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DETAILED COSTING DOCUMENT FOR THE CENTRALIZED WASTE TREATMENT INDUSTRY

(EPA-821-R-95-002)

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SECTION 1
INTRODUCTION

This document presents the costs estimated for compliance with the Centralized Waste Treatment (CWT) Industry effluent limitations guidelines and standards. It is a more detailed discussion of the summary information that is presented in Section 7 of the "Development Document for Proposed Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry" (EPA 821-R-95-006).

Section 2 of this document provides a general description of how the individual treatment technology and regulatory option costs were developed. In Sections 3 through 6, the development of capital costs, operating and maintenance (O & M) costs, and land requirements for each of the specific wastewater and sludge treatment technologies is described in detail.

Additional compliance costs to be incurred by facilities, which are not dependent upon a regulatory option or treatment technology, are presented in Section 7. These additional items are retrofit costs, monitoring costs, RCRA permit modification costs, and land costs.

SECTION 2
COSTS DEVELOPMENT

2.1 *TECHNOLOGY COSTS*

Cost information for the technologies selected is available from several sources. The first source of information is the data base developed from the 1991 Waste Treatment Industry (WTI) Questionnaire responses. A second source of information is the Organic Chemicals and Plastics and Synthetic Fibers (OCPSF) industrial effluent limitations guidelines and standards development document, which utilizes the 1983 U.S. Army Corps of Engineers' Computer Assisted Procedure for Design and Evaluation of Wastewater Treatment Systems (CAPDET). A third source is engineering literature. The fourth source of information is the CWT sampling facilities. The fifth source of information is vendors' quotations. Vendors' recommendations were used extensively in the costing of the various technologies. The data from the WTI Questionnaire contained a limited amount of process cost information, and was used wherever possible.

The total costs developed include the capital costs of the investment, annual O & M costs, land requirement costs, sludge disposal costs, monitoring costs, RCRA permit modification costs, and retrofit costs. All of the costs were either scaled up or scaled down to 1989 dollars using the Engineering News Record (ENR) Construction Cost Index, as 1989 is the base year for the WTI Questionnaire.

The capital costs for the technologies are primarily based on vendors' quotations. The equipment costs typically include the cost of the treatment unit and some ancillary equipment associated with that technology. Investment costs added to the equipment cost include piping, instrumentation and controls, pumps, installation, engineering, and contingency. The standard factors used to estimate the capital costs are listed in Table 2-1.

Table 2-1. Standard Capital Cost Factors

Factor	Capital Cost
Equipment Cost	Technology-Specific Cost
Installation	25 to 55 percent of equipment cost
Piping	31 to 66 percent of equipment cost
Instrumentation and Controls	6 to 30 percent of equipment cost
Total Construction Cost (TCC)	Equipment + Installation + Piping + Instrumentation and Controls
Engineering	15 percent of TCC
Contingency	15 percent of TCC
Total Indirect Cost	Engineering + Contingency
Total Capital Cost	Total Construction Cost + Total Indirect Cost

The annual O & M costs for the various systems were derived from the vendors' information or from engineering literature. The annual O & M cost is comprised of energy, maintenance, taxes and insurance, labor, treatment chemicals (if needed), and residuals management (also if needed). The standard factors used to estimate the O & M costs are listed in Table 2-2. All of the parameters used in costing the CWT Industry are explained further in this document.

Table 2-2. Standard O & M Cost Factors

Factor	O & M Cost (1989 $)
Maintenance	4 percent of Total Capital Cost
Taxes and Insurance	2 percent of Total Capital Cost
Labor	$30,300 to $31,200 per man-year
Electricity	$0.08 per kilowatt-hour
Residuals Management	Technology-Specific Cost
Granular Activated Carbon	$0.70 per pound
Lime (Calcium Hydroxide)	$57 per ton
Polymer	$3.38 per pound
Sodium Hydroxide (100 percent solution)	$560 per ton
Sodium Hydroxide (50 percent solution)	$275 per ton
Sodium Hypochlorite	$0.64 per pound
Sulfur Dioxide	$230 per ton
Sulfuric Acid	$80 per ton
Total O & M Cost	Maintenance + Taxes and Insurance + Labor + Electricity + Chemicals + Residuals

2.2 *OPTION COSTS*

Engineering costs were developed for each of the individual treatment technologies which comprise the CWT regulatory options. These technology-specific costs, broken down into capital, O & M, and land components, are presented in detail in the following sections of this document.

To estimate the cost of an entire regulatory option, it is necessary to sum the costs of the individual treatment technologies which make up that option. In some instances, an option consists of only one treatment technology; for those cases, the option cost is equal to the technology cost.

The CWT subcategory regulatory options are described in Table 2-3. The treatment technologies included in each option are listed, and the subsections of this document which contain the corresponding cost information are indicated.

Table 2-3. CWT Subcategory Options

Subcategory/Option	Treatment Technology	Subsection
Metals 1	Chemical Precipitation	3.1.1
	Liquid Filtration or Clarification/Sludge Filtration	3.3.1 or 3.2/6.1
Metals 2	Selective Metals Precipitation	3.1.2
	Liquid Filtration	3.3.2
	Secondary Precipitation	3.1.3
	Liquid Filtration or Clarification/Sludge Filtration	3.3.2 or 3.2/6.1
Metals 3	Metals Option 2 Technologies	(above)
	Tertiary Precipitation	3.1.4
	Clarification	3.2
	pH Adjustment	3.1.4
Metals - Hexavalent Chromium Waste Pretreatment	Chromium Reduction using Sulfur Dioxide	3.9
Metals - Cyanide Waste Pretreatment	Cyanide Destruction at Special Operating Conditions	3.8
Oils 2	Ultrafiltration	5.1
Oils 3	Oils Option 2 Technologies	(above)
	Carbon Adsorption	3.7
	Reverse Osmosis	5.2
Oils 4	Oils Option 3 Technologies	(above)
	Carbon Adsorption	3.7
Organics 1	Equalization	3.4
	Air Stripping	3.5`
	Sequencing Batch Reactor	4.1
	Multi-Media Filtration	3.6
Organics 2	Organics Option 1 Technologies	(above)
	Carbon Adsorption	3.7

SECTION 3
PHYSICAL/CHEMICAL/THERMAL WASTEWATER TREATMENT TECHNOLOGY COSTS

3.1 *CHEMICAL PRECIPITATION*

3.1.1 *Chemical Precipitation - Metals Option 1*

Chemical precipitation systems are used to remove dissolved metals from wastewater. Lime and caustic were selected as the precipitants because of their effectiveness and widespread use in the CWT Industry.

The CWT Metals Option 1 chemical precipitation system equipment consists of a mixed reaction tank with pumps, a treatment chemical feed system, and an unmixed wastewater holding tank. The system is operated on a batch basis, treating one batch per day, five days per week. The average chemical precipitation batch duration reported by respondents to the 1991 WTI Questionnaire was four hours. Therefore, a one batch per day treatment schedule would provide sufficient time for the average facility to pump, treat, and test its waste. A holding tank equal to the daily waste volume, up to a maximum size of 5,000 gallons (equivalent to one tank truck receipt), was provided to allow facilities flexibility in managing waste receipts.

Total capital cost estimates were developed for the Metals Option 1 chemical precipitation systems. For facilities with no chemical precipitation system in-place, the components of the chemical precipitation system included the precipitation tank with a mixer, pumps, feed system, and holding tank. These cost estimates were obtained from manufacturer's recommendations. The total construction cost was developed by adding installation, piping, and instrumentation and controls to the equipment cost at 35 percent, 30 percent, and 30 percent of the equipment cost, respectively. The total capital cost estimates included engineering and contingency, which were estimated at 30 percent of the total construction cost. All capital cost estimates were converted to 1989 dollars using ENR's Construction Cost Index.

For facilities that already have a precipitation tank (treatment in-place), a capital cost upgrade was determined; this consists of the cost of a holding tank only.

The itemized chemical precipitation capital cost and capital upgrade cost estimates for Option 1 are presented in Tables 3-1 and 3-2, respectively. The corresponding capital cost and capital upgrade cost curves are presented in Figures 3-1 and 3-2. The resulting chemical precipitation capital cost and capital upgrade cost equations for Metals Option 1 are presented as Equations 3-1 and 3-2, respectively.

$$\ln(Y1) = 14.019 + 0.481\ln(X) - 0.00307(\ln(X))^2 \quad (3\text{-}1)$$

$$\ln(Y1) = 10.671 - 0.083\ln(X) - 0.032(\ln(X))^2 \quad (3\text{-}2)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

The O & M cost estimates for facilities with no treatment in-place were based on estimated energy usage, maintenance, labor, taxes and insurance, and chemical usage cost. The energy usage and costs were divided into electricity, lighting, and controls. Energy costs were based on power requirements of 0.5 kwhr per 1,000 gallons of wastewater. Lighting and controls were assumed at $1,000 per year and electrical cost at $0.08 per kwhr.

The maintenance costs were estimated at four percent of the total capital cost while taxes and insurance were estimated at two percent of the total capital cost. The labor cost was approximated at $31,200 per man-year at two hours per batch.

Chemical cost estimates were calculated based on stoichiometric, pH adjustment, and buffer adjustment requirements. For facilities with no chemical precipitation in-place, the stoichiometric requirements were based on the amount of chemicals required to precipitate each of the metals from the Metals Subcategory average raw influent concentrations to Option 1 levels. The chemicals used were lime at 75 percent of the required removals and caustic at 25 percent of the required removals. The pH

Table 3-1. Capital Costs for Chemical Precipitation - Metals Option 1

Flow (MGD)	Avg. Vendor Equipment Cost	Holding Tank	Install.	Total Construction Cost	Engineer. & Conting.	Total Capital Cost (1989 $)
0.000001	282	217	175	674	202	876
0.00001	1,030	762	627	2,419	726	3,145
0.0005	9,286	6,400	5,490	21,176	6,353	27,529
0.001	13,709	9,330	8,064	31,103	9,331	40,434
0.005	33,709	22,390	19,635	75,734	22,720	98,454
0.01	50,006	22,390	25,339	97,735	29,321	127,056
0.05	123,550	22,390	51,079	197,019	59,106	256,125
0.1	182,398	22,390	71,676	276,464	82,939	359,403
0.5	450,652	22,390	165,565	638,607	191,582	830,189
1.0	665,304	22,390	240,693	928,387	278,516	1,206,903
5.0	1,643,772	22,390	583,157	2,299,319	674,796	2,924,115

Table 3-2. Capital Cost Upgrades for Chemical Precipitation - Metals Option 1

Flow (MGD)	Average Vendor Equipment Cost	Installation	Total Construction Cost	Engineering & Contingency	Total Capital Cost (1989 $)
0.000001	217	76	293	88	381
0.00001	762	267	1,029	309	1,338
0.0005	6,400	2,240	8,640	2,592	11,232
0.001	9,330	3,266	12,596	3,779	16,375
0.005	22,390	7,837	30,227	9,068	39,295

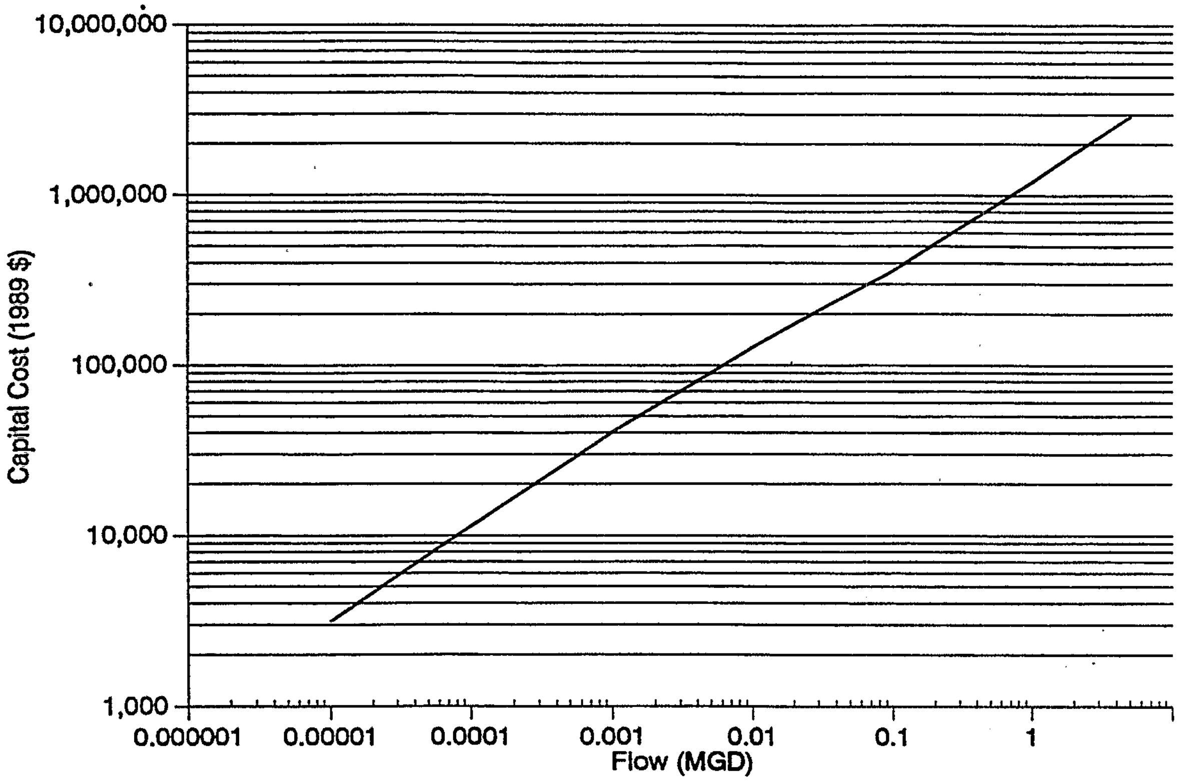

Figure 3-1 Capital Cost Curve for Chemical Precipitaiton - Metals Option 1

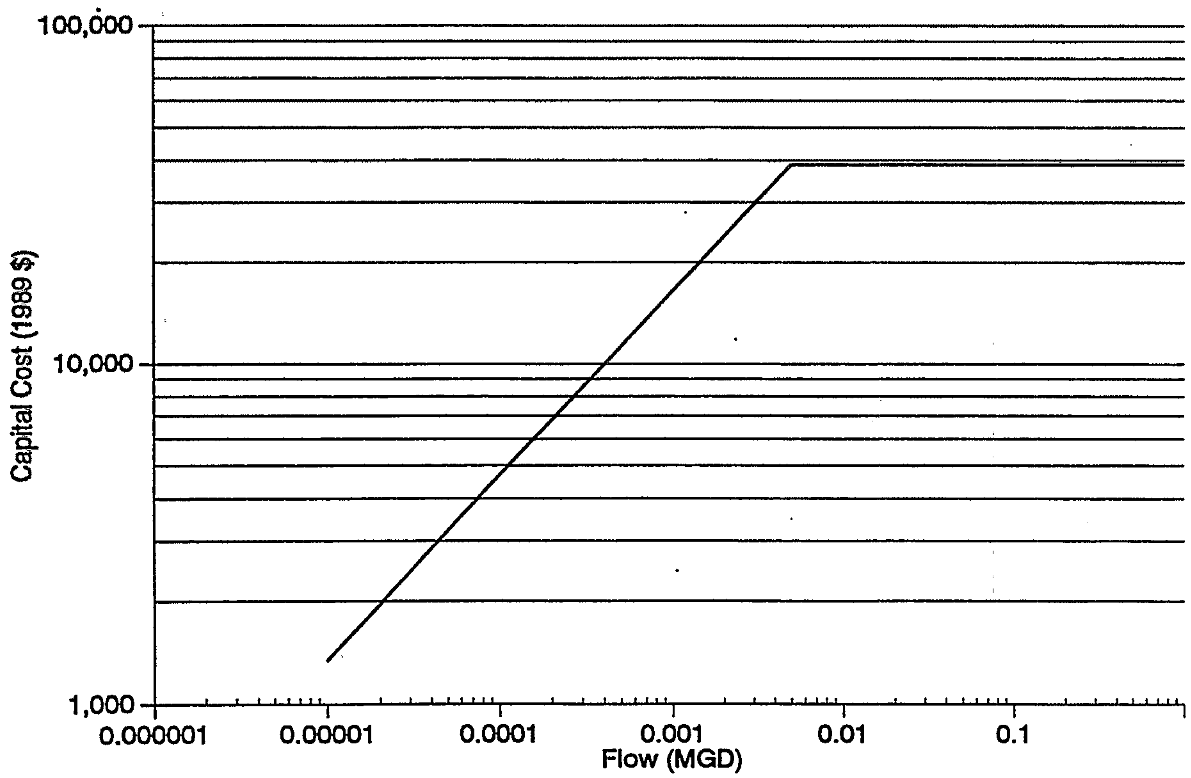

Figure 3-2 Capital Upgrade Cost Curve for Chemical Precipitation - Metals Option 1

adjustment and buffer adjustment requirements were estimated to be 50 percent of the stoichiometric requirement. Finally, a 10 percent excess of chemical dosage was added. Table 3-3 presents the lime and caustic requirements for the chemical precipitation system. The cost of lime at $57 per ton and caustic at $275 per ton (50 percent solution) were obtained from the Chemical Marketing Reporter.

The itemized annual O & M cost estimates for facilities with no treatment in-place are presented in Table 3-4 and the subsequent cost curve is presented in Figure 3-3. The O & M cost equation for Metals Option 1 chemical precipitation is:

$$\ln(Y2) = 15.206 + 1.091\ln(X) + 0.05(\ln(X))^2 \qquad (3\text{-}3)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

Table 3-4. O & M Costs for Chemical Precipitation - Metals Option 1

Flow (MGD)	Energy	Maintenance	Labor	Taxes & Insurance	Chemical Cost	Total O & M Cost (1989 $)
0.000001	1,000	35	13,116	18	1	14,170
0.00001	1,000	126	13,116	63	44	14,349
0.001	1,010	1,617	13,475	809	4,416	21,327
0.01	1,104	5,082	14,741	2,541	44,162	67,630
0.05	1,520	10,245	15,696	5,123	225,225	257,809
0.1	2,040	14,376	16,126	7,188	441,617	481,347
0.5	6,200	33,208	17,171	16,604	2,208,086	2,281,269
1.0	11,400	48,276	17,641	24,138	4,416,172	4,517,627
5.0	53,000	116,964	18,784	58,482	22,080,858	22,328,080

An O & M upgrade cost was estimated for facilities with chemical precipitation treatment in-place. It was assumed that these facilities already meet current Metals Subcategory performance levels. The ratio of current-to-Metals Option 1 vs. raw-to-

Table 3-3 LIME AND CAUSTIC REQUIREMENTS FOR CHEMICAL PRECIPITATION – METALS OPTION 1

POLLUTANT	RAW LEVEL (MG/L)	OPTION 1 LEVEL (MG/L)	R-A LEVEL (MG/L)	DOSAGE RATES		FLOW=0.00001 MGD		FLOW=0.001 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	308.483	5.858	302.625	4.11	4.45	30.4	10.9	3,037	1,094	303,723	109,450	3,037,231	1,094,497
ANTIMONY	93.934	0.337	93.597	1.52	1.64	3.5	1.3	347	125	34,706	12,507	347,056	125,065
ARSENIC	1.449	0.067	1.382	2.47	2.67	0.1	0.03	8	3	832	300	8,325	3,000
BARIUM	1.717	0.518	1.199	0.54	0.58	0.02	0.01	2	1	158	57	1,576	568
BORON	129.603	38.327	91.276	10.27	11.10	22.9	8.2	2,286	824	228,637	82,392	2,286,366	823,916
CADMIUM	35.955	0.021	35.934	0.66	0.71	0.6	0.2	58	21	5,771	2,080	57,712	20,797
CHROMIUM	955.361	0.367	954.994	2.13	2.31	49.7	17.9	4,973	1,792	497,293	179,205	4,972,928	1,792,046
COBALT	20.807	0.145	20.662	1.88	2.04	0.9	0.3	95	34	9,494	3,421	94,940	34,213
COPPER	1413.838	0.257	1413.581	1.16	1.26	40.2	14.5	4,016	1,447	401,565	144,708	4,015,652	1,447,082
IRIDIUM	29.687	5.538	24.149	0.77	0.83	0.5	0.2	45	16	4,536	1,635	45,358	16,345
IRON	480.047	14.285	465.762	1.99	2.15	22.6	8.1	2,258	814	225,817	81,375	2,258,166	813,753
LEAD	170.034	0.209	169.825	0.71	0.77	3.0	1.1	296	107	29,591	10,664	295,914	106,636
LITHIUM	74.544	1	73.544	5.33	5.76	9.6	3.4	956	345	95,649	34,468	956,492	344,682
LUTETIUM	0.803	0.567	0.236	0.63	0.69	0.004	0.001	0.37	0.13	37	13	365	132
MANGANESE	21.2	0.233	20.967	2.69	2.91	1.4	0.5	138	50	13,778	4,965	137,785	49,652
MERCURY	0.264	0.004	0.26	0.37	0.40	0.002	0.001	0.23	0.08	23	8	234	84
MOLYBDENUM	40.415	5.379	35.036	2.31	2.50	2.0	0.7	198	71	19,777	7,127	197,770	71,268
NICKEL	301.428	2.235	299.193	1.89	2.04	13.8	5.0	1,380	497	138,039	49,744	1,380,391	497,438
PHOSPHORUS	110.631	8.04	102.591	5.97	6.46	14.9	5.4	1,495	539	149,497	53,873	1,494,967	538,727
RHENIUM	6.08	5.397	0.683	0.79	0.86	0.01	0.005	1	0.5	132	48	1,324	477
SELENIUM	0.268	0.13	0.138	1.87	2.03	0.006	0.002	1	0.23	63	23	631	227
SILICON	195.377	2.59	192.787	5.27	5.70	24.8	8.9	2,478	893	247,788	89,293	2,477,876	892,928
SILVER	0.902	0.05	0.852	0.34	0.37	0.007	0.003	1	0.26	71	26	713	257
TANTALUM	5.072	3.168	1.904	1.02	1.11	0.047	0.017	5	2	475	171	4,749	1,711
TELLERIUM	7.803	5.468	2.335	1.16	1.25	0.1	0.02	7	2	661	238	6,607	2,381
THALLIUM	0.375	0.062	0.313	0.54	0.59	0.004	0.001	0.41	0.15	41	15	415	149
TIN	1077.825	0.284	1077.541	1.25	1.35	32.8	11.8	3,278	1,181	327,773	118,116	3,277,731	1,181,164
TITANIUM	640.944	0.043	640.901	3.09	3.34	48.3	17.4	4,831	1,741	483,069	174,079	4,830,689	1,740,789
URANIUM	10.259	8.041	2.218	0.62	0.67	0.03	0.01	3	1	335	121	3,353	1,208
VANADIUM	31.086	0.062	31.024	2.91	3.14	2.2	0.8	220	79	21,988	7,924	219,883	79,237
ZINC	796.813	1.276	795.537	1.13	1.22	22.0	7.9	2,197	792	219,654	79,155	2,196,540	791,546
TOTALS			6853.05			346	125	34,610	12,472	3,460,974	1,247,198	34,609,739	12,471,978

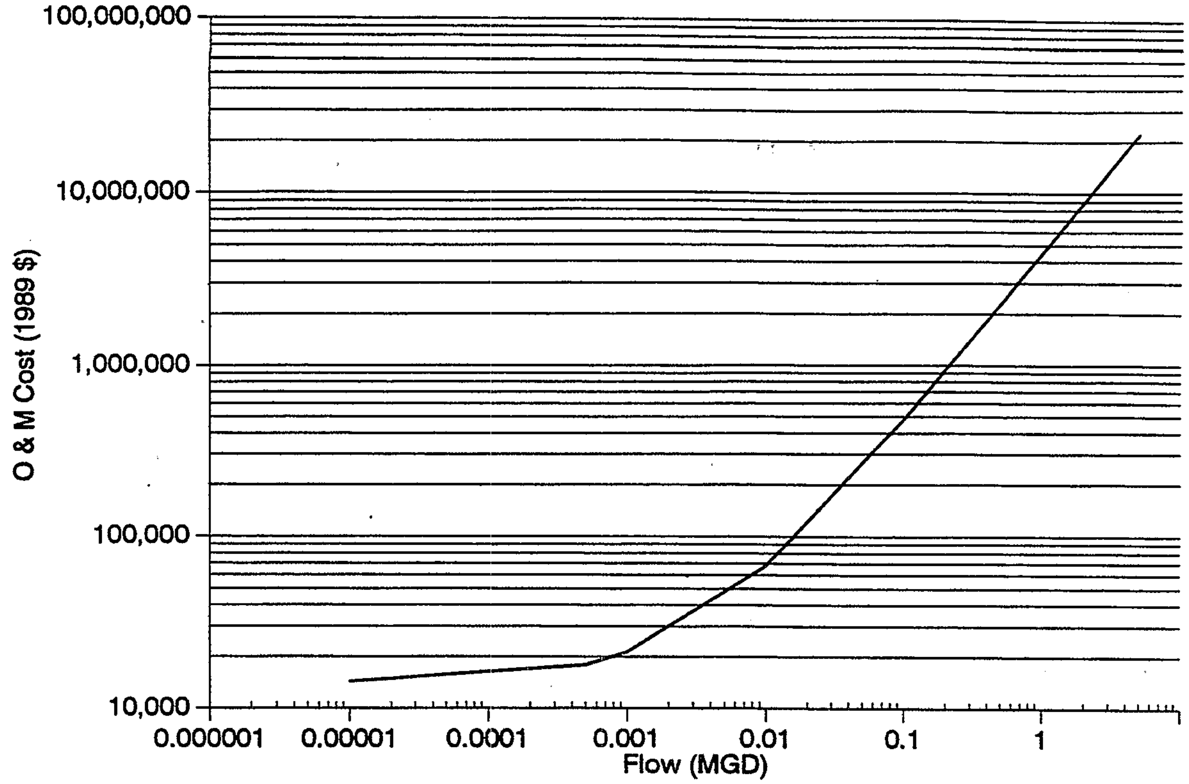

Figure 3-3 O & M Cost Curve for Chemical Precipitation - Metals Option 1

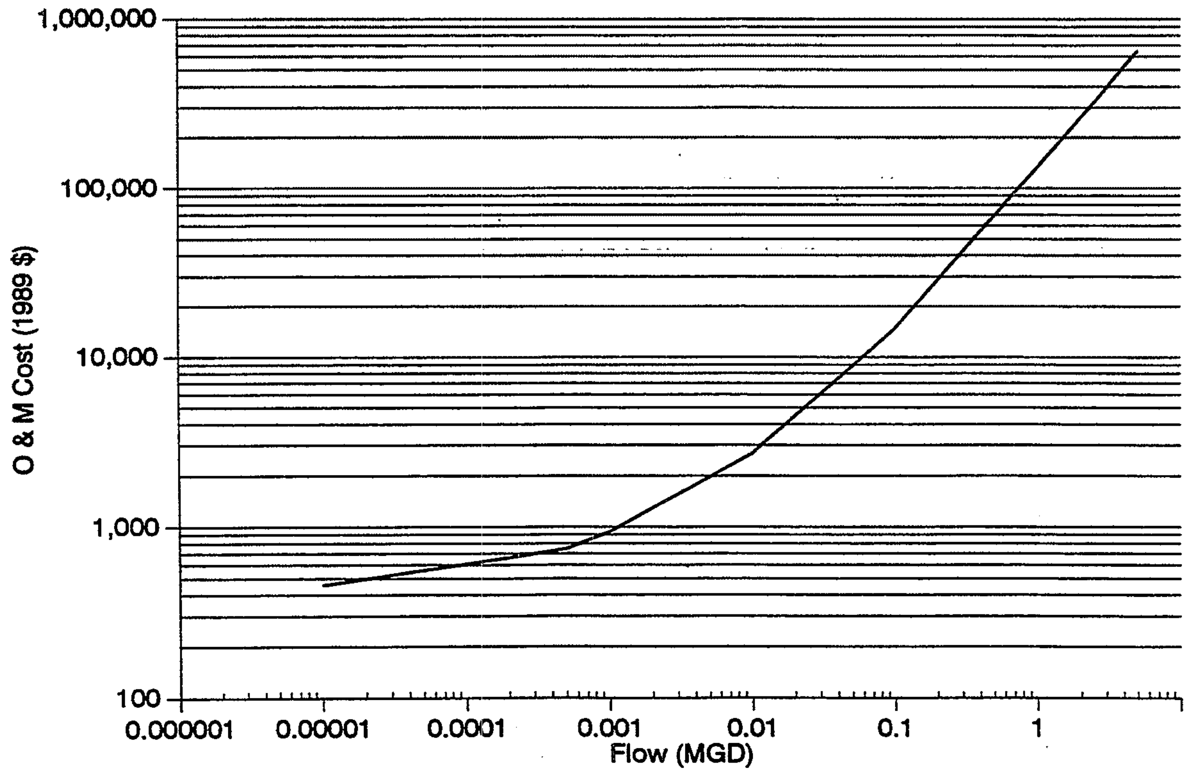

Figure 3-4 O & M Upgrade Cost Curve for Chemical Precipitation - Metals Option 1

current levels is approximately 0.03, therefore, the energy, maintenance, and labor components of the O & M upgrade cost were calculated at three percent of the total O & M cost for these components. Taxes and insurance were estimated to be two percent of the total capital cost for the holding tank.

