.68	3.3	4.7	0.68	5.3	6.7	4.2	5.3	14
26	0.68	2.9	3.9	0.68	4.8	5.8	5.6	4.8	13
51	0.76	2.3	2.8	0.76	4.1	4.6	10	4.1	11
210	0.77	1.8	1.9	0.77	3.5	3.6	37	3.5	9.2
430	0.83	1.6	1.7	0.83	3.1	3.2	74	3.1	8.2
520	0.91	1.3	1.4	0.91	2.5	2.6	90	2.5	7.2

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(AUTOMATIC GENERATOR)

LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 7% (¢/1000gal)
1.8	0.33	15	27	0.33	17	29	0.74	17	44
4.8	0.33	6.3	10	0.33	8.6	13	0.99	8.6	21
11	0.33	3.9	5.7	0.33	6.0	7.7	1.5	6.0	14
18	0.68	3.3	5.0	0.68	5.3	7.0	4.2	5.3	17
26	0.68	2.9	4.4	0.68	4.8	6.4	5.6	4.8	16
51	0.76	2.3	2.7	0.76	4.1	4.7	10	4.1	13
210	0.77	1.8	2.2	0.77	3.5	4.2	37	3.5	12
430	0.83	1.6	2.1	0.83	3.1	3.1	74	3.1	10
520	0.91	1.3	1.4	0.91	2.5	2.6	90	2.5	9.1

(1) Cost were adjusted to account for an increase in basin contact time from the information reported in Table 7-10

TABLE 7-13 (cont.)
ESTIMATED INSTALLATION AND UPGRADE COSTS
FOR CHLORINE DIOXIDE AS PRIMARY DISINFECTANT
(AUTOMATIC GENERATOR)

LARGE SYSTEMS

Design Flow (mgd)	Log Inactivation = 1			Log Inactivation = 3			Log Inactivation = 5		
	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)	Upgrade Capital Cost[(1)] ($M)	Upgrade O&M Cost (¢/1000gal)	Total Upgrade Cost @ 10% (¢/1000gal)
1.8	0.33	15	30	0.33	17	32	0.74	17	51
4.8	0.33	6.3	11	0.33	8.6	14	0.99	8.6	24
11	0.33	3.9	6.1	0.33	6.0	8.1	1.5	6.0	16
18	0.68	3.3	5.5	0.68	5.3	7.5	4.2	5.3	21
26	0.68	2.9	4.7	0.68	4.8	6.7	5.6	4.8	19
51	0.76	2.3	2.9	0.76	4.1	4.9	10	4.1	16
210	0.77	1.8	2.2	0.77	3.5	4.2	37	3.5	13
430	0.83	1.6	2.1	0.83	3.1	3.1	74	3.1	12
520	0.91	1.3	1.4	0.91	2.5	2.7	90	2.5	11

(1) Cost were adjusted to account for an increase in basin contact time from the information reported in Table 7-10

B.2 References

1. USEPA. 1998a. Technologies and Costs for Control of Disinfection By-Products. Washington, DC.

2. USEPA. 1998b. *Regulatory Impact Analysis for the Stage 1 Disinfectant/Disinfection Byproduct Rule*. Prepared by Science Applications International Corporation for the USEPA, Office of Ground Water and Drinking Water, Washington, DC.

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