Chemical upgrade costs were calculated based on current-to-Metals Option 1 removals with no additional chemicals used for pH adjustment and solution buffering, as these steps would be part of the in-place treatment system. A 10 percent excess of chemical dosage was added to the stoichiometric requirements. Table 3-5 presents the lime and caustic requirements for the chemical precipitation upgrades.

The itemized O & M upgrade costs for Option 1 are presented in Table 3-6 while the resulting cost curve is presented in Figure 3-4. The O & M upgrade cost equation for Metals Option 1 chemical precipitation is:

$$\ln(Y2) = 11.702 + 1.006\ln(X) + 0.044(\ln(X))^2 \qquad (3\text{-}4)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

Table 3-6. O & M Upgrade Costs for Chemical Precipitation - Metals Option 1

Flow (MGD)	Energy	Maintenance	Labor	Taxes & Insurance	Chemical Cost	Total O & M Cost (1989 $)
0.000001	30	1	394	8	2	435
0.00001	30	4	394	27	2	457
0.001	30	49	404	32	129	939
0.01	35	152	442	786	1,287	2,702
0.05	46	307	470	786	6,562	8,171
0.1	61	431	483	786	12,867	14,628
0.5	186	996	515	786	64,333	66,816
1.0	342	1,448	530	786	128,666	131,772
5.0	1,590	3,509	563	786	643,328	649,776

Table 3-5 LIME AND CAUSTIC REQUIREMENTS FOR CHEMICAL PRECIPITATION UPGRADES – METALS OPTION 1

POLLUTANT	CURRENT LEVEL (MG/L)	OPTION 1 LEVEL (MG/L)	C-1 LEVEL (MG/L)	DOSAGE RATES		FLOW=0.00001 MGD		FLOW=0.001 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ANTIMONY	2.373	0.337	2.036	1.52	1.64	0.06	0.02	5.5	2.0	554	200	5,536	1,995
ARSENIC	0.818	0.067	0.751	2.47	2.67	0.03	0.01	3.3	1.2	332	120	3,317	1,195
BARIUM	3.724	0.518	3.206	0.54	0.58	0.03	0.01	3.1	1.1	309	111	3,090	1,114
BORON	41.092	38.327	2.765	10.27	11.10	0.51	0.18	50.8	18.3	5,079	1,830	50,791	18,303
CADMIUM	0.323	0.021	0.302	0.66	0.71	0.004	0.001	0.4	0.1	36	13	356	128
CHROMIUM	2.328	0.367	1.961	2.13	2.31	0.07	0.03	7.5	2.7	749	270	7,488	2,699
COBALT	0.389	0.145	0.244	1.88	2.04	0.01	0.003	0.8	0.3	82	30	822	296
COPPER	1.368	0.257	1.111	1.16	1.26	0.02	0.01	2.3	0.8	231	83	2,314	834
IRIDIUM	9.413	5.538	3.875	0.77	0.83	0.05	0.02	5.3	1.9	534	192	5,337	1,923
LEAD	0.401	0.209	0.192	0.71	0.77	0.002	0.001	0.2	0.1	25	9	245	88
LITHIUM	23.635	1	22.635	5.33	5.76	2.16	0.78	215.9	77.8	21,588	7,780	215,882	77,795
MANGANESE	1.827	0.233	1.594	2.69	2.91	0.08	0.03	7.7	2.8	768	277	7,682	2,768
MERCURY	0.027	0.004	0.023	0.37	0.40	0.0002	0.0001	0.02	0.01	2	1	15	5
MOLYBDENUM	12.814	5.379	7.435	2.31	2.50	0.31	0.11	30.8	11.1	3,078	1,109	30,777	11,091
SELENIUM	0.15	0.13	0.020	1.87	2.03	0.001	0.0002	0.1	0.02	7	2	67	24
SILICON	61.947	2.59	59.357	5.27	5.70	5.59	2.02	559.5	201.6	55,947	20,161	559,468	201,610
SILVER	0.421	0.05	0.371	0.34	0.37	0.002	0.001	0.2	0.1	23	8	228	82
THALLIUM	0.263	0.062	0.201	0.54	0.59	0.002	0.001	0.2	0.1	20	7	195	70
TIN	25.11	0.284	24.826	1.25	1.35	0.55	0.20	55.4	20.0	5,538	1,996	55,379	19,957
TITANIUM	1.094	0.043	1.051	3.09	3.34	0.06	0.02	5.8	2.1	581	209	5,809	2,093
VANADIUM	9.856	0.062	9.794	2.91	3.14	0.51	0.18	50.9	18.3	5,090	1,834	50,905	18,344
ZINC	2.586	1.276	1.310	1.13	1.22	0.03	0.01	2.7	1.0	265	96	2,652	956
TOTALS			145.06			10	4	1,008	363	100,836	36,337	1,008,358	363,372

Land requirements were estimated for facilities with no chemical precipitation in-place and for facilities requiring only an upgrade. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. This data was plotted and the land area equation was determined. The land requirements are presented in Table 3-7 with subsequent cost curves in Figures 3-5 and 3-6. The land requirement and land requirement upgrade equations for Metals Option 1 chemical precipitation are presented as Equations 3-5 and 3-6, respectively.

$$\ln(Y3) = -1.019 + 0.299\ln(X) + 0.015(\ln(X))^2 \quad (3\text{-}5)$$

$$\ln(Y3) = -2.866 - 0.023\ln(X) - 0.006(\ln(X))^2 \quad (3\text{-}6)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

Table 3-7. Land Requirements for Chemical Precipitation - Metals Option 1

Flow (MGD)	Chemical Precipitation Land Requirements (Acres)	Chemical Precipitation Upgrade Land Requirements (Acres)
0.00001	0.0791	0.0395
0.0001	0.0823	0.041
0.001	0.094	0.047
0.01	0.125	0.0574
0.05	0.1724	0.0574
0.1	0.1768	0.0574
0.5	0.2434	0.0574
1.0	0.4474	0.0574

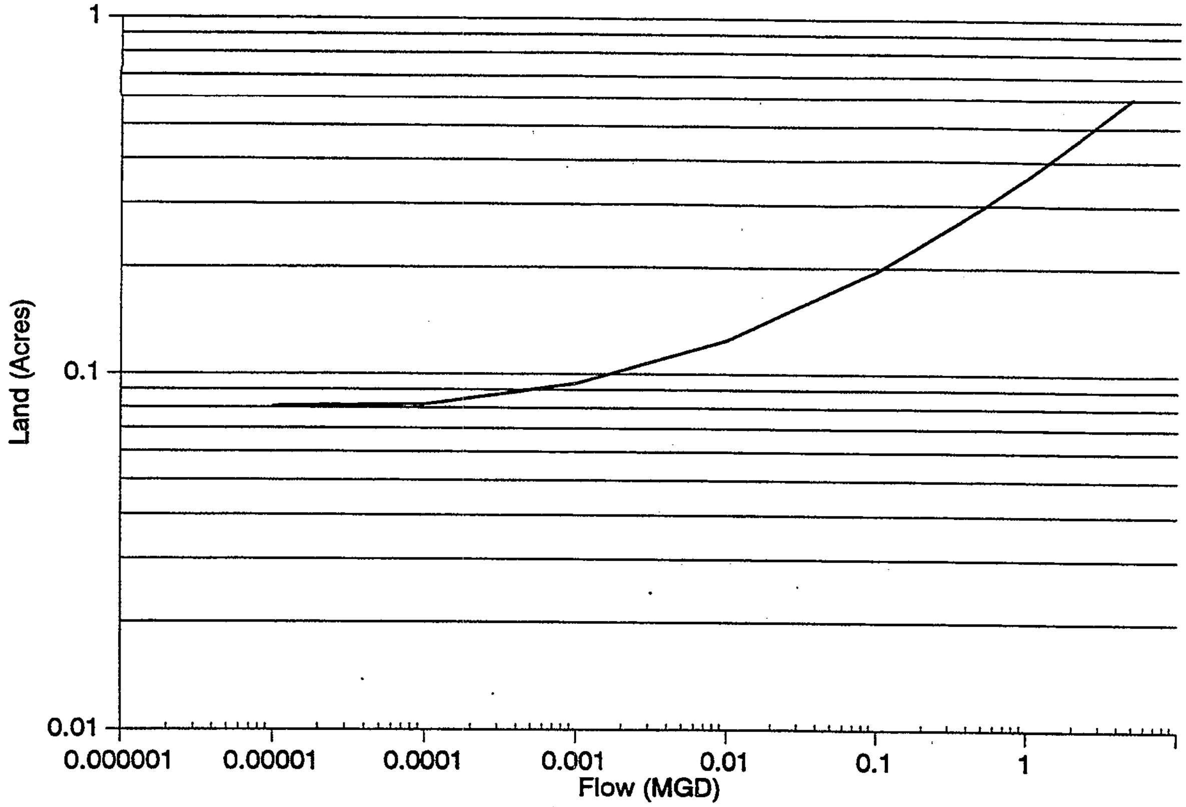

Figure 3-5 Land Requirement Curve for Chemical Precipitation - Metals Option 1

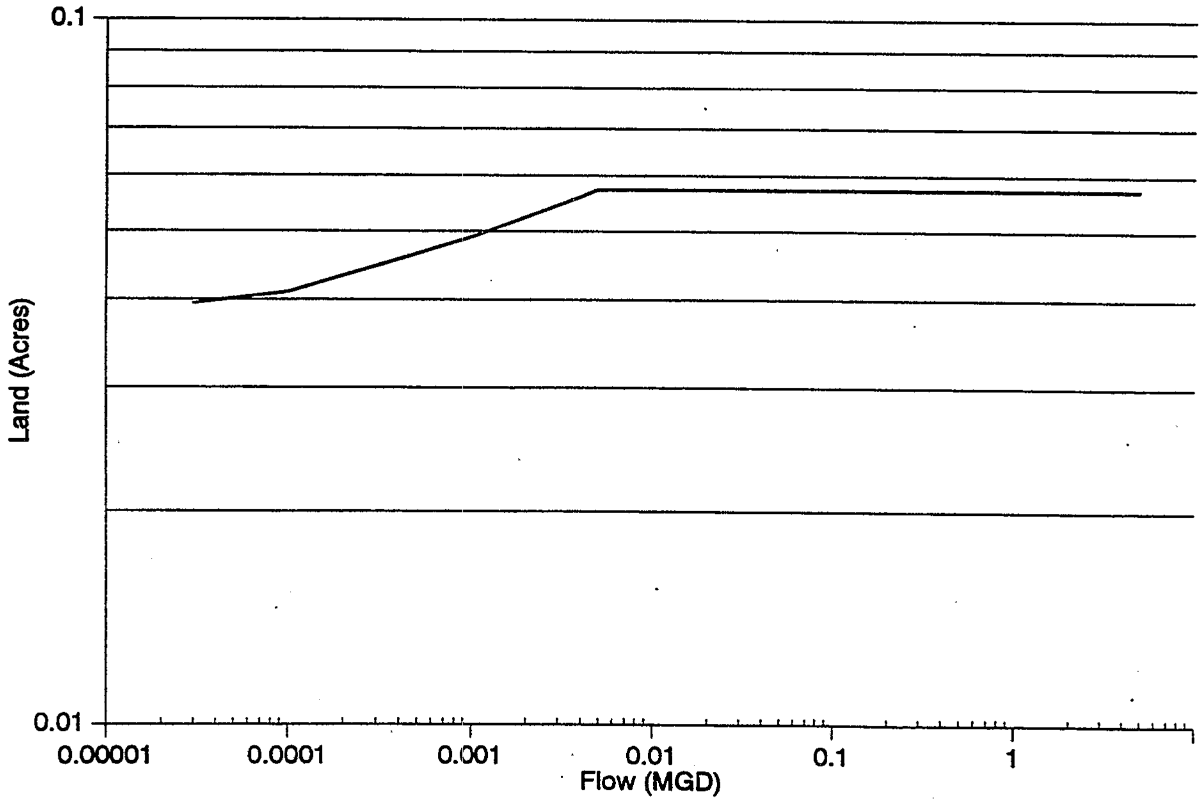

Figure 3-6 Land Requirement Upgrade Curve Chemical Precipitation - Metals Option 1

3.1.2 *Selective Metals Precipitation - Metals Option 2*

The CWT Metals Option 2 selective metals precipitation system equipment consists of four mixed reaction tanks, each sized for 25 percent of the total daily flow, with pumps and treatment chemical feed systems. Four tanks are included to allow the facility to segregate its wastes into smaller batches, thereby facilitating metals recovery and avoiding interference with other incoming waste receipts. A four batch per day treatment schedule was used, where the sum of four batch volumes equal the facility's daily incoming waste volume.

Capital cost estimates for the selective metals precipitation systems were estimated using the same methodology as outlined for the Metals Option 1 chemical precipitation systems. However, four precipitation tanks were costed, each tank sized to received 25 percent of the overall flow. The other components of the total capital cost (i.e. installation, piping, instrumentation, and engineering and contingency fee) were calculated as outlined for Metals Option 1.

Table 3-8 presents the itemized total capital cost estimates for the selective metals precipitation treatment systems while Figure 3-7 presents the resulting cost curve. The cost equation for the Metals Option 2 selective metals precipitation capital cost is:

$$\ln(Y1) = 14.461 + 0.544\ln(X) + 0.0000047(\ln(X))^2 \qquad (3\text{-}7)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

The O & M cost estimates for the selective metals precipitation system for facilities with no chemical precipitation treatment in-place were estimated using the same methodology as outlined for Metals Option 1. However, since the proposed design included four tanks instead of one, the labor cost was estimated at four times the labor cost of the single chemical precipitation unit. Maintenance and taxes and insurance were still estimated at four percent and two percent of the total capital cost, respectively.

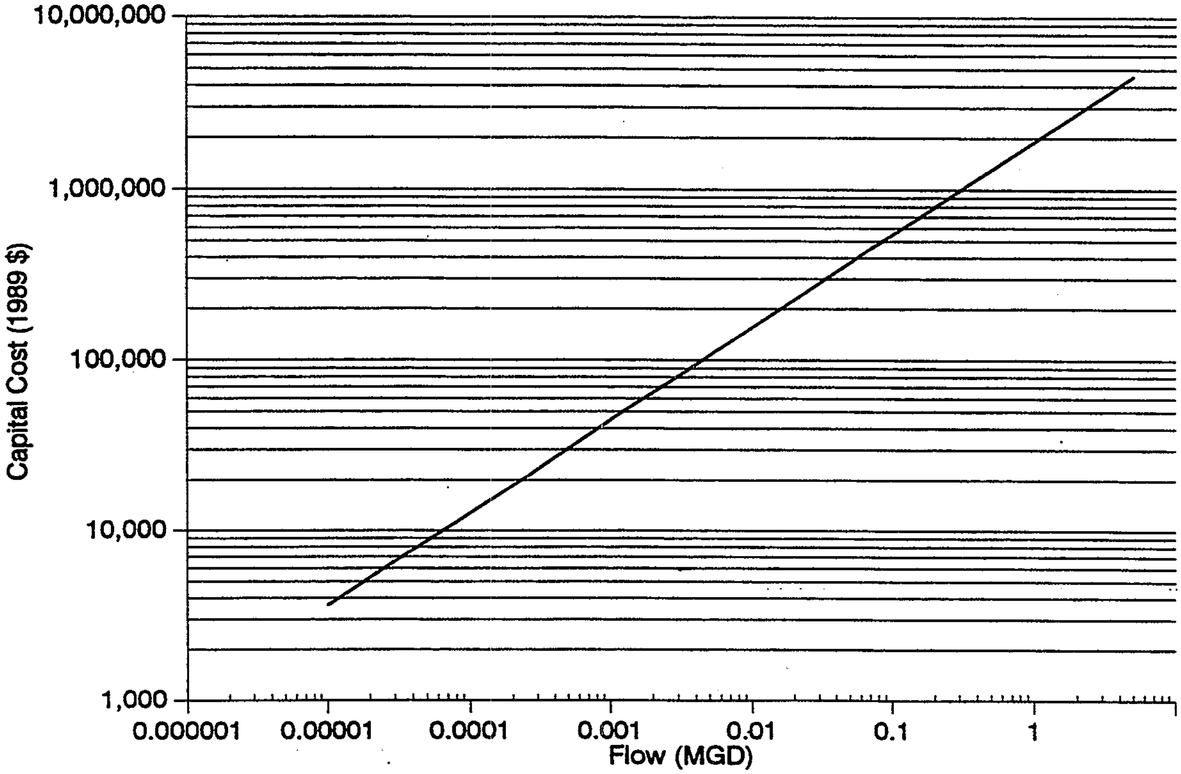

Figure 3-7 Capital Cost Curve for Selective Metals Precipitation - Metals Option 2

Table 3-8. Capital Costs for Selective Metals Precipitation - Metals Option 2

Flow (MGD)	Equip.	Installation	Piping	Instrument. & Controls	Engineer. & Conting.	Total Capital Costs (1989 $)
0.000001	410	143	123	123	240	1,038
0.00001	1433	502	430	430	839	3,634
0.001	17,554	6,144	5,266	5,266	10,269	44,499
0.01	61,428	21,500	18,429	18,429	35,936	155,721
0.1	214,966	75,238	64,490	64,490	125,755	544,938
0.5	515,951	180,583	154,785	154,785	301,831	1,307,936
1.0	752,262	263,292	225,679	225,679	440,073	1,906,983
5.0	1,805,546	631,941	541,664	541,664	1,056,245	4,577,060

Energy requirements were estimated the same as for the Metals Option 1 chemical precipitation systems since energy is related to the flow of the system.

Treatment chemical costs were estimated based on the same principles as for Metals Option 1 chemical precipitation. The stoichiometric requirements were calculated based on the Metals Subcategory average raw influent concentrations to Metals Option 1 removal levels. The chemicals used were caustic at 40 percent of the required removals and lime at 60 percent of the required removals. Table 3-9 presents the lime and caustic requirements for selective metals precipitation.

For facilities with chemical precipitation in-place, an O & M upgrade cost was estimated using the same methodology as for Metals Option 1 with the exception of the chemical costs. Chemical costs were estimated using a different methodology since these facilities already meet Metals Option 1 levels. The in-place treatment system is assumed to use a dosage ratio of 25 percent caustic and 75 percent lime to achieve the raw influent to current performance removals. The selective metals precipitation upgrade requires these facilities to change their existing dosage mix to 40 percent caustic and 60 percent lime to reach current performance levels, then apply the full 40 percent and 60 percent dosages to further achieve the current performance to Metals Option 1 removals. The increase in caustic cost (to increase from 25 percent to 40 percent) minus the lime

Table 3-9 LIME AND CAUSTIC REQUIREMENTS FOR SELECTIVE METALS PRECIPITATION – METALS OPTION 2

POLLUTANT	RAW LEVEL (MG/L)	OPTION 1 LEVEL (MG/L)	R-1 LEVEL (MG/L)	DOSAGE RATES		FLOW=0.00001 MGD		FLOW=0.001 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	308.483	5.858	302.625	4.11	4.45	24.3	17.5	2,430	1,751	242,978	175,120	2,429,784	1,751,196
ANTIMONY	93.934	0.337	93.597	1.52	1.64	2.8	2.0	278	200	27,764	20,010	277,645	200,104
ARSENIC	1.449	0.067	1.382	2.47	2.67	0.1	0.0	7	5	666	480	6,660	4,800
BARIUM	1.717	0.518	1.199	0.54	0.58	0.0	0.0	1	1	126	91	1,261	909
BORON	129.602	38.327	91.275	10.27	11.10	18.3	13.2	1,829	1,318	182,907	131,825	1,829,073	1,318,251
CADMIUM	35.955	0.021	35.934	0.66	0.71	0.5	0.3	46	33	4,617	3,328	46,169	33,275
CHROMIUM	955.361	0.367	954.994	2.13	2.31	39.8	28.7	3,978	2,867	397,834	286,727	3,978,343	2,867,274
COBALT	20.807	0.145	20.662	1.88	2.04	0.8	0.5	76	55	7,595	5,474	75,952	54,740
COPPER	1413.838	0.257	1413.581	1.16	1.26	32.1	23.2	3,213	2,315	321,252	231,533	3,212,522	2,315,331
IRIDIUM	29.687	5.538	24.149	0.77	0.83	0.4	0.3	36	26	3,629	2,615	36,286	26,152
IRON	480.047	14.285	465.762	1.99	2.15	18.1	13.0	1,807	1,302	180,653	130,201	1,806,532	1,302,005
LEAD	170.034	0.209	169.825	0.71	0.77	2.4	1.7	237	171	23,673	17,062	236,731	170,617
LITHIUM	74.544	1	73.544	5.33	5.76	7.7	5.5	765	551	76,519	55,149	765,194	551,491
LUTETIUM	0.803	0.567	0.236	0.63	0.69	0.0	0.0	0	0	29	21	292	211
MANGANESE	21.2	0.233	20.967	2.69	2.91	1.1	0.8	110	79	11,023	7,944	110,228	79,443
MERCURY	0.264	0.004	0.26	0.37	0.40	0.0	0.0	0	0	19	13	187	135
MOLYBDENUM	40.415	5.379	35.036	2.31	2.50	1.6	1.1	158	114	15,822	11,403	158,216	114,029
NICKEL	301.428	2.235	299.193	1.89	2.04	11.0	8.0	1,104	796	110,431	79,590	1,104,313	795,901
PHOSPHORUS	110.631	8.04	102.591	5.97	6.46	12.0	8.6	1,196	862	119,597	86,196	1,195,974	861,963
RHENIUM	6.08	5.397	0.683	0.79	0.86	0.0	0.0	1	1	106	76	1,059	764
SELENIUM	0.268	0.13	0.138	1.87	2.03	0.0	0.0	1	0	50	36	505	364
SILICON	195.377	2.59	192.787	5.27	5.70	19.8	14.3	1,982	1,429	198,230	142,869	1,982,301	1,428,686
SILVER	0.902	0.05	0.852	0.34	0.37	0.0	0.0	1	0	57	41	570	411
TANTALUM	5.072	3.168	1.904	1.02	1.11	0.0	0.0	4	3	380	274	3,799	2,738
TELLERIUM	7.803	5.468	2.335	1.16	1.25	0.1	0.0	5	4	529	381	5,285	3,809
THALLIUM	0.375	0.062	0.313	0.54	0.59	0.0	0.0	0	0	33	24	332	239
TIN	1077.825	0.284	1077.541	1.25	1.35	26.2	18.9	2,622	1,890	262,218	188,986	2,622,185	1,889,863
TITANIUM	640.944	0.043	640.901	3.09	3.34	38.6	27.9	3,865	2,785	386,455	278,526	3,864,551	2,785,262
URANIUM	10.259	8.041	2.218	0.62	0.67	0.0	0.0	3	2	268	193	2,682	1,933
VANADIUM	31.086	0.062	31.024	2.91	3.14	1.8	1.3	176	127	17,591	12,678	175,907	126,780
ZINC	796.813	1.276	795.537	1.13	1.22	17.6	12.7	1,757	1,266	175,723	126,647	1,757,232	1,266,473
TOTALS			6853.0			277	200	27,688	19,955	2,768,777	1,995,515	27,687,771	19,955,151

credit (to decrease from 75 percent to 60 percent) were accounted for in the in-place treatment removals from raw to current levels. Metals Option 2 uses a higher percentage of caustic than does Metals Option 1 because the sludge resulting from caustic precipitation facilitates metals recovery. Table 3-10 presents the dosage requirements for the raw to current removals using a 60 percent lime and 40 percent caustic dosage mix. Table 3-11 presents the dosage credit that in-place facilities receive for their existing 75 percent lime and 25 percent caustic dosage mix. The upgrade costs were calculated using the Table 3-10 requirements minus the Table 3-11 credits, plus the Table 3-12 60 percent and 40 percent dosage requirements for the current to Metals Option 1 removals.

Tables 3-13 and 3-14 present the itemized O & M cost estimates and O & M upgrade cost estimates for selective metals precipitation. Figures 3-8 and 3-9 present the resulting cost curves. The equations for the Metals Option 2 selective metals precipitation O & M cost and O & M upgrade cost estimates are presented as Equations 3-8 and 3-9, respectively.

$$\ln(Y2) = 15.566 + 0.999\ln(X) + 0.049(\ln(X))^2 \qquad (3\text{-}8)$$

$$\ln(Y2) = 14.276 + 0.789\ln(X) + 0.041(\ln(X))^2 \qquad (3\text{-}9)$$

where:

X = Flow Rate (MGD) and
Y2 = O & M Cost (1989 $).

The land requirements for selective metals precipitation were calculated based on the equipment dimensions provided by vendors. The system dimensions were scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.). The rule-of-thumb used to scale the dimensions adds a 20-foot perimeter around the unit. Table 3-15 presents the land requirements for the selective metal precipitation treatment systems and Figure 3-10 presents the resulting cost curve. The land requirement equation for Metals Option 2 selective metals precipitation is:

Table 3-10 60% LIME AND 40% CAUSTIC REQUIREMENTS FOR SELECTIVE METALS PRECIPITATION UPGRADES (RAW TO CURRENT REMOVALS) – METALS OPTION 2

POLLUTANT	RAW LEVEL (MG/L)	CURRENT LEVEL (MG/L)	R–C LEVEL (MG/L)	DOSAGE RATES		FLOW=0.00001 MGD		FLOW=0.001 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	308.483	1.395	307.088	4.11	4.45	18.1	13.0	1,808	1,303	180,812	130,315	1,808,120	1,303,149
ANTIMONY	93.934	2.373	91.561	1.52	1.64	2.0	1.4	199	144	19,918	14,355	199,177	143,551
ARSENIC	1.449	0.818	0.631	2.47	2.67	0.0	0.0	2	2	223	161	2,230	1,607
BARIUM	1.717	3.724	0	0.54	0.58	0.0	0.0	0	0	0	0	0	0
BORON	129.602	41.092	88.51	10.27	11.10	13.0	9.4	1,301	937	130,069	93,743	1,300,687	937,432
CADMIUM	35.955	0.323	35.632	0.66	0.71	0.3	0.2	34	24	3,357	2,420	33,573	24,197
CHROMIUM	955.361	2.328	953.033	2.13	2.31	29.1	21.0	2,911	2,098	291,146	209,835	2,911,461	2,098,350
COBALT	20.807	0.389	20.418	1.88	2.04	0.6	0.4	55	40	5,504	3,967	55,041	39,669
COPPER	1413.838	1.368	1412.47	1.16	1.26	23.5	17.0	2,354	1,697	235,400	169,658	2,353,998	1,696,575
IRIDIUM	29.687	9.413	20.274	0.77	0.83	0.2	0.2	22	16	2,234	1,610	22,340	16,101
IRON	480.047	12.715	467.332	1.99	2.15	13.3	9.6	1,329	958	132,926	95,802	1,329,256	958,022
LEAD	170.034	0.401	169.633	0.71	0.77	1.7	1.2	173	125	17,341	12,498	173,407	124,978
LITHIUM	74.544	23.635	50.909	5.33	5.76	3.9	2.8	388	280	38,844	27,995	388,437	279,954
LUTETIUM	0.803	0.254	0.549	0.63	0.69	0.0	0.0	0	0	50	36	498	359
MANGANESE	21.2	1.827	19.373	2.69	2.91	0.7	0.5	75	54	7,469	5,383	74,688	53,829
MERCURY	0.264	0.027	0.237	0.37	0.40	0.0	0.0	0	0	13	9	125	90
MOLYBDENUM	40.415	12.814	27.601	2.31	2.50	0.9	0.7	91	66	9,140	6,588	91,403	65,876
NICKEL	301.428	1.926	299.502	1.89	2.04	8.1	5.8	811	584	81,067	58,426	810,666	584,264
PHOSPHORUS	110.631	5.337	105.294	5.97	6.46	9.0	6.5	900	649	90,016	64,876	900,155	648,761
RHENIUM	6.08	1.928	4.152	0.79	0.86	0.0	0.0	5	3	472	340	4,723	3,404
SELENIUM	0.268	0.15	0.118	1.87	2.03	0.0	0.0	0	0	32	23	317	228
SILICON	195.377	61.947	133.43	5.27	5.70	10.1	7.3	1,006	725	100,611	72,513	1,006,113	725,127
SILVER	0.902	0.421	0.481	0.34	0.37	0.0	0.0	0	0	24	17	236	170
STRONTIUM	7.597	2.409	5.188	0.84	0.91	0.1	0.0	6	5	627	452	6,271	4,519
TANTALUM	5.072	1.608	3.464	1.02	1.11	0.1	0.0	5	4	507	365	5,068	3,653
TELLERIUM	7.803	2.474	5.329	1.16	1.25	0.1	0.1	9	6	885	638	8,846	6,375
THALLIUM	0.375	0.263	0.112	0.54	0.59	0.0	0.0	0	0	9	6	87	63
TIN	1077.825	25.11	1052.715	1.25	1.35	18.8	13.5	1,879	1,354	187,863	135,397	1,878,632	1,353,969
TITANIUM	640.944	1.094	639.85	3.09	3.34	28.3	20.4	2,829	2,039	282,936	203,918	2,829,357	2,039,176
TUNGSTEN	8.356	2.649	5.707	1.21	1.31	0.1	0.1	10	7	986	711	9,862	7,108
URANIUM	10.259	3.253	7.006	0.62	0.67	0.1	0.0	6	4	621	448	6,213	4,478
VANADIUM	31.086	9.856	21.23	2.91	3.14	0.9	0.6	88	64	8,827	6,362	88,275	63,621
ZINC	796.813	2.586	794.227	1.13	1.22	12.9	9.3	1,287	927	128,651	92,722	1,286,515	927,218
TOTALS			6743.06			196	141	19,586	14,116	1,958,578	1,411,588	19,585,777	14,115,875

Table 3-11 75% LIME AND 25% CAUSTIC CREDIT FOR SELECTIVE METALS PRECIPITATION UPGRADES (RAW TO CURRENT REMOVALS) – METALS OPTION 2

POLLUTANT	RAW LEVEL (MG/L)	CURRENT LEVEL (MG/L)	R–C LEVEL (MG/L)	DOSAGE RATES LIME (LBS/LB)	DOSAGE RATES CAUSTIC (LBS/LB)	FLOW=0.00001 MGD LIME (LBS/YR)	FLOW=0.00001 MGD CAUSTIC (LBS/YR)	FLOW=0.001 MGD LIME (LBS/YR)	FLOW=0.001 MGD CAUSTIC (LBS/YR)	FLOW=0.1 MGD LIME (LBS/YR)	FLOW=0.1 MGD CAUSTIC (LBS/YR)	FLOW=1.0 MGD LIME (LBS/YR)	FLOW=1.0 MGD CAUSTIC (LBS/YR)
ALUMINUM	308.483	1.395	307.088	4.11	4.45	22.6	8.1	2,260	814	226,015	81,447	2,260,150	814,468
ANTIMONY	93.934	2.373	91.561	1.52	1.64	2.5	0.9	249	90	24,897	8,972	248,971	89,719
ARSENIC	1.449	0.818	0.631	2.47	2.67	0.0	0.0	3	1	279	100	2,787	1,004
BARIUM	1.717	3.724	0	0.54	0.58	0.0	0.0	0	0	0	0	0	0
BORON	129.602	41.092	88.51	10.27	11.10	16.3	5.9	1,626	586	162,586	58,590	1,625,859	585,895
CADMIUM	35.955	0.323	35.632	0.66	0.71	0.4	0.2	42	15	4,197	1,512	41,966	15,123
CHROMIUM	955.361	2.328	953.033	2.13	2.31	36.4	13.1	3,639	1,311	363,933	131,147	3,639,326	1,311,469
COBALT	20.807	0.389	20.418	1.88	2.04	0.7	0.2	69	25	6,880	2,479	68,801	24,793
COPPER	1413.838	1.368	1412.47	1.16	1.26	29.4	10.6	2,942	1,060	294,250	106,036	2,942,497	1,060,359
IRIDIUM	29.687	9.413	20.274	0.77	0.83	0.3	0.1	28	10	2,793	1,006	27,925	10,063
IRON	480.047	12.715	467.332	1.99	2.15	16.6	6.0	1,662	599	166,157	59,876	1,661,570	598,764
LEAD	170.034	0.401	169.633	0.71	0.77	2.2	0.8	217	78	21,676	7,811	216,758	78,111
LITHIUM	74.544	23.635	50.909	5.33	5.76	4.9	1.7	486	175	48,555	17,497	485,546	174,971
LUTETIUM	0.803	0.254	0.549	0.63	0.69	0.0	0.0	1	0	62	22	623	225
MANGANESE	21.2	1.827	19.373	2.69	2.91	0.9	0.3	93	34	9,336	3,364	93,361	33,643
MERCURY	0.264	0.027	0.237	0.37	0.40	0.0	0.0	0	0	16	6	156	56
MOLYBDENUM	40.415	12.814	27.601	2.31	2.50	1.1	0.4	114	41	11,425	4,117	114,254	41,173
NICKEL	301.428	1.926	299.502	1.89	2.04	10.1	3.7	1,013	365	101,333	36,516	1,013,332	365,165
PHOSPHORUS	110.631	5.337	105.294	5.97	6.46	11.3	4.1	1,125	405	112,519	40,548	1,125,194	405,475
RHENIUM	6.08	1.928	4.152	0.79	0.86	0.1	0.0	6	2	590	213	5,904	2,128
SELENIUM	0.268	0.15	0.118	1.87	2.03	0.0	0.0	0	0	40	14	396	143
SILICON	195.377	61.947	133.43	5.27	5.70	12.6	4.5	1,258	453	125,764	45,320	1,257,641	453,204
SILVER	0.902	0.421	0.481	0.34	0.37	0.0	0.0	0	0	30	11	295	106
STRONTIUM	7.597	2.409	5.188	0.84	0.91	0.1	0.0	8	3	784	282	7,838	2,825
TANTALUM	5.072	1.608	3.464	1.02	1.11	0.1	0.0	6	2	634	228	6,336	2,283
TELLERIUM	7.803	2.474	5.329	1.16	1.25	0.1	0.0	11	4	1,106	398	11,057	3,985
THALLIUM	0.375	0.263	0.112	0.54	0.59	0.0	0.0	0	0	11	4	109	39
TIN	1077.825	25.11	1052.715	1.25	1.35	23.5	8.5	2,348	846	234,829	84,623	2,348,290	846,231
TITANIUM	640.944	1.094	639.85	3.09	3.34	35.4	12.7	3,537	1,274	353,670	127,449	3,536,696	1,274,485
TUNGSTEN	8.356	2.649	5.707	1.21	1.31	0.1	0.0	12	4	1,233	444	12,328	4,443
URANIUM	10.259	3.253	7.006	0.62	0.67	0.1	0.0	8	3	777	280	7,767	2,799
VANADIUM	31.086	9.856	21.23	2.91	3.14	1.1	0.4	110	40	11,034	3,976	110,343	39,763
ZINC	796.813	2.586	794.227	1.13	1.22	16.1	5.8	1,608	580	160,814	57,951	1,608,143	579,511
TOTALS			6743.056			245	88	24,482	8,822	2,448,222	882,242	24,482,221	8,822,422

Table 3-12 LIME AND CAUSTIC REQUIREMENTS FOR SELECTIVE METALS PRECIPITATION UPGRADES (CURRENT TO OPTION 1 REMOVALS) – METALS OPTION 2

POLLUTANT	CURRENT LEVEL (MG/L)	OPTION 1 LEVEL (MG/L)	C-1 LEVEL (MG/L)	DOSAGE RATES		FLOW=0.00001 MGD		FLOW=0.001 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	1.385	5.858	0	4.11	4.45	0	0	0	0	0	0	0	0
ANTIMONY	2.373	0.337	2.036	1.52	1.64	0.044	0.032	4.4	3.2	443	319	4,429	3,192
ARSENIC	0.818	0.067	0.751	2.47	2.67	0.027	0.019	2.7	1.9	265	191	2,654	1,913
BARIUM	3.724	0.518	3.206	0.54	0.58	0.025	0.018	2.5	1.8	247	178	2,472	1,782
BORON	41.092	38.327	2.765	10.27	11.10	0.406	0.293	40.6	29.3	4,063	2,928	40,633	29,285
CADMIUM	0.323	0.021	0.302	0.66	0.71	0.003	0.002	0.3	0.2	28	21	285	205
CHROMIUM	2.328	0.367	1.961	2.13	2.31	0.060	0.043	6.0	4.3	599	432	5,991	4,318
COBALT	0.389	0.145	0.244	1.88	2.04	0.007	0.005	0.7	0.5	66	47	658	474
COPPER	1.368	0.257	1.111	1.16	1.26	0.019	0.013	1.9	1.3	185	133	1,852	1,334
IRIDIUM	9.413	5.538	3.875	0.77	0.83	0.043	0.031	4.3	3.1	427	308	4,270	3,077
IRON	12.715	14.285	0	1.99	2.15	0	0	0	0	0	0	0	0
LEAD	0.401	0.209	0.192	0.71	0.77	0.002	0.001	0.2	0.1	20	14	196	141
LITHIUM	23.635	1	22.635	5.33	5.76	1.727	1.245	172.7	124.5	17,271	12,447	172,705	124,472
LUTETIUM	0.254	0.567	0	0.63	0.69	0	0	0	0	0	0	0	0
MANGANESE	1.827	0.233	1.594	2.69	2.91	0.061	0.044	6.1	4.4	615	443	6,145	4,429
MERCURY	0.027	0.004	0.023	0.37	0.40	0.0001	0.0001	0.01	0.01	1	1	12	9
MOLYBDENUM	12.814	5.379	7.435	2.31	2.50	0.246	0.177	24.6	17.7	2,462	1,775	24,622	17,745
NICKEL	1.926	2.235	0	1.89	2.04	0	0	0	0	0	0	0	0
PHOSPHORUS	5.337	8.04	0	5.97	6.46	0	0	0	0	0	0	0	0
RHENIUM	1.928	5.397	0	0.79	0.86	0	0	0	0	0	0	0	0
SELENIUM	0.15	0.13	0.02	1.87	2.03	0.001	0.0004	0.1	0.04	5	4	54	39
SILICON	61.947	2.59	59.357	5.27	5.70	4.476	3.226	447.6	322.6	44,757	32,258	447,574	322,576
SILVER	0.421	0.05	0.371	0.34	0.37	0.002	0.001	0.2	0.1	18	13	182	131
STRONTIUM	2.409	9.366	0	0.84	0.91	0	0	0	0	0	0	0	0
TANTALUM	1.608	3.168	0	1.02	1.11	0	0	0	0	0	0	0	0
TELLERIUM	2.474	5.468	0	1.16	1.25	0	0	0	0	0	0	0	0
THALLIUM	0.263	0.062	0.201	0.54	0.59	0.002	0.001	0.2	0.1	16	11	156	113
TIN	25.11	0.284	24.826	1.25	1.35	0.443	0.319	44.3	31.9	4,430	3,193	44,303	31,930
TITANIUM	1.094	0.043	1.051	3.09	3.34	0.046	0.033	4.6	3.3	465	335	4,647	3,349
TUNGSTEN	2.649	10.743	0	1.21	1.31	0	0	0	0	0	0	0	0
URANIUM	3.253	8.041	0	0.62	0.67	0	0	0	0	0	0	0	0
VANADIUM	9.856	0.062	9.794	2.91	3.14	0.407	0.294	40.7	29.4	4,072	2,935	40,724	29,350
ZINC	2.586	1.276	1.31	1.13	1.22	0.021	0.015	2.1	1.5	212	153	2,122	1,529
TOTALS			145.06			8	6	807	581	80,669	58,140	806,686	581,395

Table 3-13. O & M Costs for Selective Metals Precipitation - Metals Option 2

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Chemical Costs	Total O & M Cost (1989 $)
0.000001	1,000	42	21	52,464	6	53,533
0.00001	1,000	145	73	52,464	63	53,745
0.001	1,010	1,780	890	53,900	6,277	63,857
0.01	1,104	6,229	3,114	58,964	62,768	132,179
0.1	2,040	21,798	10,899	64,504	627,677	726,918
0.5	6,200	52,317	26,159	68,684	3,138,386	3,291,746
1.0	11,400	76,279	38,140	70,564	6,276,772	6,473,155
5.0	53,000	183,082	91,541	75,136	31,383,862	31,786,621

Table 3-14. O & M Upgrade Costs - Selective Metals Precipitation - Metals Option 2

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Chemical Cost	Total O & M Cost (1989 $)
0.000001	1,000	42	21	52,464	3	53,530
0.00001	1,000	145	73	52,464	15	53,697
0.001	1,010	1,780	890	53,900	1,499	59,079
0.01	1,104	6,229	3,114	58,964	14,991	84,402
0.05	1,520	14,950	7,475	62,784	74,952	161,681
0.1	2,040	21,798	10,899	64,504	149,902	249,143
0.5	6,200	52,317	26,159	68,684	749,512	902,892
1.0	11,400	76,279	38,140	70,564	1,499,025	1,695,408
5.0	53,000	183,082	91,541	75,136	7,495,126	7,897,885

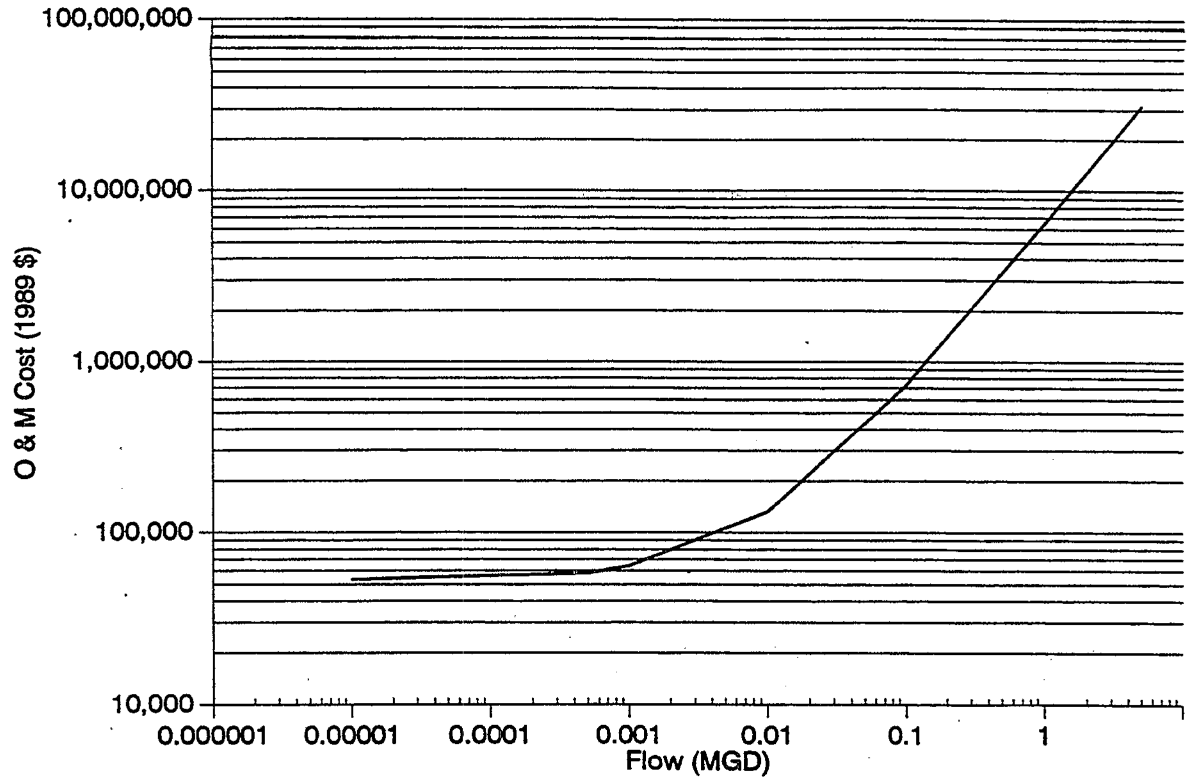

Figure 3-8 O & M Cost Curve for Selective Metals Precipitation - Metals Option 2

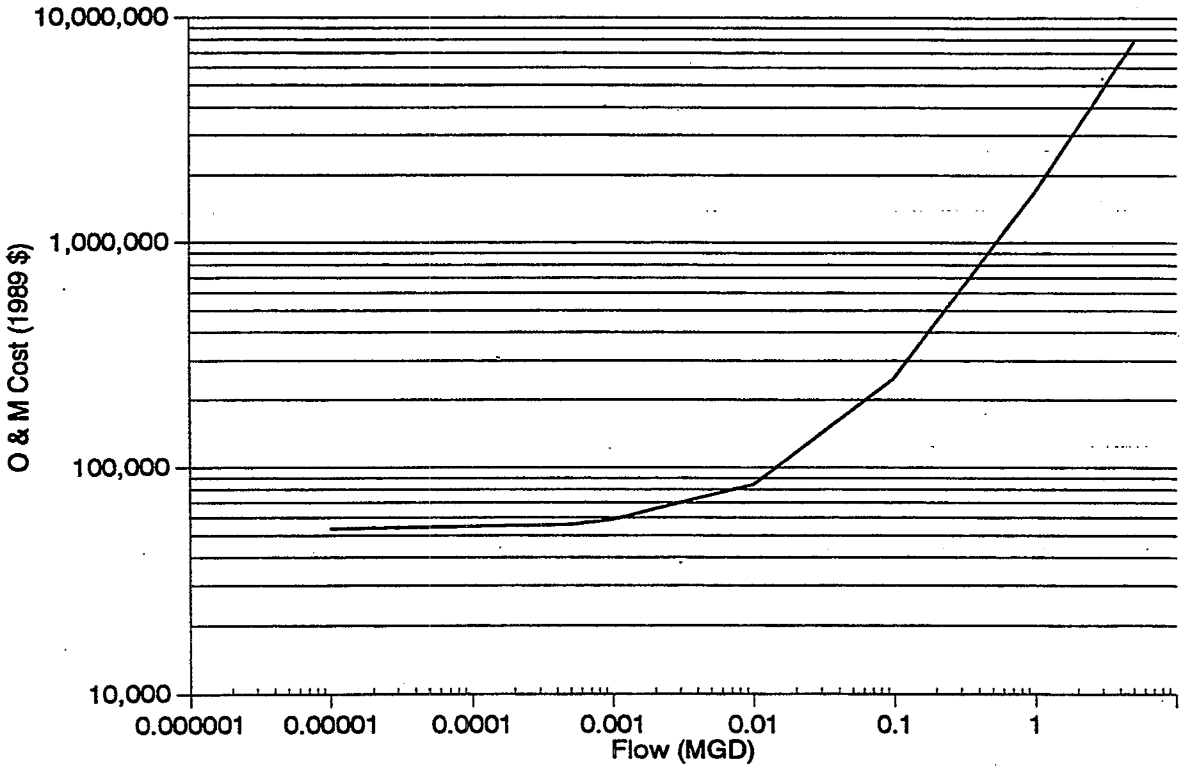

Figure 3-9 O & M Upgrade Cost Curve for Selective Metals Preciptation - Metals Option 2

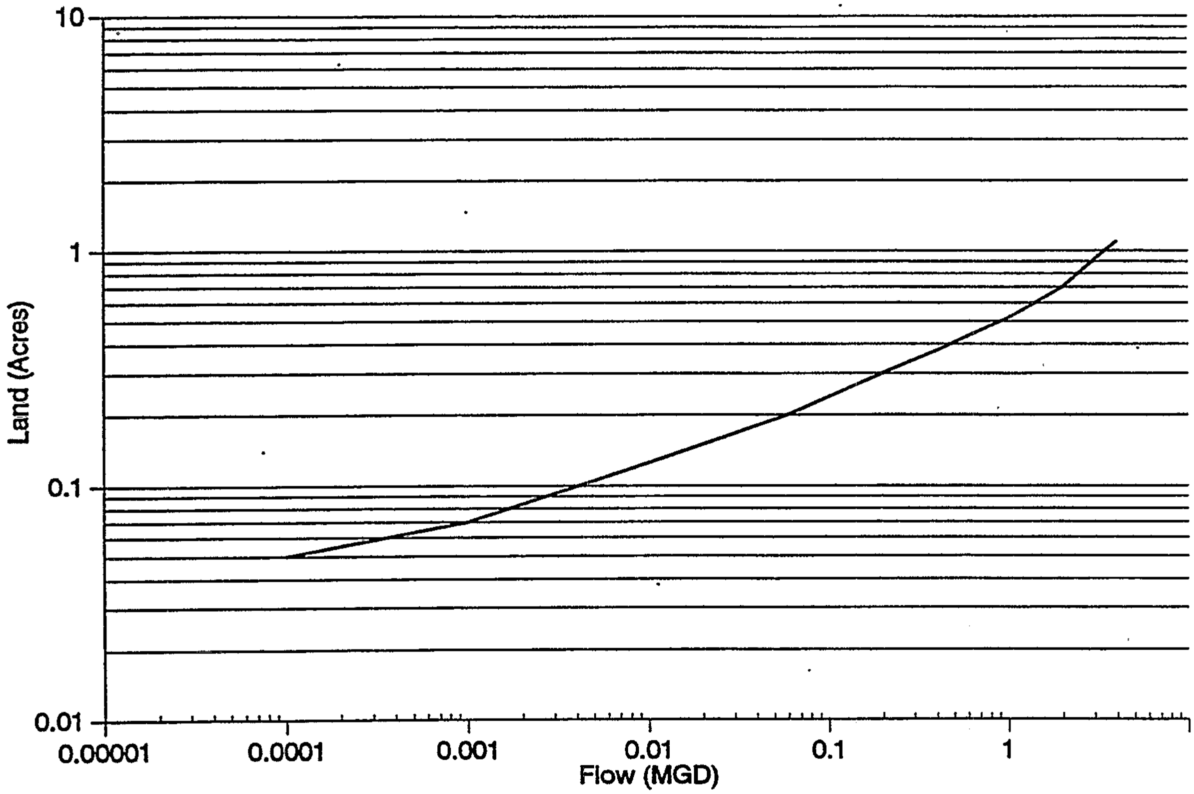

Figure 3-10 Land Requirement Curve Selective Metals Precipitation - Metals Option 2

$$\ln(Y3) = -0.575 + 0.420\ln(X) + 0.025(\ln(X))^2 \qquad (3\text{-}10)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres)

Table 3-15. Land Requirements for Selective Metals Precipitation Metals - Option 2

Flow (MGD)	Area Required (Acres)
0.016	0.1413
0.0284	0.164
0.06	0.25
0.2	0.342
0.4	0.376
1.0	0.517
2.0	0.59
3.0	0.92
4.0	1.322

3.1.3 *Secondary Precipitation - Metals Option 2*

The CWT Metals Option 2 secondary precipitation system follows the selective metals precipitation/filtration step. This equipment consists of a mixed reaction tank with pumps and a treatment chemical feed system, sized for the full daily batch volume.

The capital cost estimates for the secondary precipitation treatment systems were estimated using the same methodology as outlined for Metals Option 1. However, in this case, no costs were included for a holding tank. These cost estimates are for those facilities that have no chemical precipitation in-place. For the facilities that already have chemical precipitation in-place, the capital cost for the secondary precipitation treatment systems were assumed to be zero. These in-place chemical precipitation systems would serve as secondary precipitation systems after the installation of upstream selective metals precipitation units.

Table 3-16 presents the itemized capital cost estimates for the secondary precipitation treatment systems while Figure 3-11 presents the resulting cost curve. The cost equation for the total capital cost for Metals Option 2 secondary precipitation is:

$$\ln(Y1) = 13.829 + 0.544\ln(X) + 0.00000496(\ln(X))^2 \qquad (3\text{-}11)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

Table 3-16. Capital Costs for Secondary Precipitation - Metals Option 2

Flow (MGD)	Equipment Cost	Piping	Instrumentation & Controls	Installation	Engineering & Contingency	Total Capital Cost (1989 $)
0.000001	218	65	65	76	127	552
0.00001	762	229	229	267	446	1,931
0.001	9,329	2,799	2,799	3,265	5,457	23,649
0.01	32,646	9,794	9,794	11,426	19,098	82,758
0.05	78,355	23,507	23,507	27,424	45,838	198,631
0.1	114,243	34,273	34,273	39,985	66,832	289,606
0.5	274,201	82,260	82,260	95,970	160,408	695,100
1.0	399,788	119,936	119,936	139,926	233,876	1,013,462
5.0	959,554	287,866	287,866	335,844	561,339	2,432,469

O & M cost estimates were developed for the secondary precipitation treatment systems for facilities with and without chemical precipitation in-place. For facilities with no treatment in-place, the annual O & M costs were developed using the same methodology used for Metals Option 1. However, the chemical cost estimates were based on stoichiometric requirements only. Lime was used to precipitate the metals from

Metals Option 1 to Metals Option 2 levels with a 10 percent excess dosage factor. Table 3-17 presents the lime and caustic requirements for secondary precipitation.

For facilities with chemical precipitation in-place, an O & M upgrade cost was calculated. The O & M upgrade cost assumed that all of the components of the annual O & M cost except chemical costs were zero. The chemical costs are the same as calculated for the full O & M costs.

Tables 3-18 and 3-19 present the itemized annual O & M and O & M upgrade cost estimates for the secondary precipitation treatment units with the corresponding cost curves in Figures 3-12 and 3-13. The O & M cost and O & M upgrade cost equations for Metals Option 2 secondary precipitation are presented as Equations 3-12 and 3-13, respectively.

$$\ln(Y2) = 11.684 + 0.477\ln(X) + 0.024(\ln(X))^2 \qquad (3\text{-}12)$$

$$\ln(Y2) = 10.122 + 1.015\ln(X) + 0.00151(\ln(X))^2 \qquad (3\text{-}13)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

Land requirements for the secondary precipitation treatment systems were estimated by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. Table 3-20 presents the land requirements for the secondary precipitation treatment systems. The land area curve is presented in Figure 3-14. The land requirement equation for Metals Option 2 secondary precipitation is:

$$\ln(Y3) = -1.15 + 0.449\ln(X) + 0.027(\ln(X))^2 \qquad (3\text{-}14)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

Table 3-17 LIME & CAUSTIC REQUIREMENTS FOR SECONDARY PRECIPITATION AND SECONDARY PRECIPITATION UPGRADES – METALS OPTION 2

POLLUTANT	OPTION 1 LEVEL (MG/L)	OPTION 2 LEVEL (MG/L)	1-2 LEVEL (MG/L)	DOSAGE RATES		FLOW=0.001 MGD		FLOW=0.01 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	5.858	0.337	5.521	4.11	0.00	54.2	0	541.8	0	5,418	0	54,179	0
ANTIMONY	0.337	0.021	0.316	1.52	0.00	1.1	0	11.5	0	115	0	1,146	0
ARSENIC	0.067	0.018	0.049	2.47	0.00	0.29	0	2.9	0	29	0	289	0
BARIUM	0.518	0.011	0.507	0.54	0.00	0.7	0	6.5	0	65	0	652	0
BORON	38.327	8.182	30.145	10.27	0.00	738.3	0	7383.2	0	73,832	0	738,320	0
CADMIUM	0.021	0.101	0	0.66	0.00	0	0	0	0	0	0	0	0
CHROMIUM	0.367	0.69	0	2.13	0.00	0	0	0	0	0	0	0	0
COBALT	0.145	0.124	0.021	1.88	0.00	0.094	0	0.9	0	9	0	94	0
COPPER	0.257	0.97	0	1.16	0.00	0	0	0	0	0	0	0	0
IRON	14.285	4.134	10.151	1.99	0.00	48.1	0	481.2	0	4,812	0	48,122	0
LEAD	0.209	0.308	0	0.71	0.00	0	0	0	0	0	0	0	0
MANGANESE	0.233	0.061	0.172	2.69	0.00	1.1	0	11.1	0	111	0	1,105	0
MERCURY	0.004	0.001	0.003	0.37	0.00	0.003	0	0.03	0	0.3	0	3	0
MOLYBDENUM	5.379	0.652	4.727	2.31	0.00	26.1	0	260.9	0	2,609	0	26,090	0
NICKEL	2.235	1.06	1.175	1.89	0.00	5.3	0	53.0	0	530	0	5,301	0
SELENIUM	0.13	0.235	0	1.87	0.00	0	0	0	0	0	0	0	0
SILVER	0.05	0.004	0.046	0.34	0.00	0.04	0	0.4	0	4	0	38	0
THALLIUM	0.062	0.025	0.037	0.54	0.00	0.048	0	0.5	0	5	0	48	0
TIN	0.284	0.029	0.255	1.25	0.00	0.8	0	7.6	0	76	0	758	0
TITANIUM	0.043	0.004	0.039	3.09	0.00	0.29	0	2.9	0	29	0	287	0
VANADIUM	0.062	0.01	0.052	2.91	0.00	0.36	0	3.6	0	36	0	360	0
ZINC	1.276	0.845	0.431	1.13	0.00	1.2	0	11.6	0	116	0	1,164	0
TOTALS			53.6			878	0	8,780	0	87,795	0	877,955	0

Table 3-18. O & M Costs for Secondary Precipitation - Metals Option 2

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Chemical Cost	Total O & M Cost (1989 $)
0.000001	1,000	22	11	13,116	1	14,150
0.00001	1,000	77	39	13,116	1	14,233
0.001	1,010	946	473	13,475	25	15,929
0.01	1,104	3,310	1,655	14,741	250	21,060
0.05	1,520	7,945	3,973	15,696	1,276	30,410
0.1	2,040	11,584	5,792	16,126	2,502	38,044
0.5	6,200	27,804	13,902	17,171	12,511	77,588
1.0	11,400	40,538	20,269	17,641	25,022	114,870
5.0	53,000	97,299	48,649	18,784	125,109	342,841

Table 3-19. O & M Upgrade Costs for Secondary Precipitation - Metals Option 2

Flow (MGD)	Chemical Cost	Total O & M Cost (1989 $)
0.0005	13	13
0.001	25	25
0.005	125	125
0.01	250	250
0.05	1,276	1,276
0.1	2,502	2,502
0.5	12,511	12,511
1.0	25,022	25,022
5.0	125,109	125,109

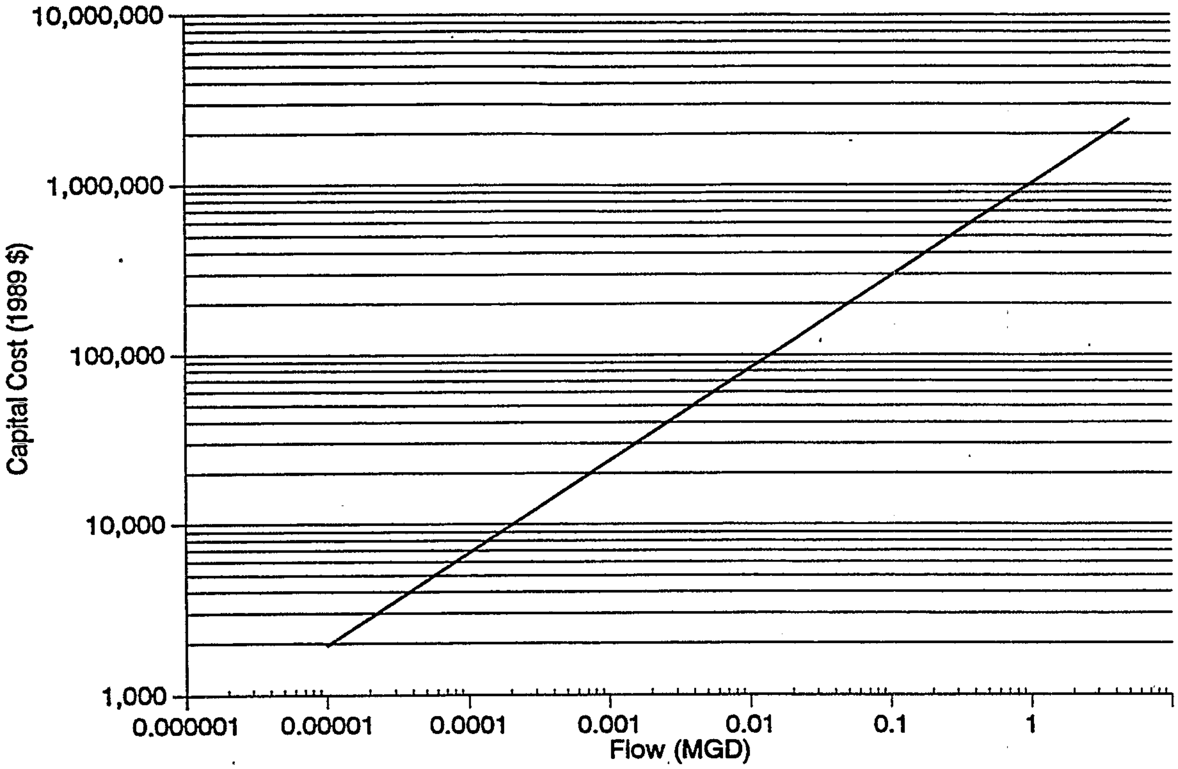

Figure 3-11 Capital Cost Curve for Secondary Precipitation - Metals Option 2

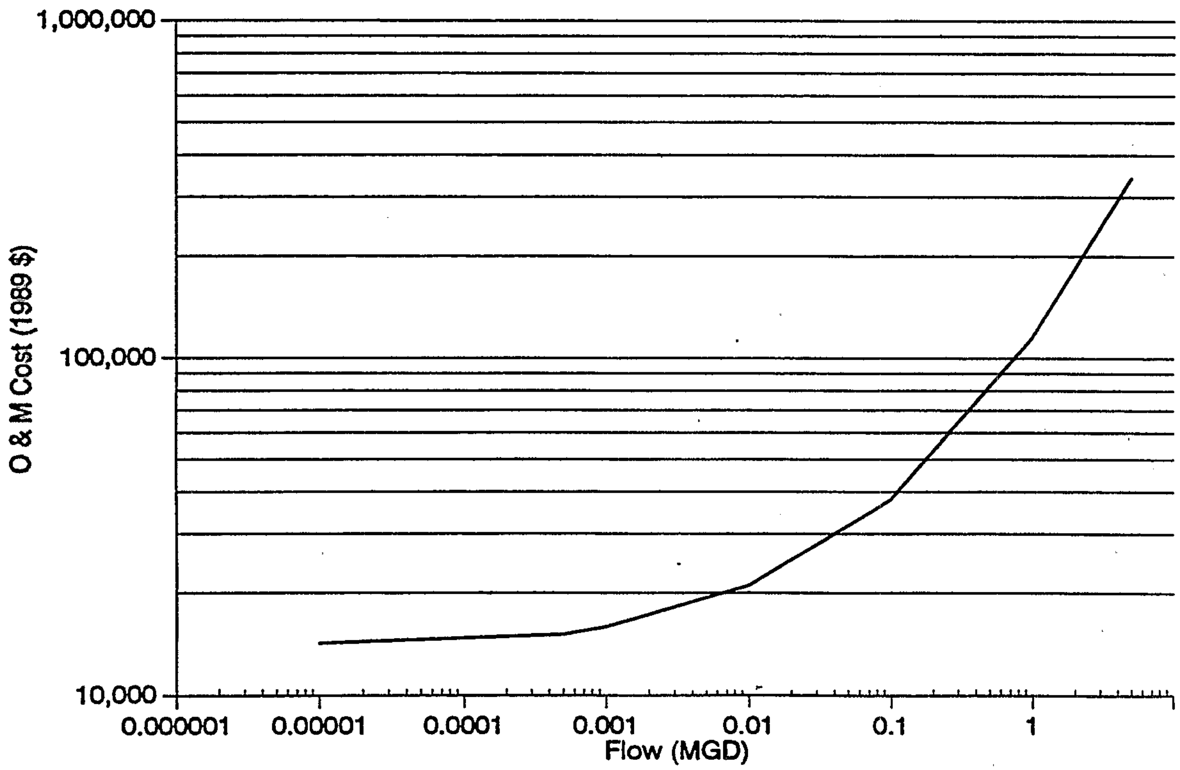

Figure 3-12 O & M Cost Curve for Secondary Precipitation - Metals Option 2

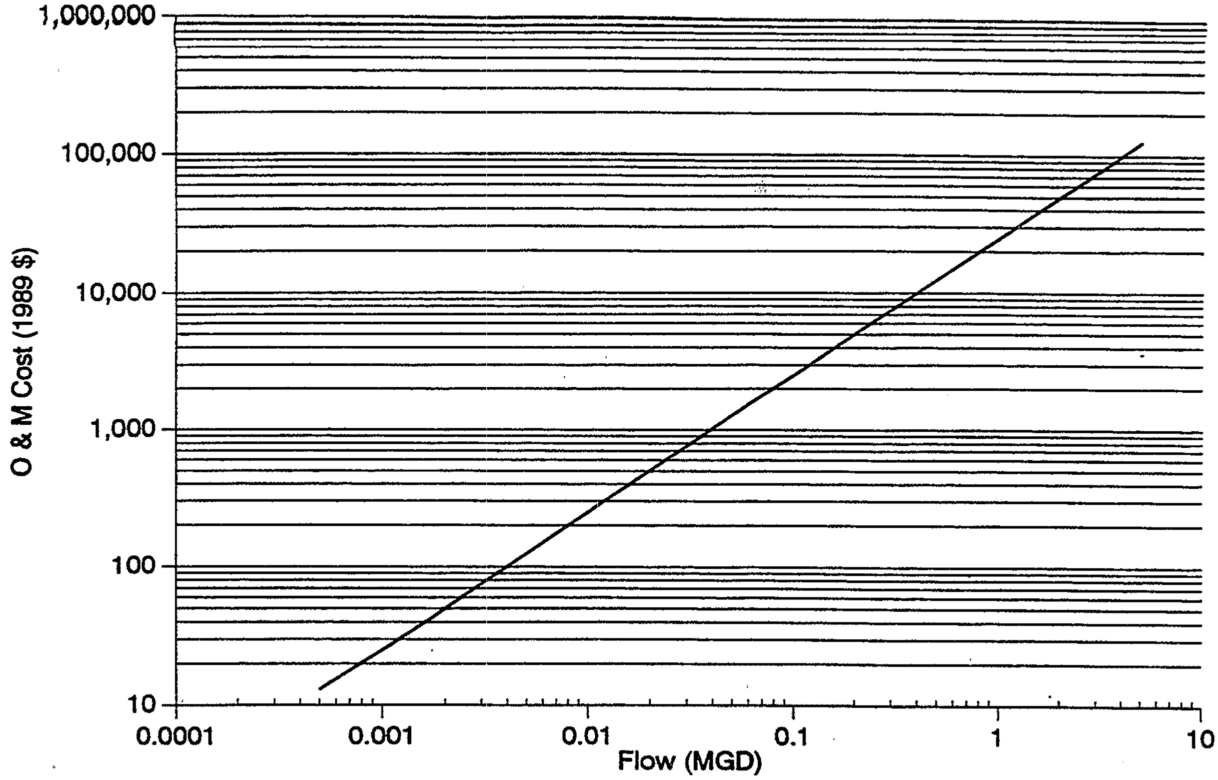

Figure 3-13 O & M Upgrade Cost Curve for Secondary Precipitation - Metals Option 2

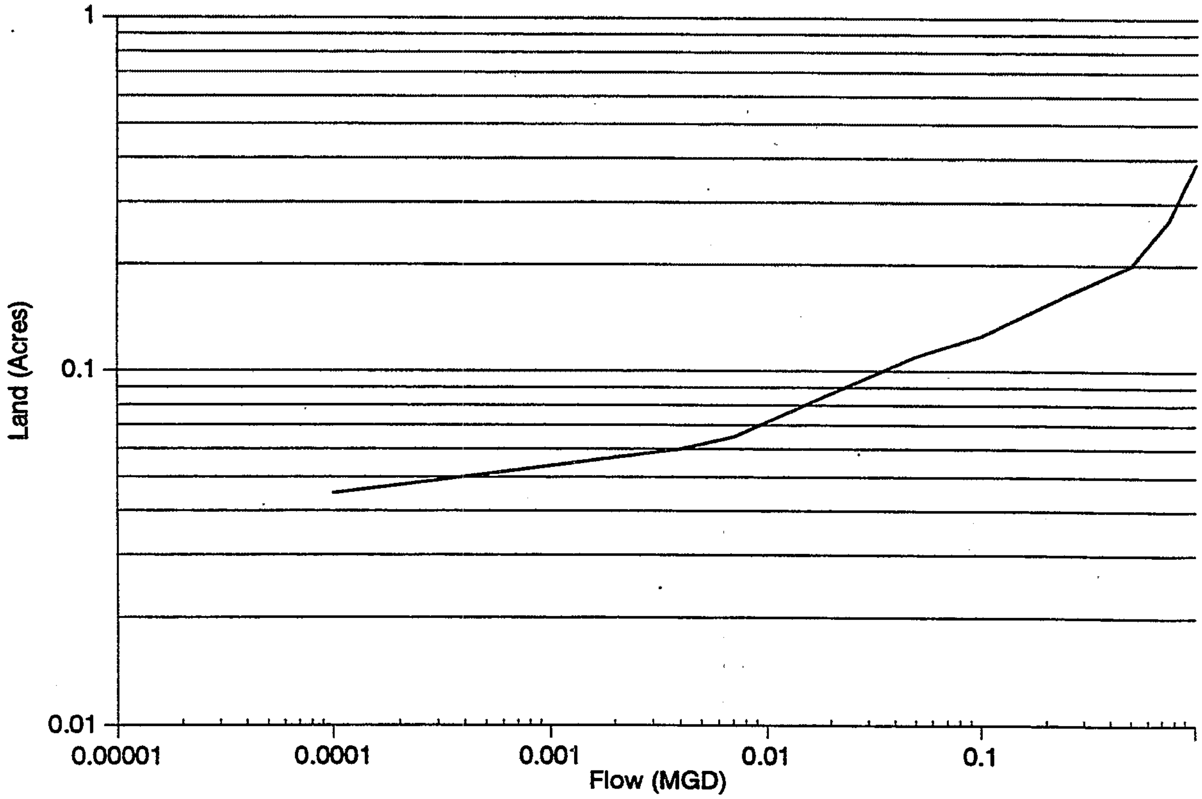

Figure 3-14 Land Requirement Curve for Secondary Precipitation - Metals Option 2

Table 3-20. Land Requirements for Secondary Precipitation - Metals Option 2

Flow (MGD)	Area Required (Acres)
0.004	0.056
0.0071	0.063
0.015	0.088
0.1	0.126
0.25	0.166
0.5	0.186
1.0	0.388

3.1.4 *Tertiary Precipitation - Metals Option 3*

The CWT Metals Option 3 tertiary precipitation system equipment consists of a rapid mix tank and a pH adjustment tank (following Metals Option 3 clarification). The wastewater is fed to the rapid mix neutralization tank where lime slurry is added to raise the pH. Effluent from the neutralization tank then flows to the clarifier for solids removal. The clarifier overflow goes to a pH adjustment tank where sulfuric acid is added to achieve the desired final pH. The following discussion explains the development of the cost estimates (i.e. capital, O & M, and land) for the rapid mix tank and the pH adjustment tank. Cost estimates for the clarifier are discussed in another section of this document.

The capital cost estimates for the rapid mix tank were developed assuming one tank with a continuous flow and a fifteen-minute detention time. The equipment cost included one tank, one agitator, and one lime feed system.

The capital cost estimates for the pH adjustment tank were developed assuming continuous flow and a five-minute detention time. The equipment cost included one tank, one agitator, and one sulfuric acid feed system.

The other components (i.e. piping, instrumentation and controls, etc.) of the total capital cost for both the rapid mix and pH adjustment tank were estimated using the same methodology as outlined for Metals Option 1. The itemized capital cost estimates for the rapid mix and pH adjustment tank are presented in Tables 3-21 and 3-22, respectively. The resulting cost curves are presented in Figures 3-15 and 3-16, respectively. The capital cost equations calculated for the rapid mix and pH adjustment tank are presented as Equations 3-15 and 3-16, respectively.

$$\ln(Y1) = 12.318 + 0.543\ln(X) - 0.000179(\ln(X))^2 \qquad (3\text{-}15)$$

$$\ln(Y1) = 11.721 + 0.543\ln(X) + 0.000139(\ln(X))^2 \qquad (3\text{-}16)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

The O & M cost estimates for the rapid mix and pH adjustment tank were estimated using the same methodology as outlined for Metals Option 1. Maintenance was estimated at four percent of the total capital cost while taxes and insurance were estimated at two percent of the total capital cost. The labor requirements were estimated at one man-hour per day at 260 days per year.

Chemical costs for the rapid mix tank were estimated based on lime addition to achieve the stoichiometric requirements for Metals Option 2 to Metals Option 3 removals with a 10 percent excess. Table 3-23 presents the lime requirements for tertiary precipitation. The chemical requirements for the pH adjustment tank were estimated based on the addition of sulfuric acid to lower the pH from 11.0 to 9.0. The price of sulfuric acid was $80.00 per ton, taken from the Chemical Marketing Reporter.

The itemized O & M cost estimates for the rapid mix and pH adjustment tanks are presented in Tables 3-24 and 3-25, respectively, while the resulting cost curves are presented in Figures 3-17 and 3-18. The O & M cost equations for the rapid mix tank and pH adjustment tank are presented as Equations 3-17 and 3-18, respectively.

Table 3-21. Capital Costs for Rapid Mix Tanks - Metals Option 3

Flow (MGD)	Equipment Cost	Piping	Instrument. & Controls	Installation	Engineering & Contingency	Total Capital Cost (1989 $)
0.00001	165	49	49	58	96	417
0.0001	592	178	178	207	347	1,502
0.001	2,073	622	622	726	1,213	5,256
0.01	7,224	2,167	2,167	2,528	4,226	18,312
0.1	25,281	7,584	7,584	8,848	14,789	64,086
0.5	60,468	18,203	18,203	21,237	35,433	153,544
1.0	88,468	26,541	26,541	30,964	51,754	224,268
5.0	212,338	63,701	63,701	74,318	124,217	538,275

Table 3-22. Capital Costs for pH Adjustment Tanks - Metals Option 3

Flow (MGD)	Equipment Cost	Piping	Instrument. & Controls	Installation	Engineering & Contingency	Total Capital Cost (1989$)
0.00001	91	27	27	32	53	230
0.0001	326	98	98	114	191	827
0.001	1,141	342	342	399	667	2,891
0.005	2,726	818	818	954	1,595	6,901
0.01	3,974	1,192	1,192	1,391	2,325	10,074
0.05	9,329	2,799	2,799	3,265	5,458	23,640
0.1	13,907	4,172	4,172	4,867	8,135	35,253
0.5	33,379	10,014	10,014	11,683	19,581	84,851
1.0	48,667	14,600	14,600	17,033	28,470	123,370
5.0	116,808	35,042	35,042	40,883	68,333	296,108

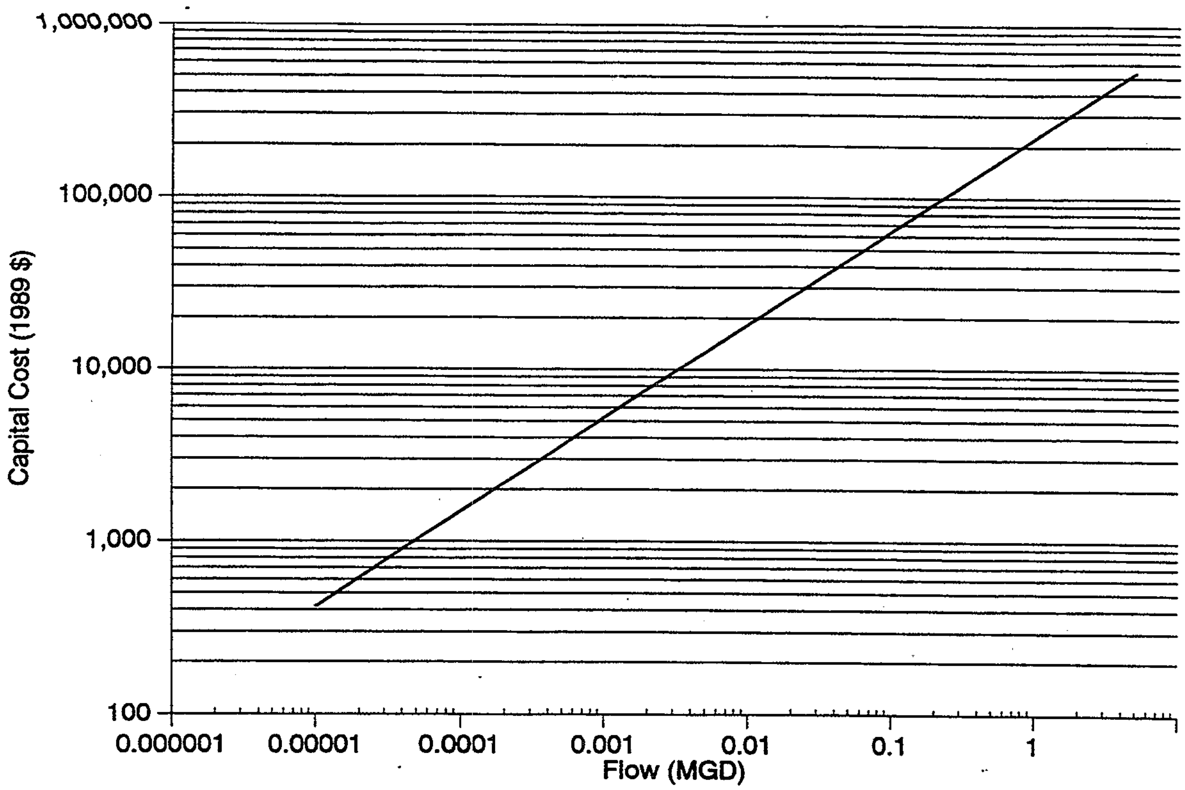

Figure 3-15 Capital Cost Curve for Rapid Mix Tanks - Metals Option 3

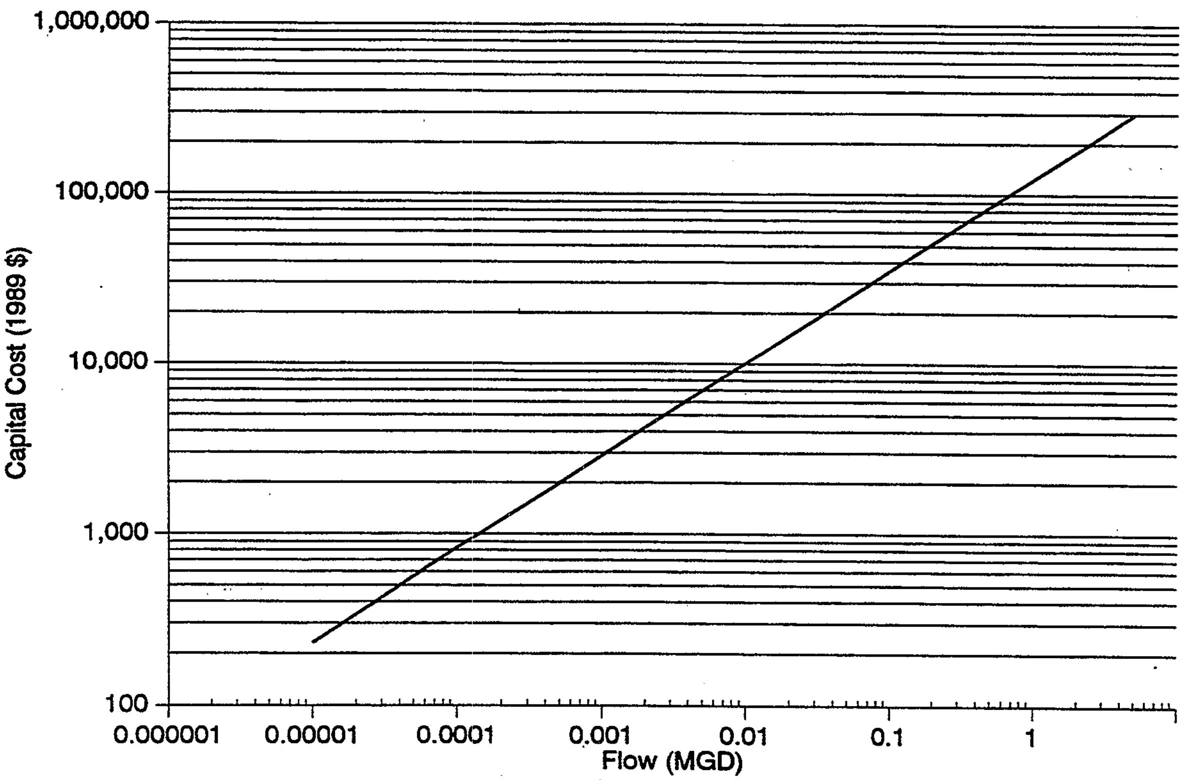

Figure 3-16 Capital Cost Curve for pH Adjustment Tanks - Metals Option 3

Table 3-23 LIME AND CAUSTIC REQUIREMENTS FOR TERTIARY CHEMICAL PRECIPITATION - METALS OPTION 3

POLLUTANT	OPTION 2 LEVEL (MG/L)	OPTION 3 LEVEL (MG/L)	2-3 LEVEL (MG/L)	DOSAGE RATES		FLOW=0.001 MGD		FLOW=0.01 MGD		FLOW=0.1 MGD		FLOW=1.0 MGD	
				LIME (LBS/LB)	CAUSTIC (LBS/LB)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)	LIME (LBS/YR)	CAUSTIC (LBS/YR)
ALUMINUM	0.337	0.102	0.235	4.11	0.00	2.3	0	23.1	0	231	0	2,306	0
ANTIMONY	0.021	0.02	0.001	1.52	0.00	0.004	0	0.04	0	0.4	0	4	0
ARSENIC	0.018	0.011	0.007	2.47	0.00	0.04	0	0.4	0	4	0	41	0
BARIUM	0.011	0.02	0	0.54	0.00	0	0	0	0	0	0	0	0
BORON	8.182	7.29	0.892	10.27	0.00	21.8	0	218.5	0	2,185	0	21,847	0
CADMIUM	0.101	0.103	0	0.66	0.00	0	0	0	0	0	0	0	0
CHROMIUM	0.69	0.108	0.582	2.13	0.00	3.0	0	29.6	0	296	0	2,963	0
COBALT	0.124	0.103	0.021	1.88	0.00	0.1	0	0.9	0	9	0	94	0
COPPER	0.97	0.144	0.826	1.16	0.00	2.3	0	22.9	0	229	0	2,294	0
IRON	4.134	0.343	3.791	1.99	0.00	18.0	0	179.7	0	1,797	0	17,972	0
LEAD	0.308	0.053	0.255	0.71	0.00	0.4	0	4.3	0	43	0	434	0
MANGANESE	0.061	0.025	0.036	2.69	0.00	0.2	0	2.3	0	23	0	231	0
MERCURY	0.001	0.002	0	0.37	0.00	0	0	0	0	0	0	0	0
MOLYBDENUM	0.652	0.555	0.097	2.31	0.00	0.5	0	5.4	0	54	0	535	0
NICKEL	1.06	0.76	0.3	1.89	0.00	1.4	0	13.5	0	135	0	1,353	0
SELENIUM	0.235	0.21	0.025	1.87	0.00	0.1	0	1.1	0	11	0	112	0
SILVER	0.004	0.004	0	0.34	0.00	0	0	0	0	0	0	0	0
THALLIUM	0.025	0.022	0.003	0.54	0.00	0.004	0	0.04	0	0.4	0	4	0
TIN	0.029	0.028	0.001	1.25	0.00	0.003	0	0.03	0	0.3	0	3	0
TITANIUM	0.004	0.003	0.001	3.09	0.00	0.01	0	0.1	0	1	0	7	0
VANADIUM	0.01	0.011	0	2.91	0.00	0	0	0	0	0	0	0	0
ZINC	0.845	0.174	0.671	1.13	0.00	1.8	0	18.1	0	181	0	1,812	0
TOTALS			7.7			52	0	520	0	5,201	0	52,014	0

Table 3-24. O & M Costs for Rapid Mix Tanks - Metals Option 3

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Chemical Cost	Total O & M Cost (1989 $)
0.00001	63	17	8	4,372	1	4,461
0.0001	63	60	30	4,372	1	4,526
0.001	63	210	105	4,492	2	4,872
0.01	69	732	366	4,914	15	6,096
0.1	128	2,563	1,282	5,375	148	9,496
0.5	388	6,142	3,071	5,724	741	16,066
1.0	713	8,971	4,485	5,880	1,482	21,531
5.0	3,313	21,531	10,766	6,261	7,412	49,283

Table 3-25. O & M Costs for pH Adjustment Tanks - Metals Option 3

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Chemical Cost	Total O & M Cost (1989 $)
0.00001	21	9	5	4,372	1	4,408
0.0001	21	33	17	4,372	1	4,444
0.001	21	116	58	4,492	2	4,689
0.01	23	403	201	4,914	18	5,541
0.1	43	1,410	705	5,375	175	7,708
0.5	130	3,394	1,697	5,724	870	11,815
1.0	238	4,935	3,467	5,880	1,735	15,255
5.0	1,104	11,844	5,922	6,261	8,660	33,790

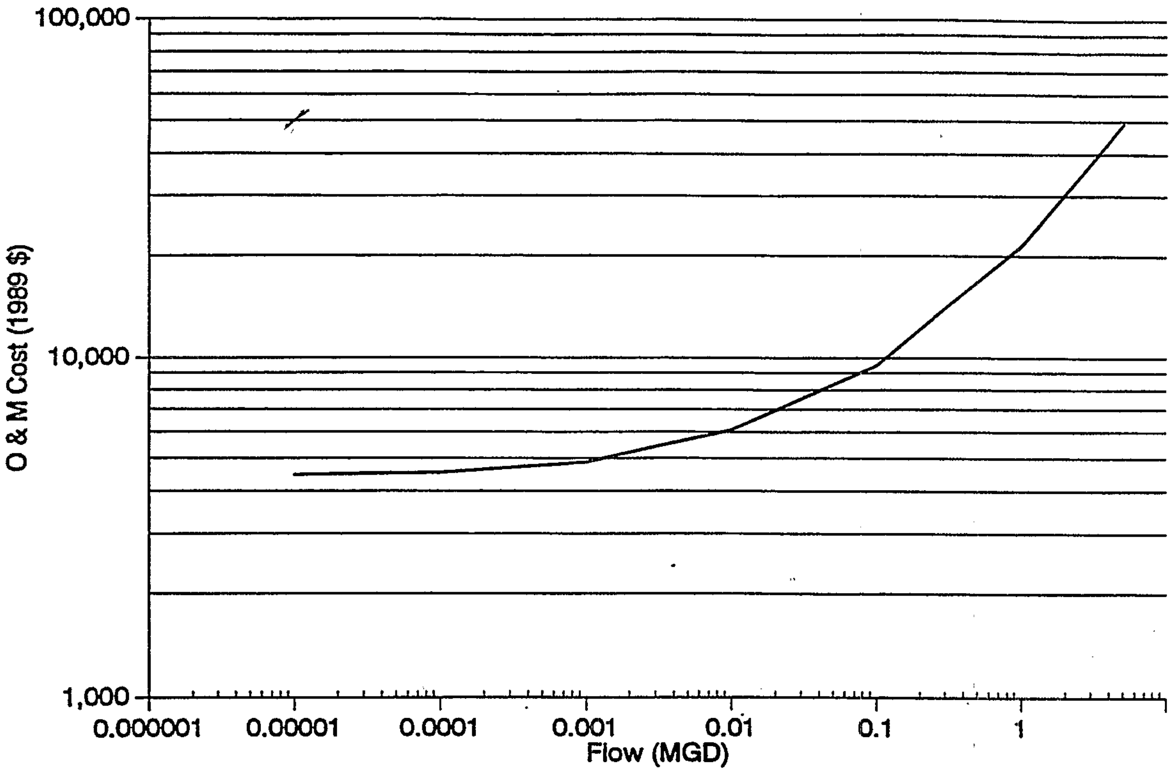

Figure 3-17 O & M Cost Curve for Rapid Mix Tanks - Metals Option 3

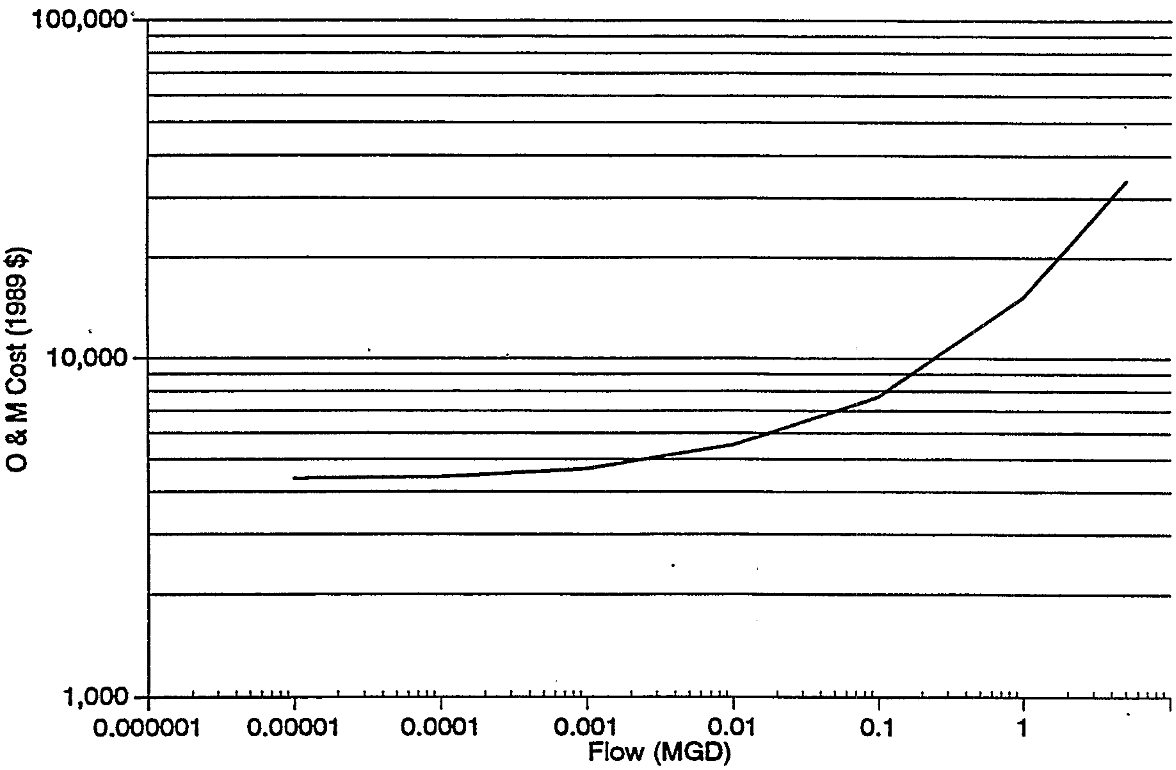

Figure 3-18 O & M Cost Curve for pH Adjustment Tanks - Metals Option 3

$$\ln(Y2) = 10.011 + 0.385\ln(X) + 0.022(\ln(X))^2 \qquad (3\text{-}17)$$

$$\ln(Y2) = 9.695 + 0.328\ln(X) + 0.019(\ln(X))^2 \qquad (3\text{-}18)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

The land requirements for the rapid mix and pH adjustment tank are presented in Table 3-26. The resulting cost curves are presented in Figures 3-19 and 3-20, respectively. The land requirements equations for the rapid mix tank and pH adjustment tank are presented as Equations 3-19 and 3-20, respectively.

$$\ln(Y3) = -2.330 + 0.352\ln(X) + 0.019(\ln(X))^2 \qquad (3\text{-}19)$$

$$\ln(Y3) = -2.67 + 0.30\ln(X) + 0.033(\ln(X))^2 \qquad (3\text{-}20)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

Table 3-26. Land Requirements for Tertiary Precipitation Tanks - Metals Option 3

Flow (MGD)	Rapid Mix Tank Land Requirements (Acres)	pH Adjustment Tank Land Requirements (Acres)
0.01	0.036	0.037
0.05	0.044	0.037
0.1	0.05	0.04
0.5	0.078	0.06
1.0	0.098	0.07
5.0	0.184	0.12

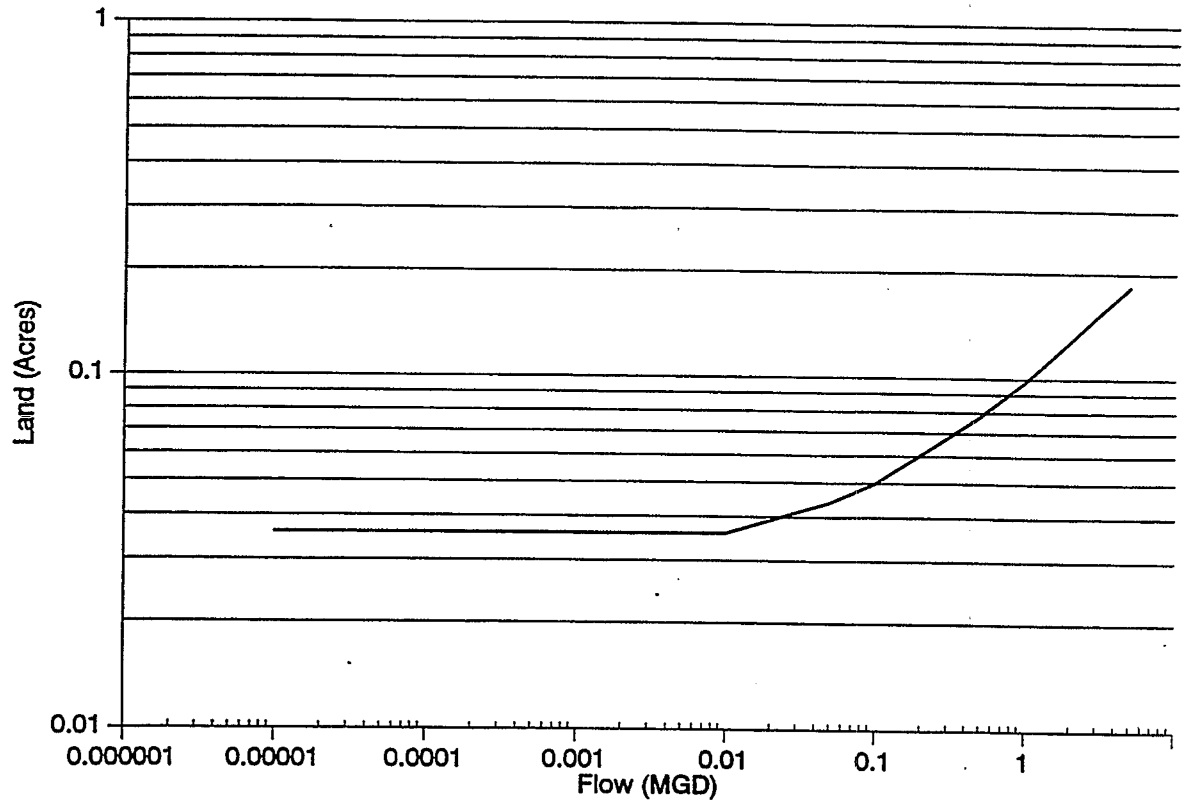

Figure 3-19 Land Requirement Curve for Rapid Mix Tanks - Metals Option 3

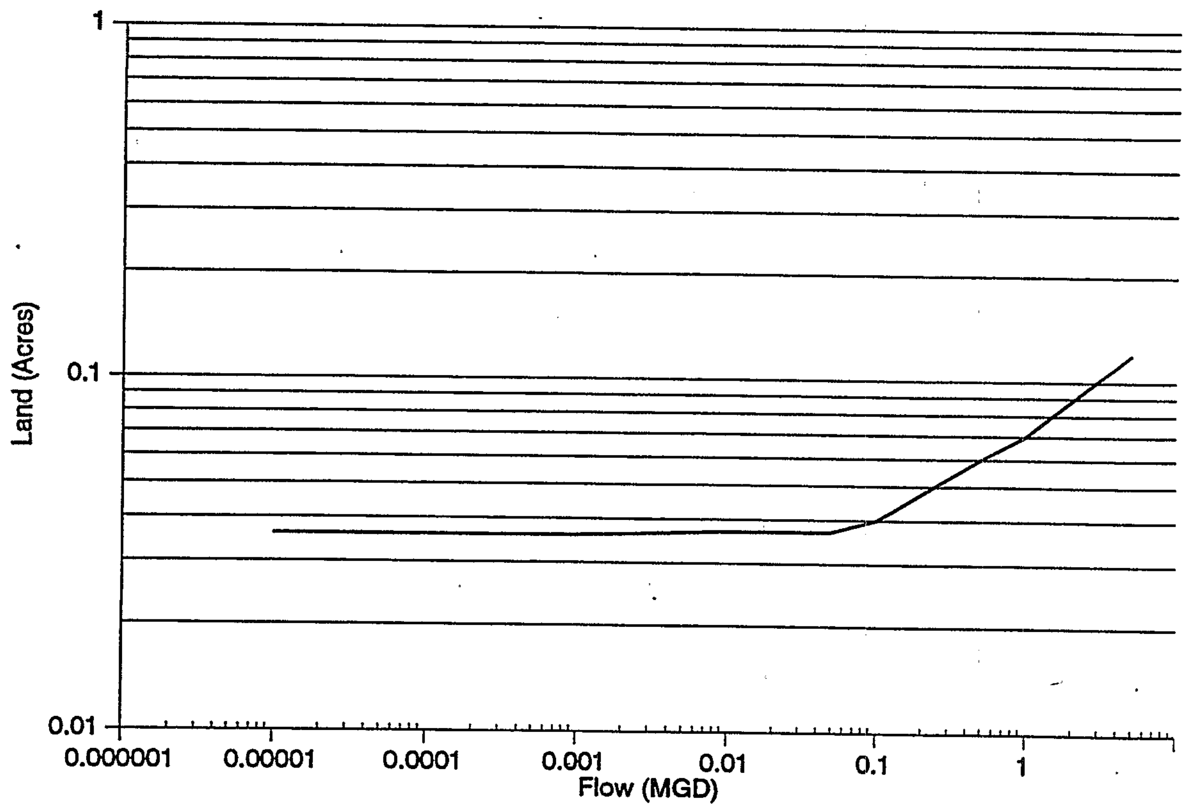

Figure 3-20 Land Requirement Curve for pH Adjustment Tanks - Metals Option 3

3.2 *CLARIFICATION*

Clarification systems provide continuous, low-cost separation and removal of suspended solids from water. Clarification is used to remove particulates, flocculated impurities, and precipitates. These clarification systems are equipped with a flocculation unit and are costed with the addition of the flocculation step.

The capital and O & M costs equations for the clarification systems were obtained from two vendor services. The influent total suspended solids (TSS) design concentration used was 40,000 mg/l or four percent solids. The effluent sludge TSS concentration was 200,000 mg/l or 20 percent solids. The effluent overflow TSS concentration was 500 mg/l at a flow rate of 80 percent of the influent flow. These parameters were taken from CWT QID 105.

The capital cost curves for the clarification systems for all Metals Options were estimated using the vendor quotes and represent equipment and installation costs. The clarification system includes a clarification unit, flocculation unit, pumps, motor, foundation, and necessary accessories. The total construction cost includes the system costs, installation, installed piping, and instrumentation and controls. Installation, installed piping, and instrumentation and controls are estimated at 35 percent, 30 percent, and 30 percent of the vendor system costs, respectively. The total capital cost includes the cost for engineering (15 percent of total construction cost) and contingency (15 percent of total construction cost). The capital costs were scaled down to 1989 dollars using ENR's Construction Cost Index. The itemized capital costs are listed in Table 3-27.

The O & M costs for all Metals Options were based on energy usage, maintenance, labor, flocculant cost, and taxes and insurance. Energy was divided into cost for electricity, lighting, and controls. Pumping costs were based on power requirements of 0.5 kwhr per 1,000 gallons of wastewater. Lighting and controls were assumed at $1,000 per year and electrical cost was $0.08 per kwhr. The maintenance was approximated at four percent of the total capital cost and taxes and insurance were two percent of the total capital cost. The labor cost used was $31,200 per man-year.

Table 3-27. Capital Costs for Clarification Systems for Metals Options 1, 2, & 3

Vol/Day (MGD)	System Cost	Install.	Piping	Instrum. & Controls	Engineer. & Conting.	Total Capital Cost (1993$)	Total Capital Cost (1989$)
0.000001	6,579	2,303	1,974	1,974	3,849	16,679	15,178
0.00001	6,579	2,303	1,974	1,974	3,849	16,679	15,178
0.0001	6,579	2,303	1,974	1,974	3,849	16,679	15,178
0.001	6,971	2,440	2,091	2,091	4,078	17,671	16,081
0.01	9,547	3,341	2,864	2,864	5,585	24,201	22,023
0.05	14,550	5,093	4,365	4,365	8,512	36,885	33,565
0.1	18,358	6,425	5,507	5,507	10,739	46,536	42,348
0.5	35,466	12,413	10,640	10,640	20,748	89,907	81,815
1.0	49,563	17,347	14,869	14,869	28,994	125,642	114,334

The labor requirements for Metals Options 1 and 2 were estimated between three hours per day (for the smaller systems) to four hours per day (for the larger systems), while the labor requirement for Metals Option 3 was one hour per day. The polymer dosage used in the flocculation step was 2.0 mg polymer per liter of wastewater. This dosage was taken from the MP&M cost model. The cost of polymer was $3.38 per pound in 1989 dollars. The O & M costs were scaled down to 1989 dollars using ENR's cost index. The itemized O & M costs for Metals Options 1 and 2 are presented in Table 3-28, with the subsequent O & M cost curve shown in Figure 3-22. The itemized O & M costs for Metals Option 3 are in Table 3-29, with the cost curve shown in Figure 3-23.

The clarification systems capital cost equation is presented as Equation 3-21, with the subsequent cost curve in Figure 3-21. The O & M cost equations for the Metals Options 1 and 2 and Metals Option 3 clarification systems are presented as Equations 3-22 and 3-23, respectively.

$$\ln(Y1) = 11.552 + 0.409\ln(X) + 0.020(\ln(X))^2 \qquad (3\text{-}21)$$

$$\ln(Y2) = 10.429 + 0.174\ln(X) + 0.0091(\ln(X))^2 \qquad (3\text{-}22)$$

Table 3-28. O & M Costs for Clarification Systems for Metals Options 1 and 2

Vol/day (MGD)	Energy	Labor	Maintenance	Taxes & Insurance	Polymer Cost	Total O & M Cost (1993$)	Total O & M Cost (1989$)
0.000001	1,000	15,741	667	334	10	17,752	16,154
0.00001	1,000	15,741	667	334	10	17,752	16,154
0.0001	1,000	15,741	667	334	10	17,752	16,154
0.001	1,010	15,857	706	353	15	17,941	16,326
0.01	1,104	16,842	968	484	150	19,548	17,789
0.05	1,520	18,210	1,475	738	750	22,693	20,651
0.1	2,040	19,005	1,861	931	1,500	25,337	23,057
0.5	6,155	21,439	3,596	1,798	7,500	40,488	36,844
1.00	11,464	22,788	5,025	2,513	15,000	56,790	51,679

Table 3-29. O & M Costs for Clarification Systems for Metals Option 3

Vol/day (MGD)	Energy	Labor	Maintenance	Taxes & Insurance	Polymer Cost	Total O & M Cost (1993$)	Total O & M Cost (1989$)
0.000001	1,000	5,247	667	334	10	7,258	6,605
0.00001	1,000	5,247	667	334	10	7,258	6,605
0.0001	1,000	5,247	667	334	10	7,258	6,605
0.001	1,010	5,286	706	353	15	7,370	6,707
0.01	1,104	5,614	968	484	150	8,320	7,571
0.05	1,520	6,070	1,475	738	750	10,553	9,603
0.1	2,040	6,335	1,861	931	1,500	12,667	11,527
0.5	6,155	7,146	3,596	1,798	7,500	26,195	23,837
1.00	11,464	7,596	5,025	2,513	15,000	41,598	37,854

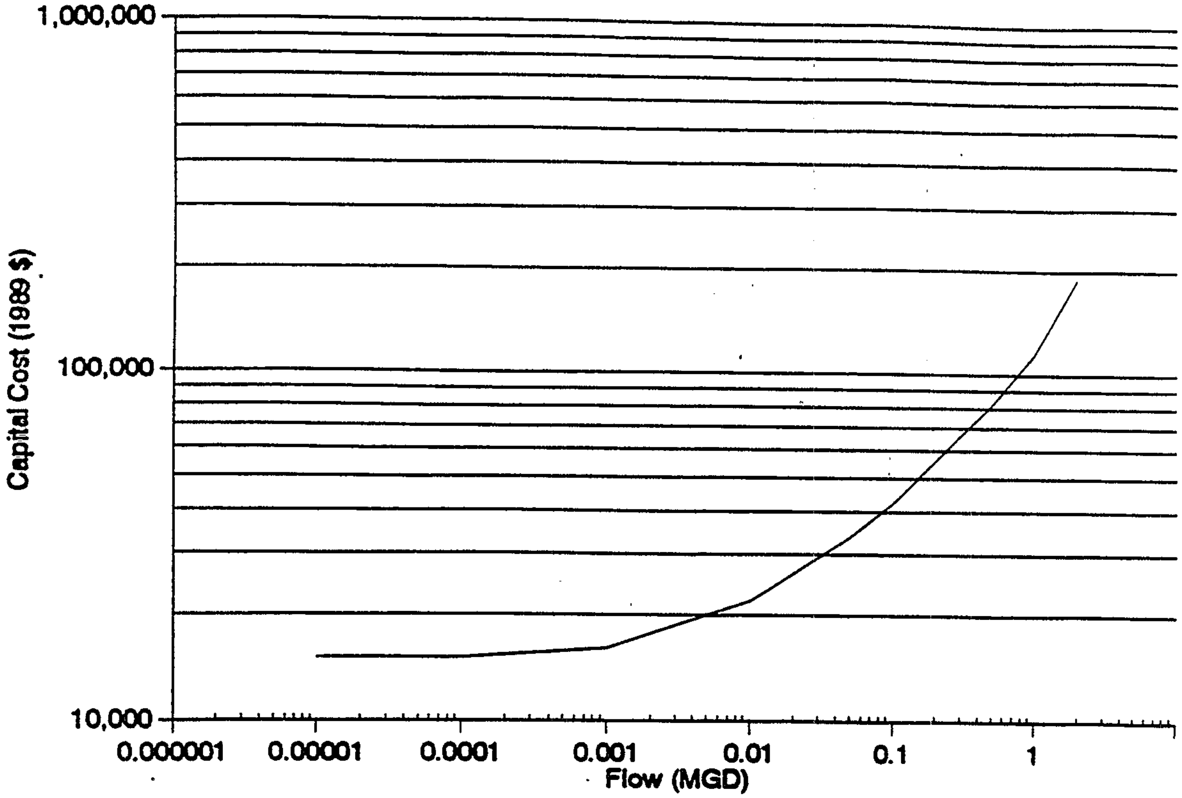

Figure 3-21 Capital Cost Curve for Clarification Systems - Options 1, 2, and 3

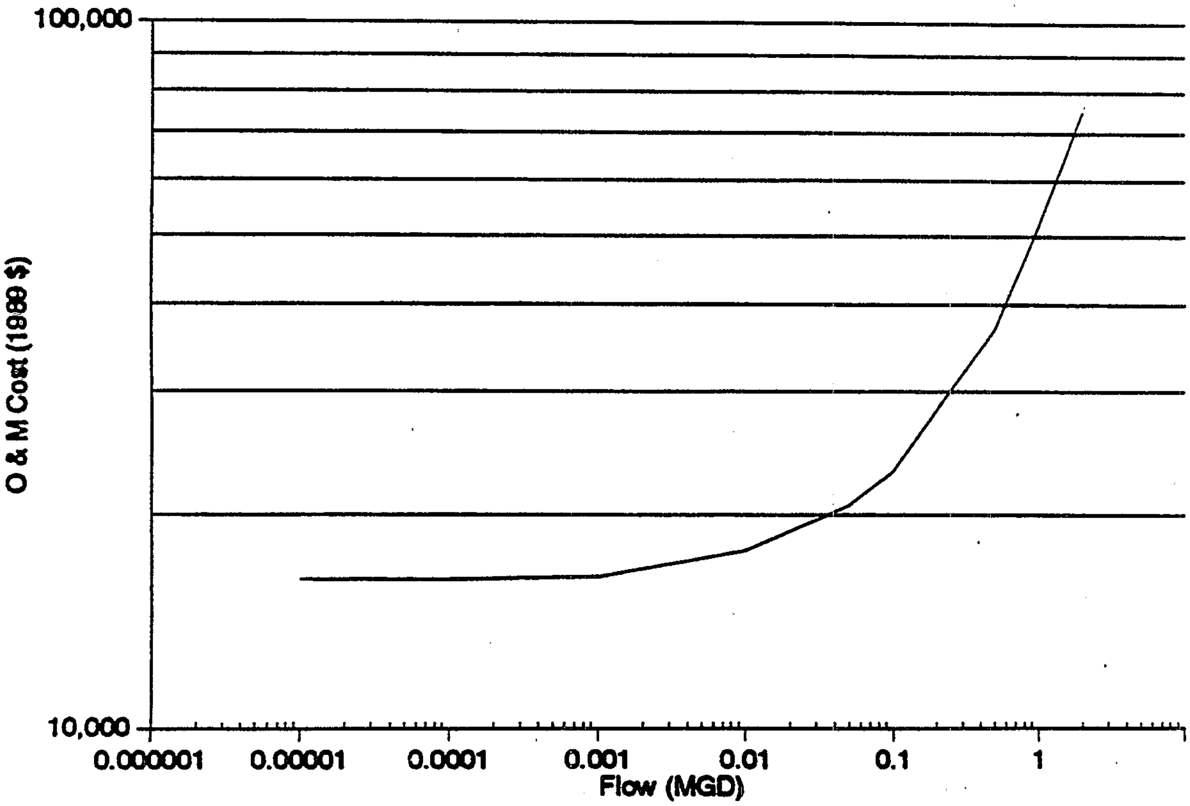

Figure 3-22 O & M Cost Curve for Clarification Systems - Options 1 and 2

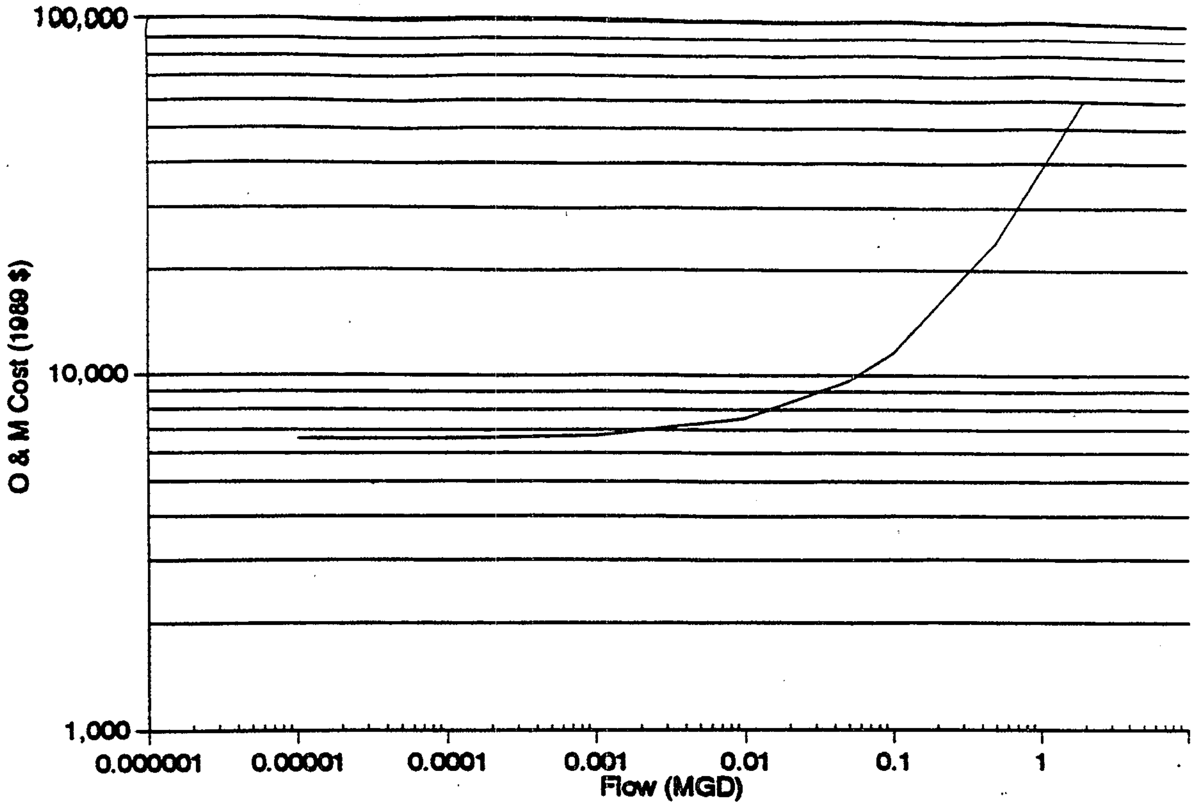

Figure 3-23 O & M Cost Curve for Clarification Systems - Option 3

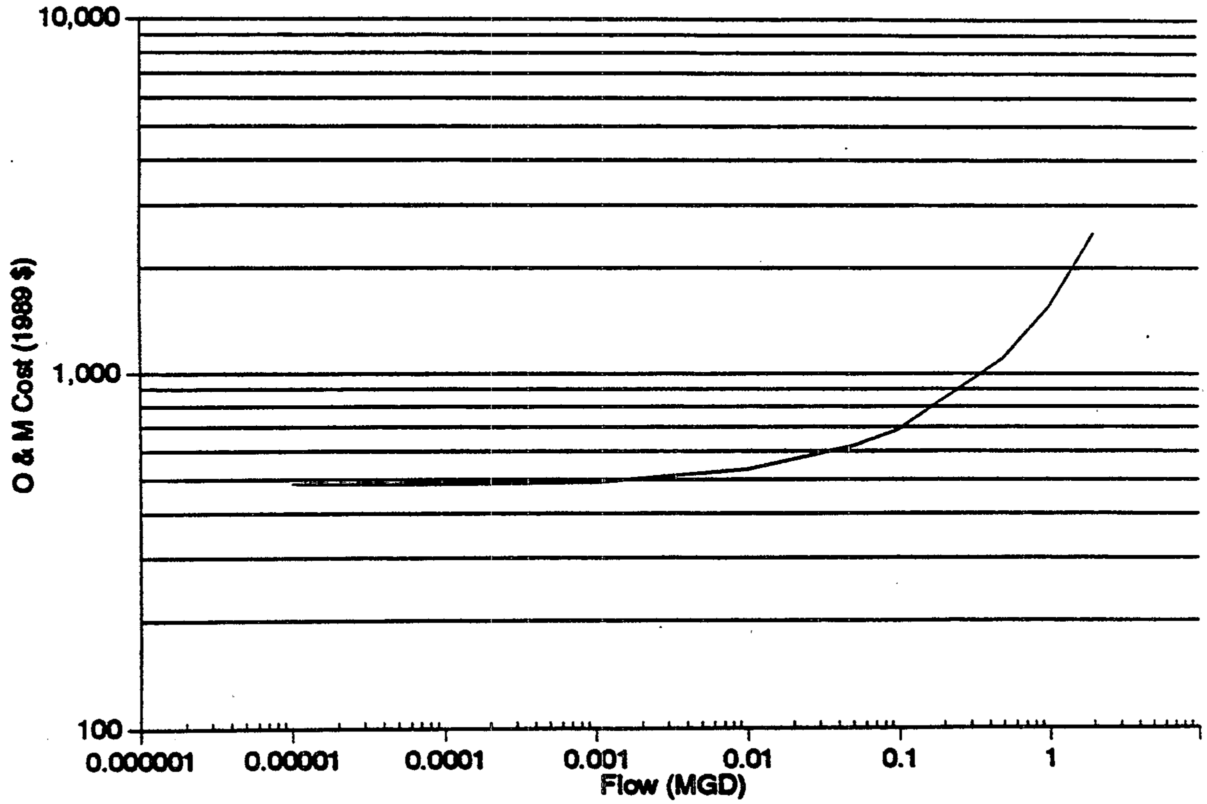

Figure 3-24 O & M Upgrade Cost Curve for Clarification Systems - Option 1

$$\ln(Y2) = 10.294 + 0.362\ln(X) + 0.019(\ln(X))^2 \quad (3\text{-}23)$$

where:

X = Flow Rate (MGD),

Y1 = Capital Cost (1989 $), and

Y2 = O & M Cost (1989 $).

A clarification system upgrade was calculated to estimate the increase in O & M costs for facilities that already have a clarification system in-place. These facilities would need to improve pollutant removals from their current performance levels to Metals Option 1 levels. To determine the required increase from current performance to Metals Option 1 levels, a comparison of the sum of the Metals current performance pollutant concentrations to Metals Option 1 levels versus the Metals Subcategory raw influent pollutant concentrations to current performance levels was calculated. This percentage increase was determined to be 3 percent, as follows:

$$\text{O \& M Upgrade Increase} = \frac{\text{Current - Metals Option 1}}{\text{Raw - Current}} = 0.03 = 3 \quad (3\text{-}24)$$

Therefore, in order for the facilities to perform at Metals Option 1 levels, an O & M cost upgrade of three percent of the total O & M costs would be realized for each facility. The O & M upgrade cost equation for Metals Option 1 clarification is:

$$\ln(Y2) = 7.166 + 0.238\ln(X) + 0.013(\ln(X))^2 \quad (3\text{-}25)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $)

The O & M upgrade cost curve is shown in Figure 3-24.

To develop land requirements for clarification systems, overall system dimensions were provided by the vendor. The system dimensions were scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.).

The equation relating the flow of the clarification system with the land requirement for all Metals Options is:

$$\ln(Y3) = -1.773 + 0.513\ln(X) + 0.046(\ln(X))^2 \quad (3\text{-}26)$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is shown in Figure 3-25.

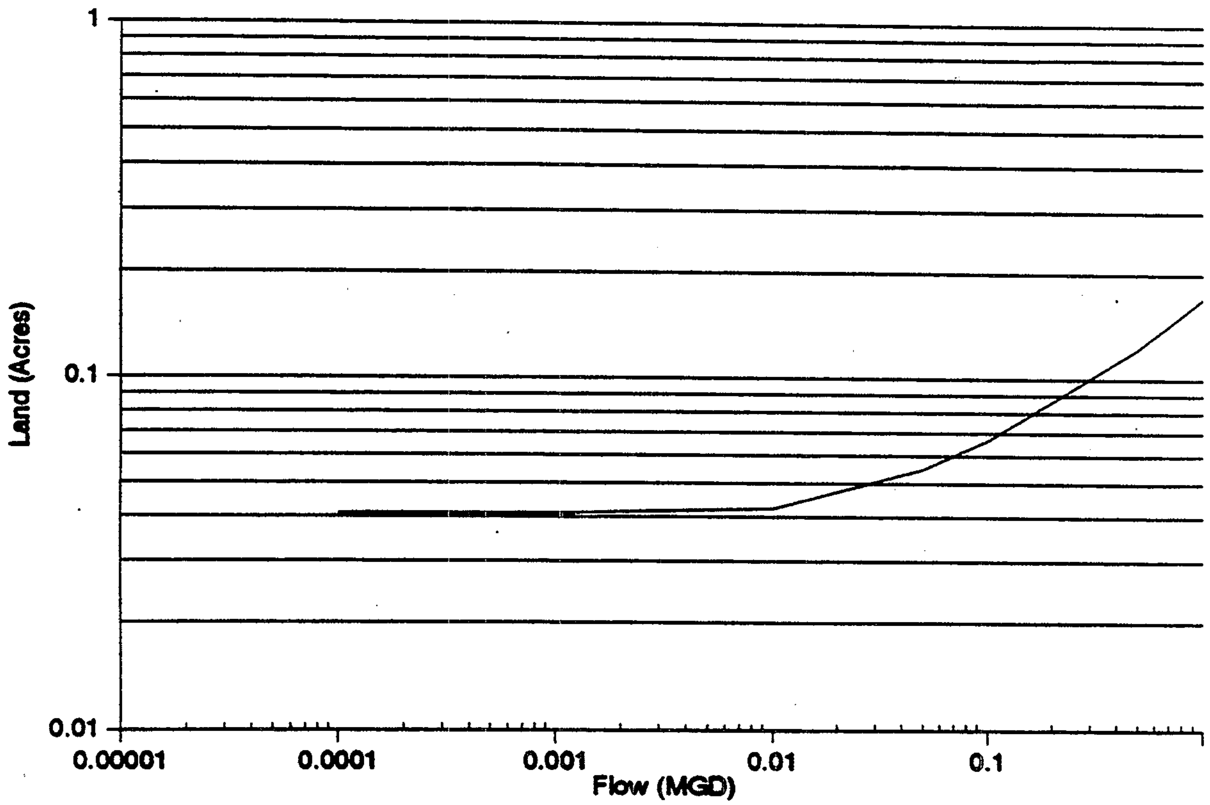

Figure 3-25 Land Requirement Curve for Clarification Systems - Options 1, 2, and 3

3.3 *PLATE AND FRAME PRESSURE FILTRATION - LIQUID STREAM*

Pressure filtration systems are used for the removal of solids from waste streams. These systems typically follow chemical precipitation or clarification.

3.3.1 *Plate and Frame Filtration - Metals Option 1*

The plate and frame pressure filtration system costs were estimated for a liquid stream; this is the full effluent stream from a chemical precipitation process. The liquid stream consists of 96 percent liquid and four percent (40,000 mg/l) solids. These influent parameters were taken from CWT QID 105.

The components of the plate and frame pressure filtration system include: filter plates; filter cloth; hydraulic pumps; pneumatic booster pumps; control panel; connector pipes; and support platform. Equipment and operational costs were obtained from manufacturers' recommendations. The capital cost equation was developed by adding installation, engineering, and contingency costs to the vendors' equipment costs. The installation cost was estimated at 35 percent of the equipment cost. Engineering and contingency fees were estimated to be 15 percent of the equipment and installation costs. The capital costs are presented in Table 3-30. All vendor cost information has been converted to 1989 dollars using ENR's Construction Index. The vendor costs were plotted and a capital cost curve was developed. The curve is presented in Figure 3-26. The capital cost equation for Metals Option 1 liquid filtration is:

$$\ln(Y1) = 14.826 + 1.089\ln(X) + 0.050(\ln(X))^2 \qquad (3\text{-}27)$$

where:

X = Flow (MGD) and

Y1 = Capital Cost (1989 $).

Table 3-30. Capital Cost for Plate and Frame Pressure Filtration - Metals Option 1 (Liquid Stream - Four Percent Solids)

Flow (MGD)	Average Vendor Equipment Cost ($)	Install. Cost	Total Capital & Installation Cost	Engineering & Contingency Fee	Total Capital Cost (1989 $)
0.000001	6,325	2,214	8,539	2,562	10,102
0.00001	6,325	2,214	8,539	2,562	10,102
0.0001	6,424	2,248	8,672	2,602	10,259
0.0010	9,826	3,439	13,265	3,980	15,693
0.0100	29,316	10,261	39,577	11,873	46,820
0.100	170,575	59,701	230,276	69,083	272,417
1.000	1,935,740	677,509	2,613,249	783,975	3,091,474

The O & M costs were based on estimated electricity usage, maintenance, labor, taxes and insurance, and filter cake disposal costs. The electricity usage and costs were based upon a usage rate of 0.5 kwhr per 1,000 gallons at $0.08 per kwhr, and lighting and control energy costs were estimated at $1,000 per year. Maintenance was approximated at four percent of the capital cost. Taxes and insurance were approximated at two percent of the capital cost. The labor cost for the plate and frame pressure filtration system was approximated at $31,200 per man-year at thirty minutes per cycle per filter press.

Filter cake disposal costs were derived from responses to the WTI Questionnaire. The disposal cost was estimated at $0.74 per gallon of filter cake; this is based on the cost of contract hauling and disposal in a Subtitle C or Subtitle D landfill. A more detailed explanation of the filter cake disposal costs development is presented in Subsection 6.2. To determine the total annual O & M costs for a plate and frame filtration system, the filter cake disposal cost must be added to the other O & M costs.

The O & M costs were converted to 1989 dollars using ENR's cost index. The itemized annual O & M costs, excluding the filter cake disposal costs, are presented in Table 3-31 with the subsequent cost curve presented in Figure 3-27.

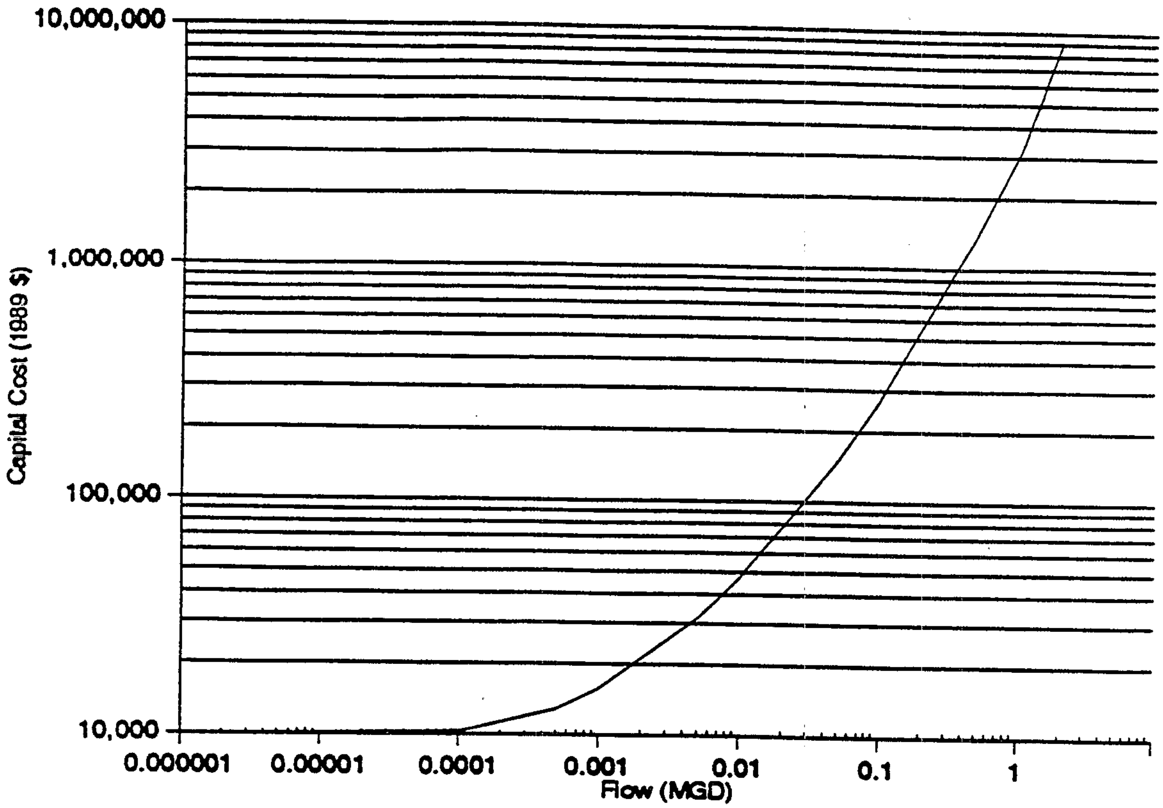

Figure 3-26 Plate & Frame Filtration (Liquid Stream) Capital Cost Curve - Metals Option 1

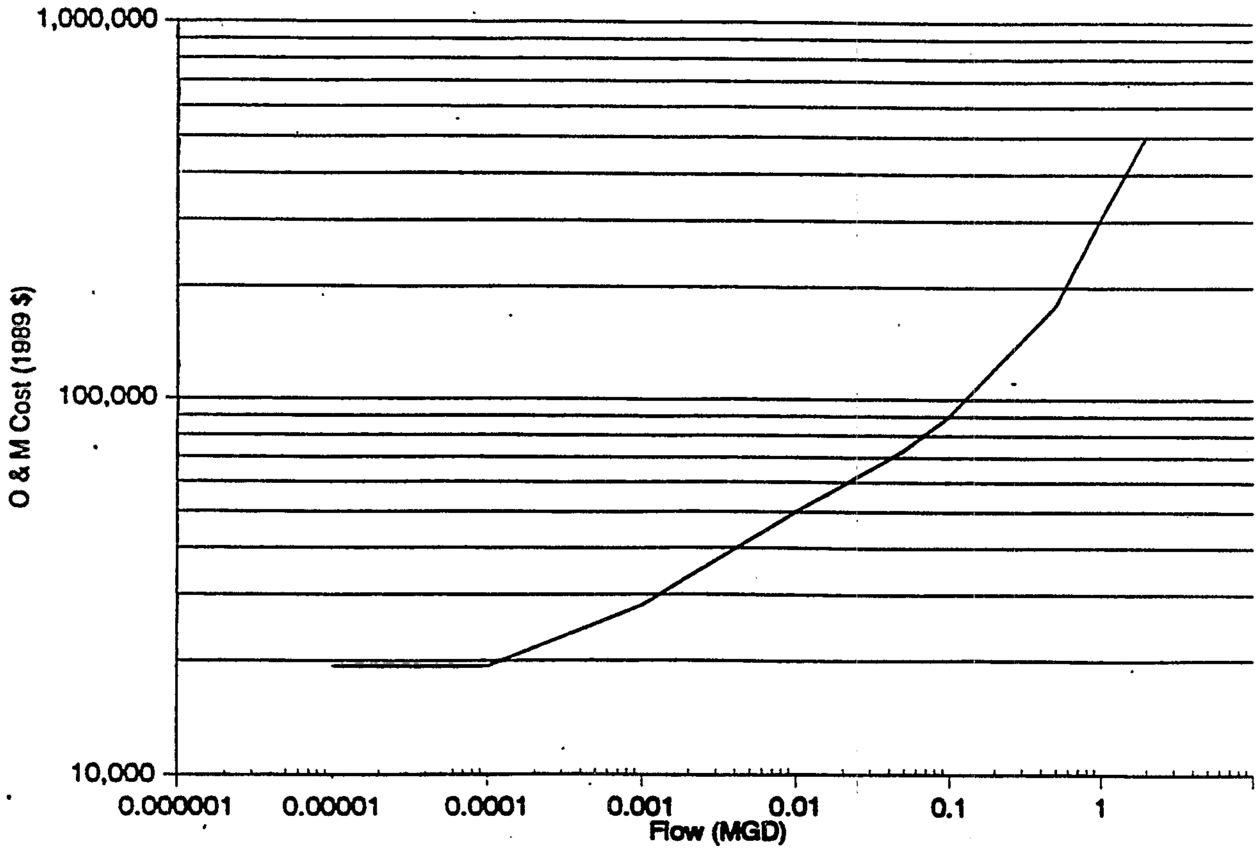

Figure 3-27 Plate & Frame Filtration (Liquid Stream) O & M Cost Curve - Metals Option 1

Table 3-31. O & M Costs for Plate & Frame Pressure Filtration - Metals Option 1 (Liquid Stream - Excluding Filter Cake Disposal Cost)

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	O & M Cost (1989 $)
0.000001	1,000	404	202	17,730	19,336
0.00001	1,000	404	202	17,730	19,336
0.0001	1,000	410	205	17,730	19,345
0.001	1,010	627	314	53,549	55,500
0.01	1,104	1,872	936	53,549	57,461
0.05	1,520	5,977	2,989	62,504	72,990
0.1	2,040	10,895	5,448	71,550	89,933
0.5	6,155	55,480	27,740	88,650	178,025
1.0	11,464	123,660	61,830	106,380	303,334

The O & M cost equation for Metals Option 1 liquid filtration is:

$$\ln(Y2) = 12.406 + 0.381\ln(X) + 0.014(\ln(X))^2 \qquad (3\text{-}28)$$

where:

X = Flow (MGD) and

Y2 = O & M Cost (1989 dollars).

A pressure filtration system upgrade was calculated to estimate the increase in O & M costs for facilities that already have a pressure filtration system in-place. These facilities would need to improve pollutant removals from their current performance levels to Metals Option 1 levels. To determine the incremental percentage increase from current performance to Metals Option 1 levels, the ratio of the current performance to Option 1 levels versus the raw data to current performance levels was calculated. This incremental percentage increase was determined to be three percent, as follows:

$$\text{O \& M Upgrade Increase} = \frac{\text{Current - Option 1}}{\text{Raw - Current}} = 0.03 = 3\ \% \qquad (3\text{-}29)$$

Therefore, in order for the facilities to perform at Metals Option 1 levels, an O & M cost upgrade of three percent of the total O & M costs (except for taxes and insurance, which are a function of the capital cost) would be realized for each facility. The itemized O & M upgrade costs without the filter cake disposal costs are presented in Table 3-32. The filter cake disposal upgrade costs are presented in Subsection 6.2.

Table 3-32. O & M Upgrade Costs for Plate & Frame Filtration for Metals Option 1 (Liquid Stream - Excluding Filter Cake Disposal Costs)

Flow (MGD)	Energy	Maintenance	Labor	O & M Cost (1989 $)
0.000001	30	12	532	574
0.00001	30	12	532	574
0.0001	30	12	532	574
0.001	30	19	1,606	1,655
0.01	33	56	1,606	1,695
0.05	46	179	1,875	2,100
0.1	61	327	2,147	2,535
0.5	185	1,664	2,660	4,509
1.0	344	3,710	3,191	7,245

The O & M upgrade cost equation for Metals Option 1 liquid filtration is:

$$\ln(Y2) = 8.707 + 0.333\ln(X) + 0.012(\ln(X))^2 \qquad (3\text{-}30)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

The O & M upgrade cost curve for Option 1 is shown in Figure 3-28.

Land requirements were calculated for the plate and frame pressure filtration systems. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. The land requirement curve is presented

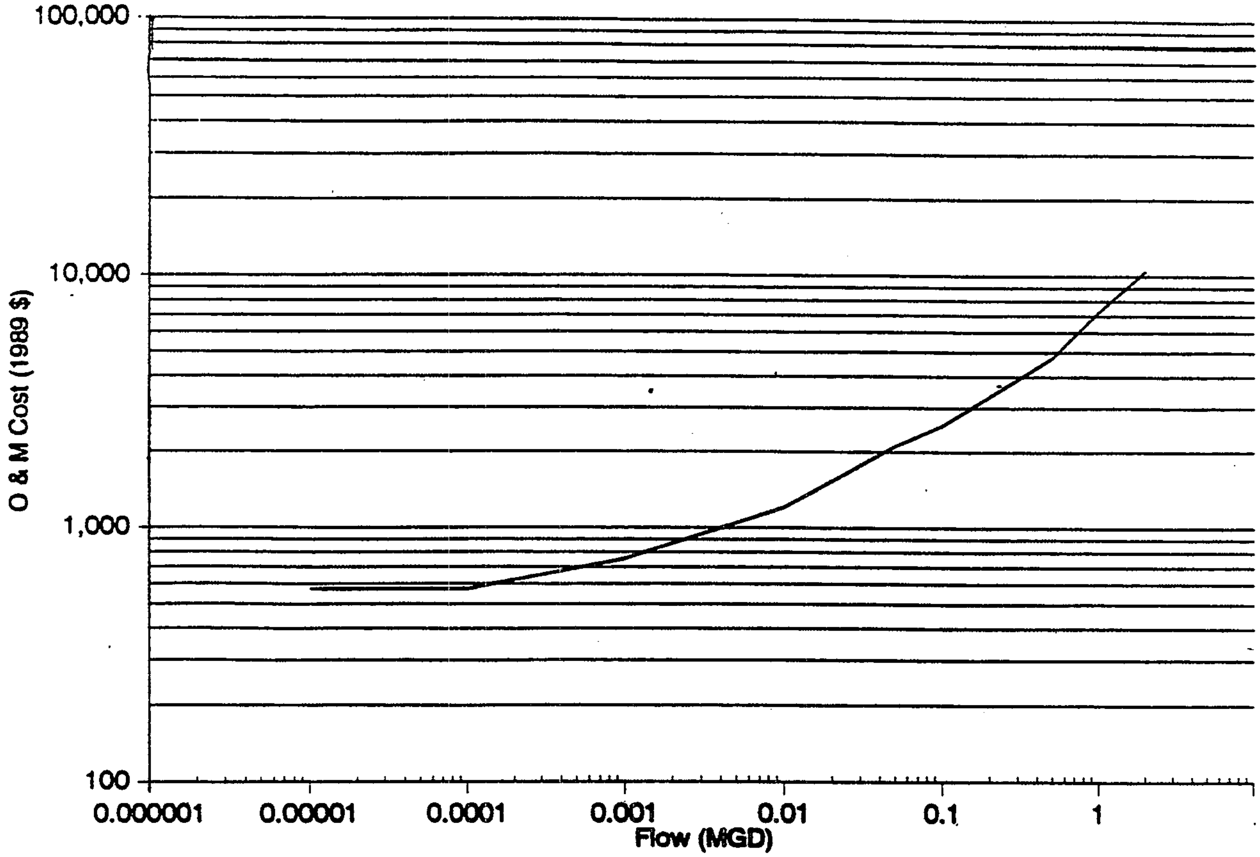

Figure 3-28 Plate & Frame Filtration (Liquid Stream) O & M Upgrade Cost Curve - Metals Option 1

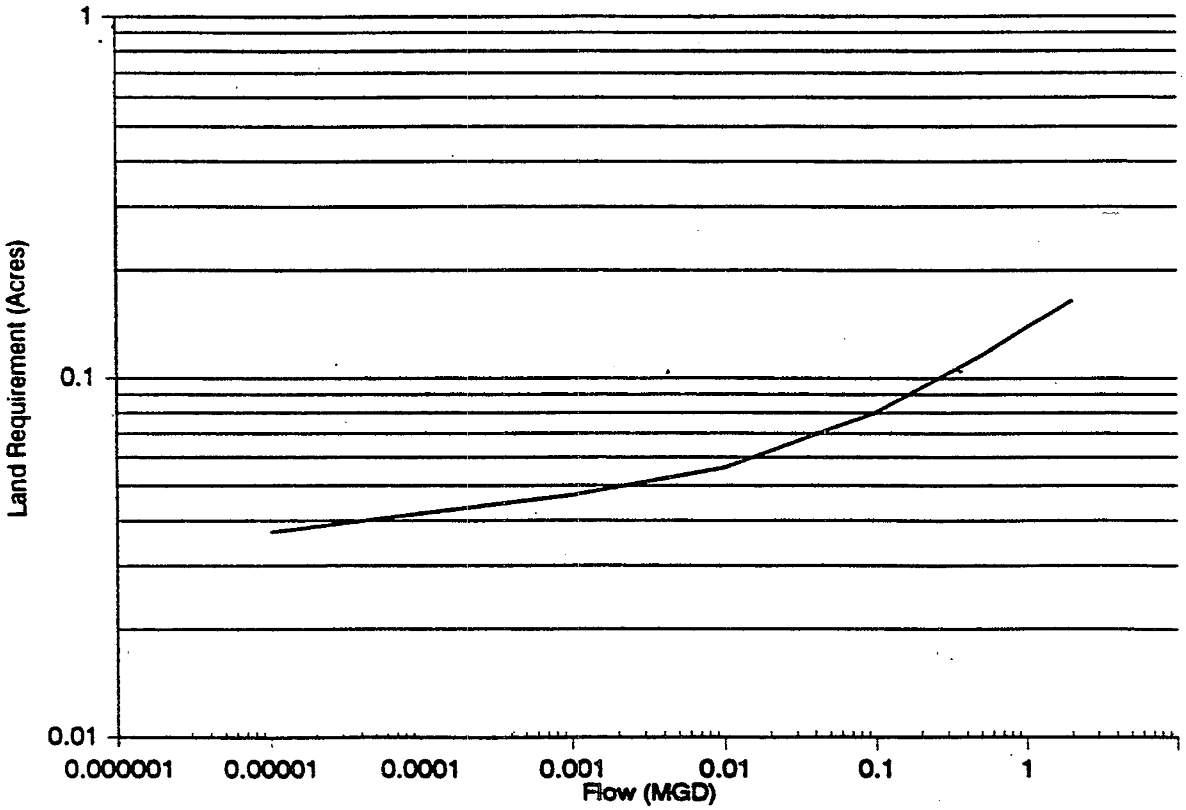

Figure 3-29 Plate & Frame Filtration (Liquid Stream) Land Requirement Curve - Metals Option 1

in Figure 3-29. The land requirement equation for Metals Option 1 liquid filtration is:

$$\ln(Y3) = -1.971 + 0.281\ln(X) + 0.018(\ln(X))^2 \quad (3\text{-}31)$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

3.3.2 *Plate and Frame Filtration - Metals Option 2*

The plate and frame pressure filtration system liquid stream costs for Metals Option 2 are based on the same parameters and are from the same vendors as Metals Option 1. The pressure filtration capital and O & M costs are computed the same as for the Metals Option 1 liquid filtration systems. The Metals Option 2 capital and O & M costs are based on two pressure filtration units processing two batches per day. These units were sized at 25 percent of the total liquid stream flow each. The capital costs are presented in Table 3-33.

The Metals Option 2 O & M costs parameters were similar to the Metals Option 1 parameters. The electricity costs were similar because electricity is based upon wastewater flow rate. The labor costs were scaled up by four to account for the two units at two batches per day. The maintenance and taxes and insurance were four percent and two percent of the Metals Option 2 capital costs, respectively. The filter cake disposal costs were the same as for Metals Option 1 and are presented in Subsection 6.2. The itemized O & M costs are presented in Table 3-34. The total O & M costs for Metals Option 2 are calculated by adding the filter cake disposal costs to the O & M costs. The capital and O & M cost equations for Metals Option 2 liquid filtration are presented as Equations 3-32 and 3-33, respectively.

$$\ln(Y1) = 14.024 + 0.859\ln(X) + 0.040(\ln(X))^2 \quad (3\text{-}32)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

Table 3-33. Capital Costs for Plate & Frame Pressure Filtration - Metals Option 2

Flow (MGD)	Average Vendor Equipment Cost	Installation Cost	Total Equipment & Installation Cost	Engineering & Contingency Fee	Total Capital Cost (1989 $)
0.000001	9,147	3,201	12,348	3,704	14,607
0.00001	9,147	3,201	12,348	3,704	14,607
0.0001	9,185	3,215	12,400	3,720	14,669
0.0010	12,813	4,485	17,298	5,189	20,463
0.0100	30,368	10,629	40,997	12,299	48,499
0.100	122,294	42,803	165,097	49,529	195,310
0.500	443,600	155,260	598,860	179,658	708,451
1.000	836,855	292,899	1,129,754	338,926	1,336,499

Table 3-34. O & M Costs for Plate & Frame Pressure Filtration - Metals Option 2

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	O & M Cost (1989 $)
0.000001	1,000	293	147	70,920	72,360
0.00001	1,000	293	147	70,920	72,360
0.0001	1,000	294	147	70,920	72,361
0.001	1,010	409	205	214,196	215,820
0.01	1,104	970	485	214,196	216,755
0.1	2,040	3,906	1,953	286,200	294,099
0.5	6,155	14,169	7,085	354,600	382,009
1.0	11,464	26,730	13,365	425,520	477,079

$$\ln(Y2) = 13.056 + 0.193\ln(X) + 0.00343(\ln(X))^2 \quad (3\text{-}33)$$

where:

$Y2$ = O & M Cost (1989 $).

The capital and O & M cost curves are presented in Figures 3-30 and 3-31, respectively.

Land requirements were calculated for Metals Option 2 plate and frame pressure filtration. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions for one system and doubling the area to account for the two systems. The Metals Option 2 liquid filtration systems requirement curve is presented in Figure 3-32; the subsequent equation is:

$$\ln(Y3) = -1.658 + 0.185\ln(X) + 0.009(\ln(X))^2 \quad (3\text{-}34)$$

where:

X = Flow (MGD) and

$Y3$ = Land Requirement (Acres).

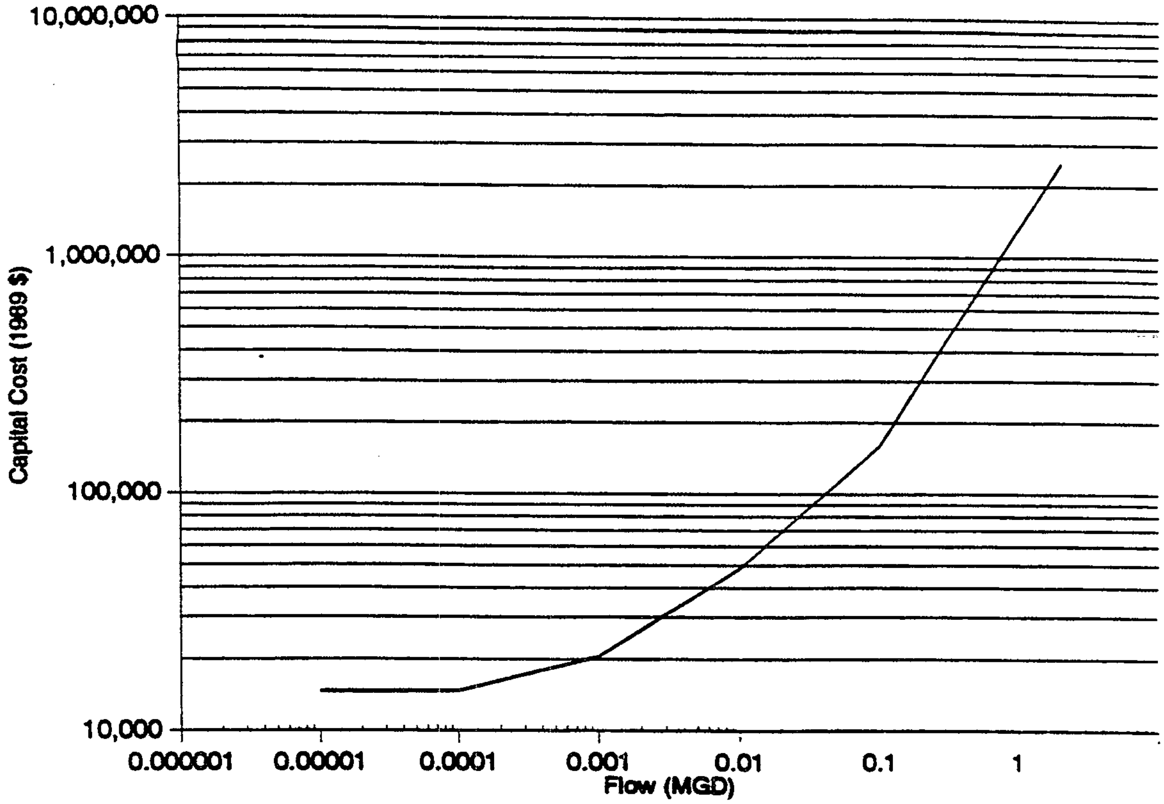

Figure 3-30 Plate & Frame Filtration (Liquid Stream) Capital Cost Curve - Metals Option 2

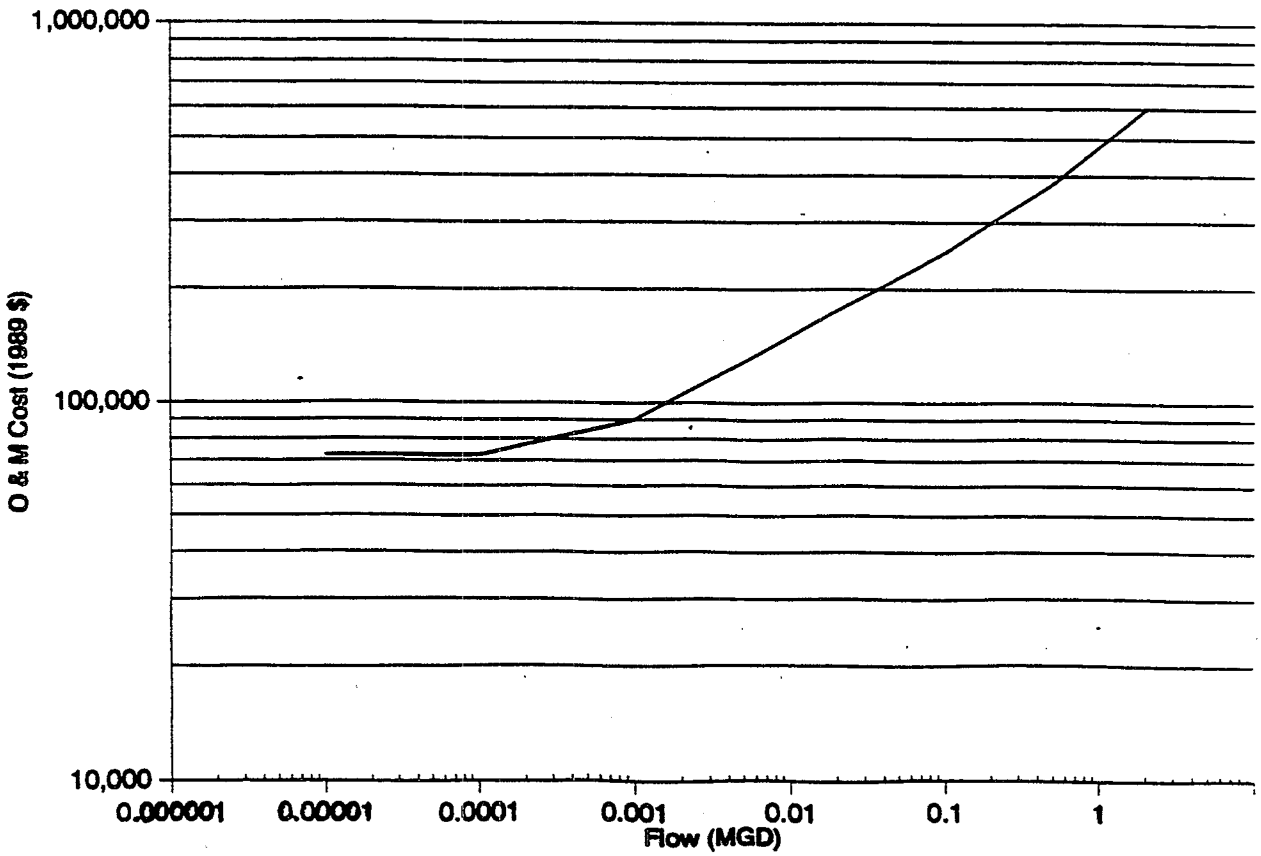

Figure 3-31 Plate & Frame Filtration (Liquid Stream) O & M Cost Curve - Metals Option 2

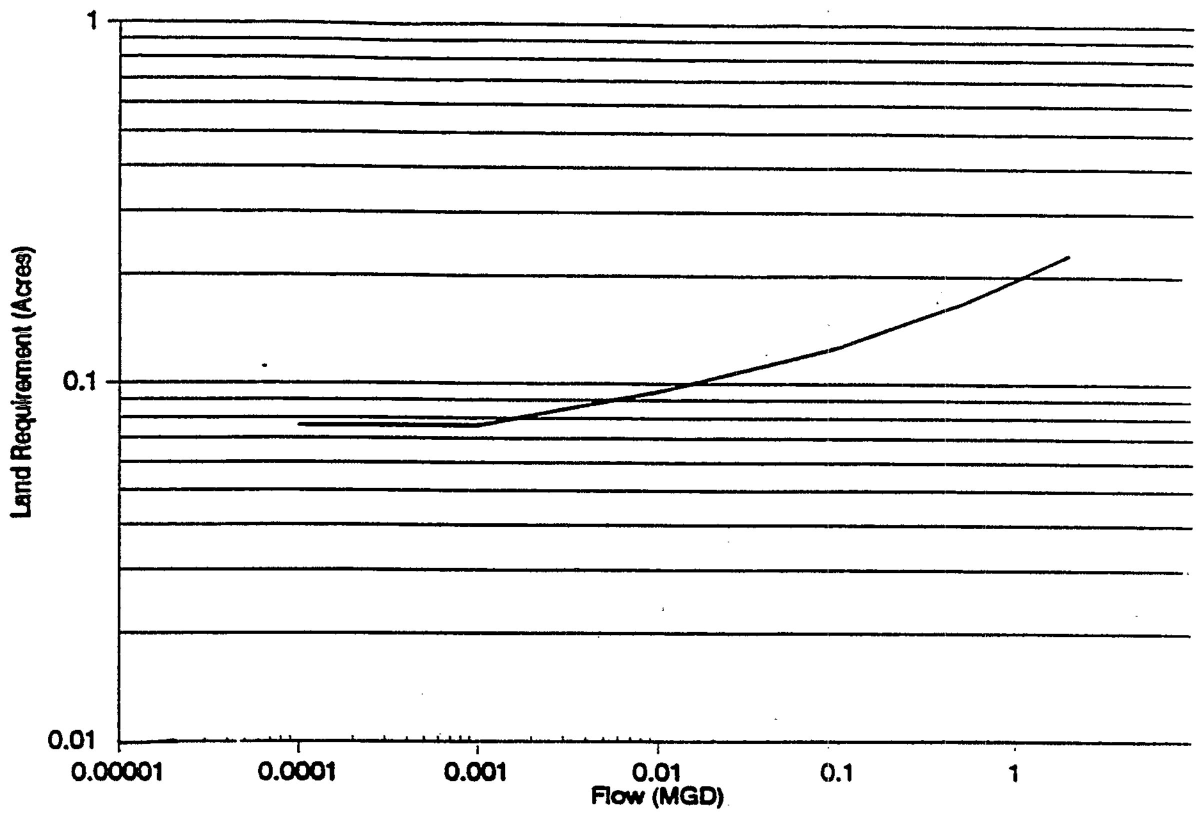

Figure 3-32 Plate & Frame Filtration (Liquid Stream) Land Requirement Curve - Metals Option 2

3.4 *EQUALIZATION*

Waste treatment facilities often need to equalize wastes by holding them in a tank for a period of time to get a stable waste stream which is easier to treat. In the CWT Industry, equalization is frequently used to minimize the variability of incoming wastes.

The equalization cost estimates and curves were obtained from OCPSF's use of the 1983 CAPDET program. The equalization process utilizes a mechanical aeration basin. The following default design parameters were used:

- Aerator mixing requirements = 0.03 hp per 1000 gallons;
- Oxygen requirements = 15.0 mg/l per hr;
- Dissolved oxygen in basin = 2.0 mg/l;
- Depth of basin = 6.0 feet; and
- Detention time = 24 hours.

The range of wastewater flows selected for these analyses was 0.001 to 5.0 MGD.

Capital costs were calculated based upon total project costs less: miscellaneous nonconstruction costs, 201 planning costs, technical costs, land costs, interest during construction, and laboratory costs. O & M costs were obtained directly from the initial year O & M costs. The capital and O & M costs were calculated in 1982 dollars and scaled up to 1989 dollars using ENR's construction index. The CAPDET capital and O & M cost equations for equalization systems are presented as Equations 3-35 and 3-36, respectively.

$$\ln(Y1) = 12.057 + 0.433\ln(X) + 0.043(\ln(X))^2 \qquad (3\text{-}35)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

$$\ln(Y2) = 11.723 + 0.311\ln(X) + 0.019(\ln(X))^2 \quad (3\text{-}36)$$

where:

Y2 = O & M Cost (1989 $).

The capital and O & M costs and land requirements are presented in Table 3-35, and the subsequent cost curves are shown in Figures 3-33 and 3-34, respectively.

Table 3-35. Capital and O & M Costs and Land Requirements for Equalization Systems

Flow Rate (MGD)	Capital Cost (1989 $)	O & M Cost (1989 $)	Land Requirement (acres)
0.001	59,800	33,400	0.0003
0.005	62,300	41,100	0.0015
0.01	64,200	45,400	0.003
0.05	73,200	59,100	0.015
0.10	80,680	67,600	0.03
0.50	119,100	97,500	0.15
0.75	137,900	108,700	0.34
1.0	155,100	117,900	0.46
1.5	215,900	137,900	0.69
2.0	222,200	150,200	0.92
3.0	309,600	178,100	1.38
4.0	352,900	202,200	1.84
5.0	423,500	226,900	2.30

To develop land requirements for the equalization systems, the CAPDET program was used. The requirements are scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.). The land equation for equalization systems is:

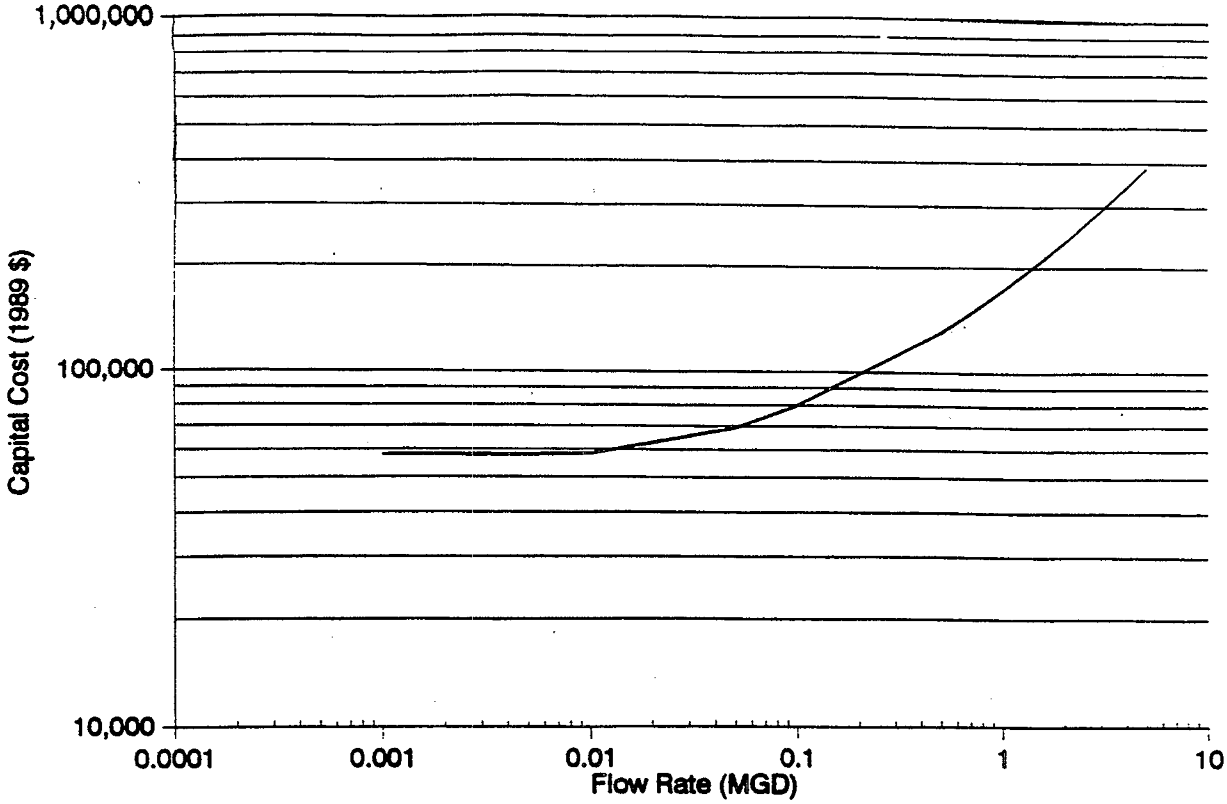

Figure 3-33 Capital Cost Curve for Equalization Systems

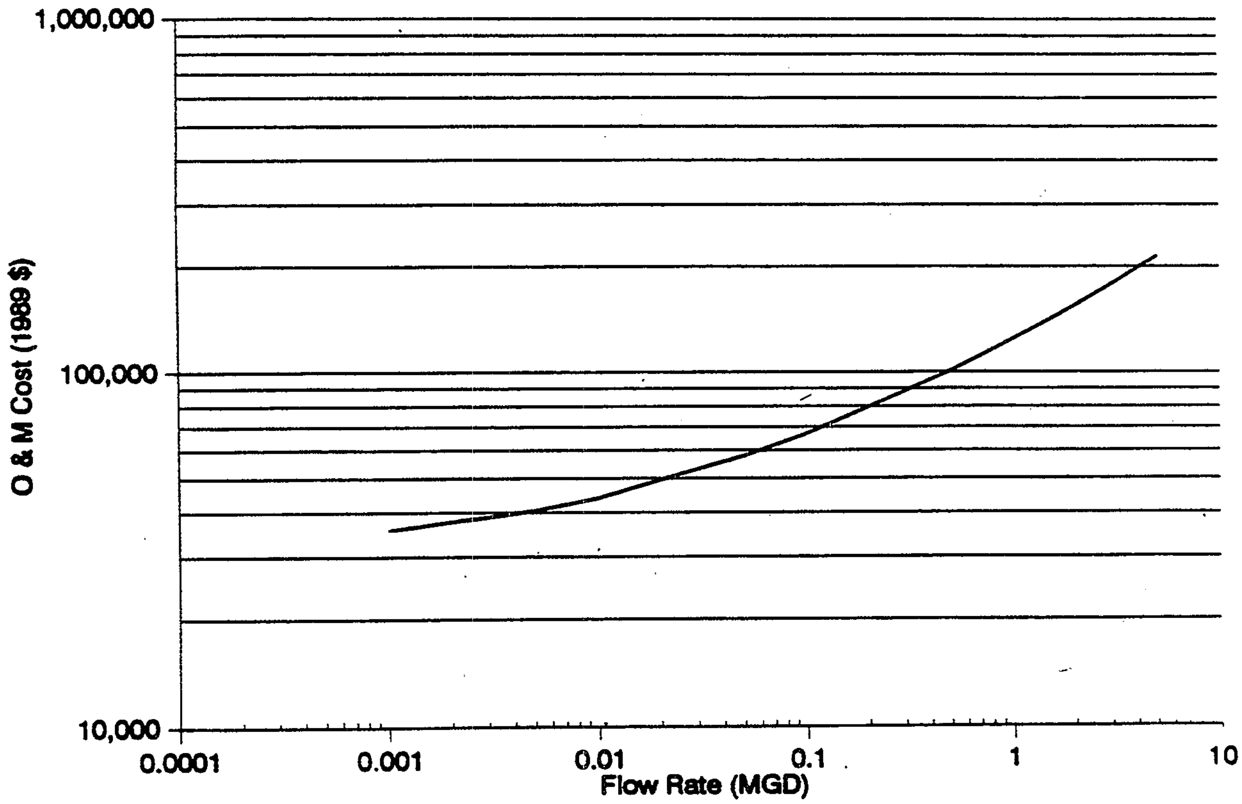

Figure 3-34 O & M Cost Curve for Equalization Systems

$$\ln(Y3) = -0.912 + 1.120\ln(X) + 0.011(\ln(X))^2 \quad (3\text{-}37)$$

where:

X = Flow Rate (MGD)

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 3-35.

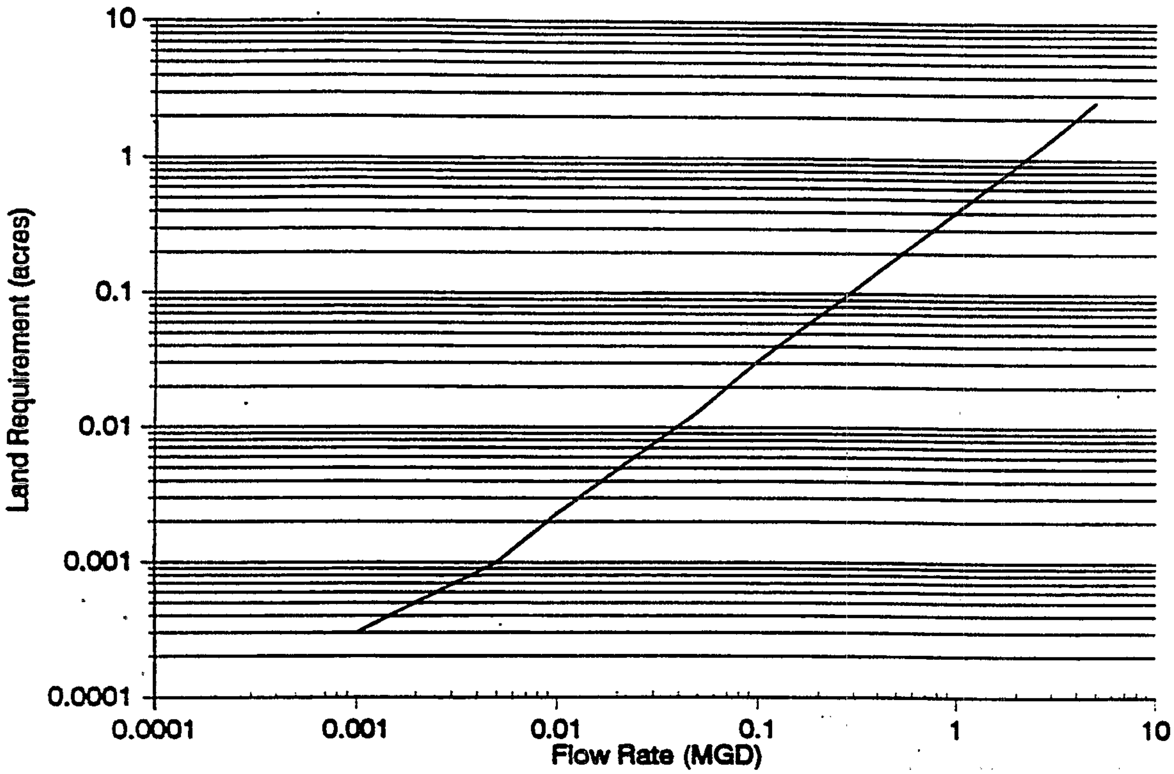

Figure 3-35 Land Requirement Curve for Equalization Systems

3.5 *AIR STRIPPING*

Air stripping is an effective wastewater treatment method for removing dissolved gases and highly volatile odorous compounds from wastewater streams by passing high volumes of air through an agitated gas-water mixture.

The capital cost curve for air strippers was obtained from four vendor services. Catalytic oxidizers were also included in the price of the capital cost for air pollution control purposes. The technology cost was based on removing medium volatile pollutants. The medium volatile pollutant 1,2-dichloroethane was used for the calculations, with an influent level of 4,000 µg/l and effluent level of 68 µg/l. The equipment costs were calculated on a flow rate range from 0.0001 MGD to 1.0 MGD. The air stripping unit costs included transfer pumps, control panels, blowers, and ancillary equipment. The costs from the vendors were averaged together in order to calculate a cost curve. The total capital cost included the cost for installation (35 percent of equipment cost), engineering (15 percent of equipment and installation cost), and contingency (15 percent of equipment and installation cost). The capital costs were calculated in 1992 dollars and scaled down to 1989 dollars using ENR's Construction Cost Index. The capital costs for the air strippers are listed in Table 3-36.

Table 3-36. Capital Costs for Air Stripping Systems

Flow (MGD)	System & Installation Cost (1989 $)	Engineering & Contingency	Total Capital Cost (1989 $)
0.0001	48,210	14,463	62,673
0.001	50,760	15,228	65,988
0.01	64,800	19,440	84,240
0.1	108,675	32,603	141,278
0.5	224,930	67,479	292,409
1.0	317,970	95,391	413,361

The O & M costs were determined by electricity usage, maintenance, labor, catalyst replacement, and taxes and insurance. The electricity usage and costs were provided by the vendors. The electricity usage for the air strippers was determined by the amount of horsepower needed to operate the systems. The electricity cost was estimated at $0.08 per kwhr. The energy needed to run the catalytic oxidizer is variable according to the type of system. Many of the systems regenerate a major portion of their heat and recycle their energy, cutting down on electricity costs. The electricity for the catalytic oxidizers were approximated at 50 percent of the electricity used for the air strippers. Maintenance was approximated at four percent of the total capital cost and taxes and insurance was two percent of the total capital cost. The labor cost for the air strippers was $31,200 per man-year at three hours per day. The catalysts used in the catalytic oxidizer are precious metal catalysts and their lifetime is approximately four years. Therefore, the catalyst beds are completely replaced about every four years. The costs for replacing the spent catalysts were divided by four to convert them to annual costs. The O & M costs were scaled down to 1989 dollars using ENR's cost index. The itemized annual O & M cost is presented in Table 3-37.

Table 3-37. O & M Costs for Air Stripping Systems

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Catalyst Replacement Cost	Total O & M Cost (1992 $)	Total O & M Cost (1989 $)
0.0001	1,050	1,928	964	16,425	33	20,400	19,176
0.001	1,575	2,030	1,015	16,425	50	21,095	19,829
0.01	2,100	2,592	1,296	16,425	102	22,515	21,164
0.1	5,250	4,347	2,174	16,425	500	28,696	26,974
0.5	11,812	9,000	4,500	16,425	1500	43,237	40,643
1.0	21,000	12,720	6,360	16,425	4250	60,755	57,110

The capital and O & M cost equations for the air stripping systems are presented as Equations 3-38 and 3-39, with their subsequent cost curves presented in Figures 3-36 and 3-37, respectively.

$$\ln(Y1) = 12.899 + 0.486\ln(X) + 0.031(\ln(X))^2 \qquad (3\text{-}38)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

$$\ln(Y2) = 10.865 + 0.298\ln(X) + 0.021(\ln(X))^2 \qquad (3\text{-}39)$$

where:

Y2 = O & M Cost (1989 $).

To develop land requirements for the air stripping and catalytic oxidizer systems, the vendor data was used. The dimensions of the air strippers, in terms of length and width, are very small compared to the catalytic oxidizers. The land requirement equation for the air stripping systems is:

$$\ln(Y) = -2.207 + 0.536\ln(X) + 0.042(\ln(X))^2 \qquad (3\text{-}40)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 3-38.

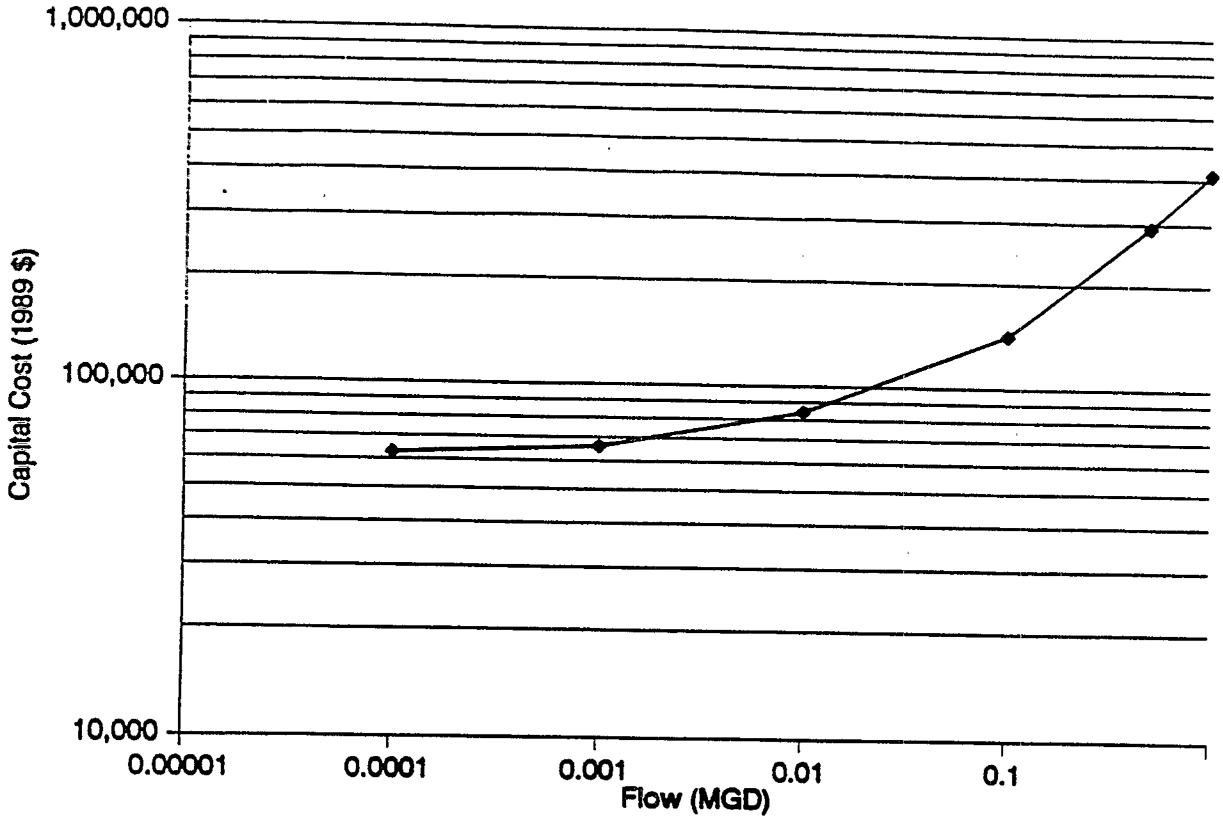

Figure 3-36 Capital Cost Curve for Air Strippers

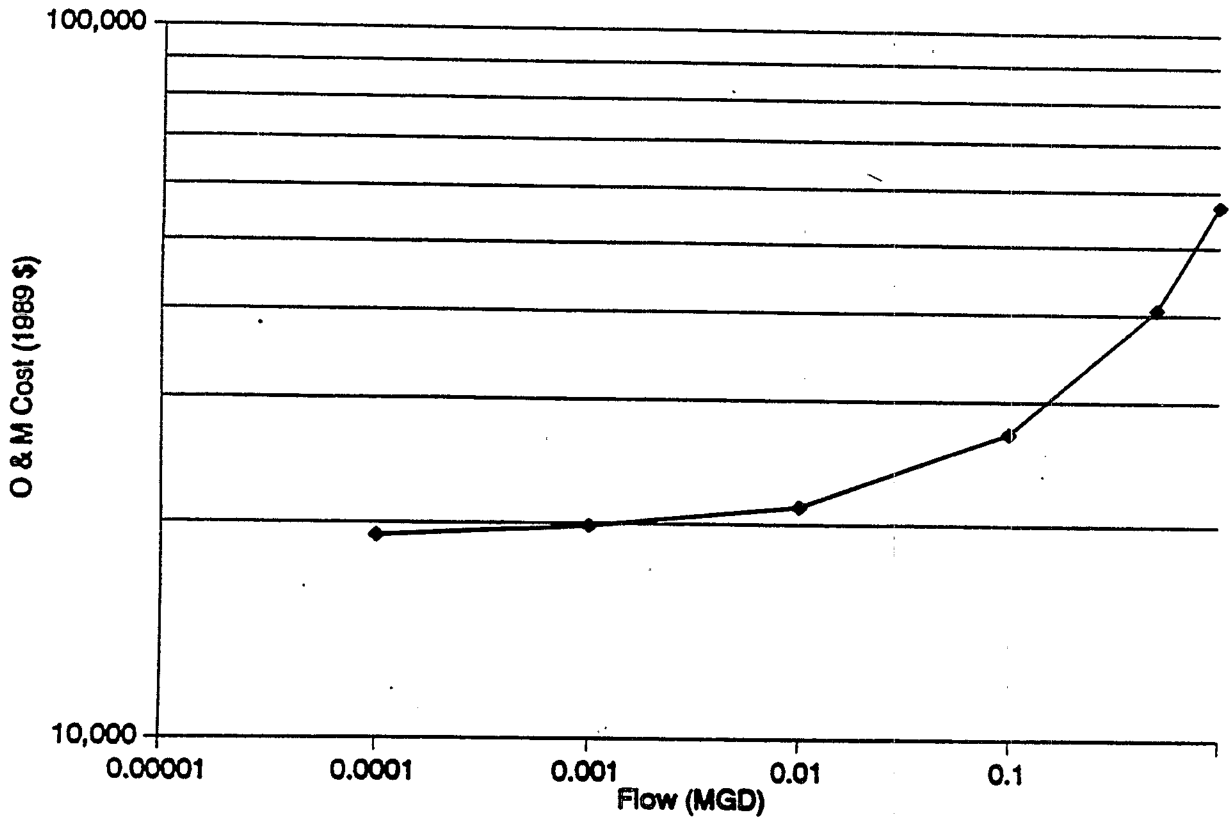

Figure 3-37 O & M Cost Curve for Air Strippers

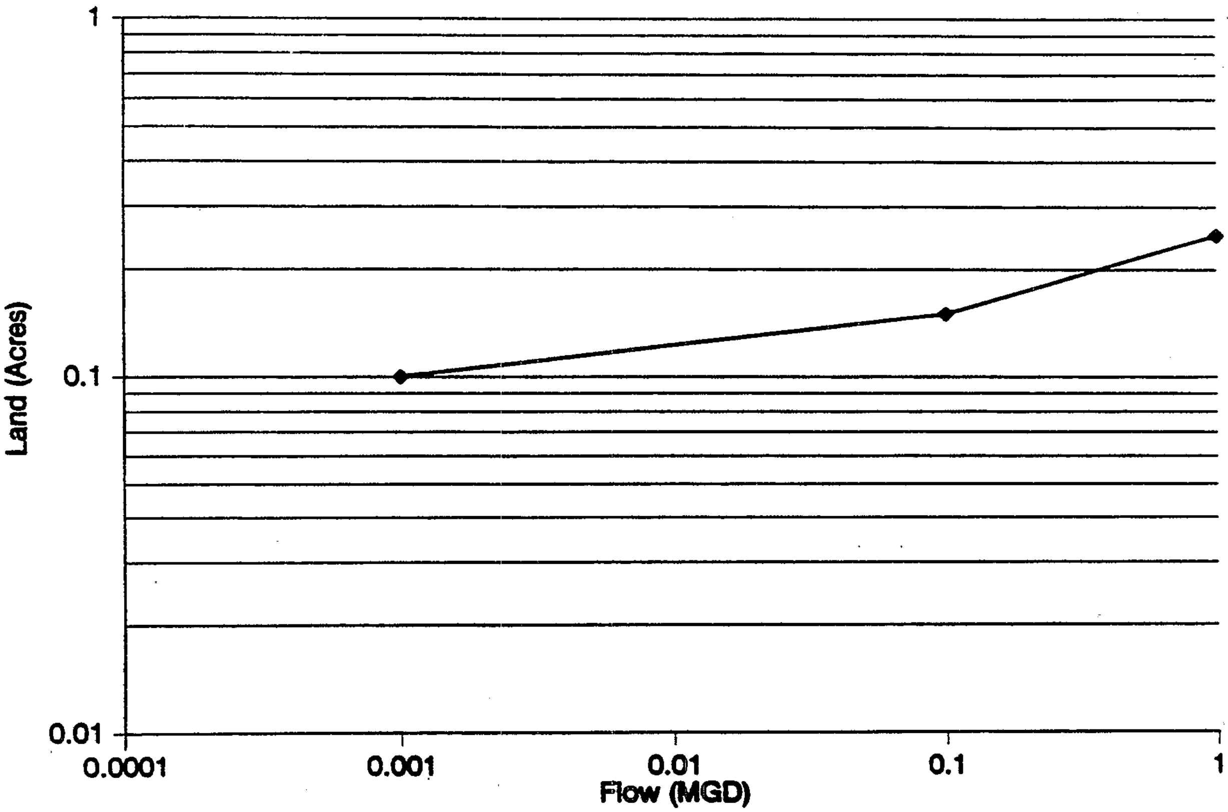

Figure 3-38 Land Requirement Curve for Air Strippers

3.6 *MULTI-MEDIA FILTRATION*

Filtration is a proven technology for the removal of residual suspended solids from wastewater. The media used in the CWT multi-media filtration process are sand and anthracite coal, supported by gravel. Large particulate matter is captured by the coarse, lighter media near the top of the filter bed. Smaller particles continue down to the lower media level, where particles as small as 10 microns are retained by the finer, heavier media. The density differences between the media allows for layer separation after backwashing. Flow controls are self-adjusting to regulate treatment and backwash rates regardless of fluctuations in water pressure, thus helping to prevent a loss of filter media from the tank.

The capital and O & M costs for the multi-media filtration systems were obtained from a vendor service. The design average influent total suspended solids design concentration used was 165 mg/l. The design average effluent total suspended solids concentration was 124 mg/l. The system costs were calculated for a flow rate range from 0.001 to 1.0 MGD.

The total capital cost curves for the multi-media filtration systems were estimated using the vendor quotes and represent equipment and installation costs. The total construction cost includes the costs of the filter, instrumentation and controls, pumps, piping, and installation. Installation, installed piping, and instrumentation and controls are estimated at 50 percent, 60 percent, and 30 percent of the filter system equipment cost, respectively. The total capital costs include the cost for engineering (15 percent of construction cost) and contingency (15 percent of construction cost). The capital costs were scaled down to 1989 dollars using ENR's construction cost index. The itemized capital costs are listed in Table 3-38.

The O & M costs include energy usage, maintenance, labor, and taxes and insurance. Energy is the cost of electricity to run the pumps, lighting, and instrumentation and controls. Pumping costs were based on power requirements of 0.5 kwhr per 1,000 gallons per pump, which includes feed, booster, and metering pumps. The cost of electricity was $0.08 per kwhr. The maintenance was approximated at four percent of the

Table 3-38. Capital Costs for Multi-Media Filtration Systems

Flow Rate (MGD)	System Cost	Installation	Piping	Instrument. & Controls	Engineering & Contingency	Total Capital Cost (1993$)	Total Capital Cost (1989 $)
0.001	1,522	761	913	457	1,096	4,749	4,322
0.01	1,942	971	1,165	583	1,398	6,059	5,514
0.05	3,237	1,619	1,942	971	2,331	10,100	9,191
0.10	5,904	2,952	3,542	1,771	4,251	18,420	16,762
0.50	13,098	6,549	7,859	3,929	9,431	40,866	37,188
1.0	27,866	13,933	16,720	8,360	20,064	86,943	79,118

Table 3-39. O & M Costs for Multi-Media Filtration Systems

Flow Rate (MGD)	Energy	Labor	Maintenance	Taxes & Insurance	Total O & M Cost (1993$)	Total O & M Cost (1989$)
0.001	1,100	21,900	173	87	23,260	21,167
0.01	1,600	21,900	221	111	23,832	21,687
0.05	1,730	21,900	368	184	24,182	22,006
0.10	7,000	21,900	670	335	29,905	27,214
0.50	31,200	21,900	1,488	744	55,332	50,352
1.0	70,000	21,900	3,165	1,583	96,648	87,950

total capital cost and taxes and insurance were two percent of the total capital cost. The labor cost for the multi-media filtration system was $31,200 per man-year at four hours per day. The O & M costs were scaled down to 1989 dollars using ENR's cost index. The itemized O & M costs are presented in Table 3-39.

The vendor capital and O & M cost equations for the multi-media filtration systems are presented as Equations 3-41 and 3-42, respectively. The capital cost and O & M cost curves are presented in Figure 3-39 and 3-40, respectively.

$$\ln(Y1) = 11.218 + 0.865\ln(X) + 0.066(\ln(X))^2 \qquad (3\text{-}41)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

$$\ln(Y2) = 11.290 + 0.580\ln(X) + 0.057(\ln(X))^2 \qquad (3\text{-}42)$$

where:

Y2 = O & M Cost (1989 $).

To develop land requirements for multi-media filtration systems, overall system dimensions were provided by the vendor. The land dimensions were scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.). The equation relating the flow of the system with the land requirement for the multi-media filtration systems is:

$$\ln(Y3) = -2.971 + 0.097\ln(X) + 0.008(\ln(X))^2 \qquad (3\text{-}43)$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 3-41.

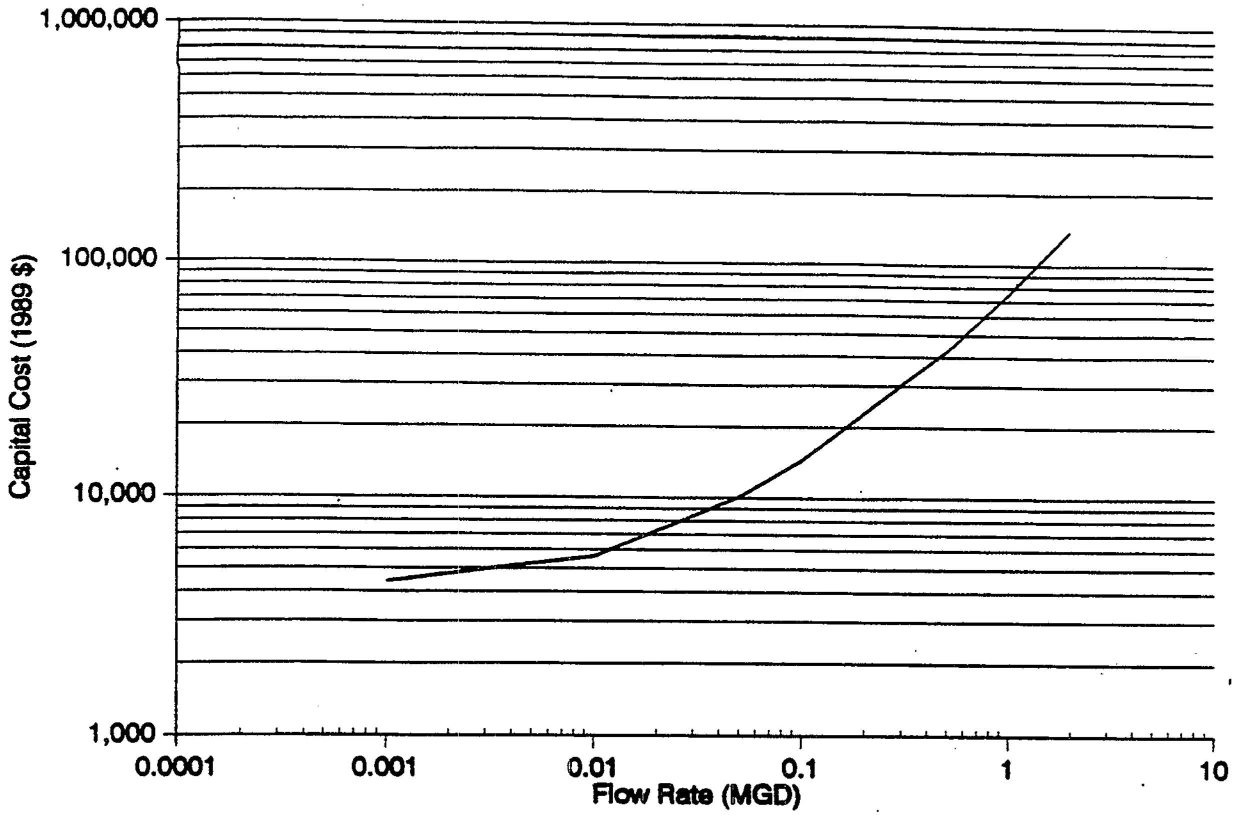

Figure 3-39 Capital Cost Curve for Multi-Media Filtration Systems

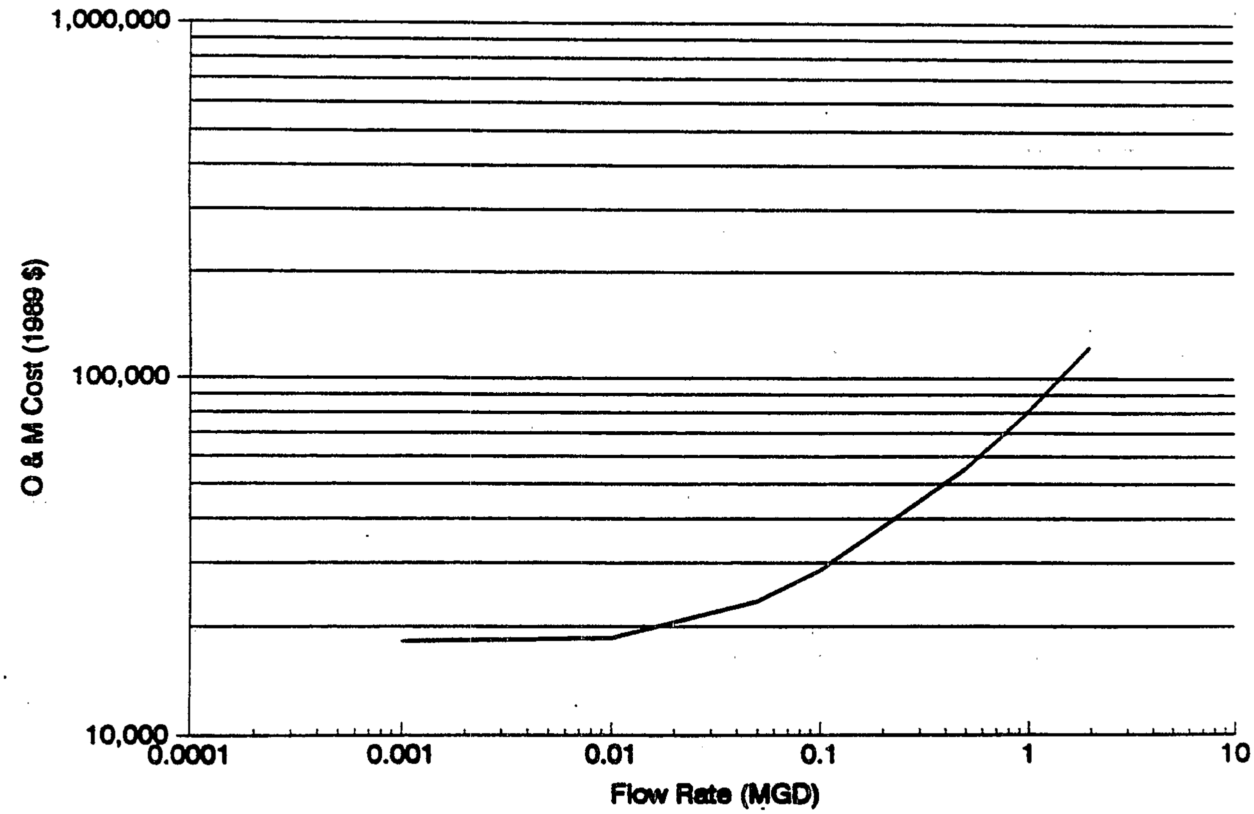

Figure 3-40 O & M Cost Curve for Multi-Media Filtration Systems

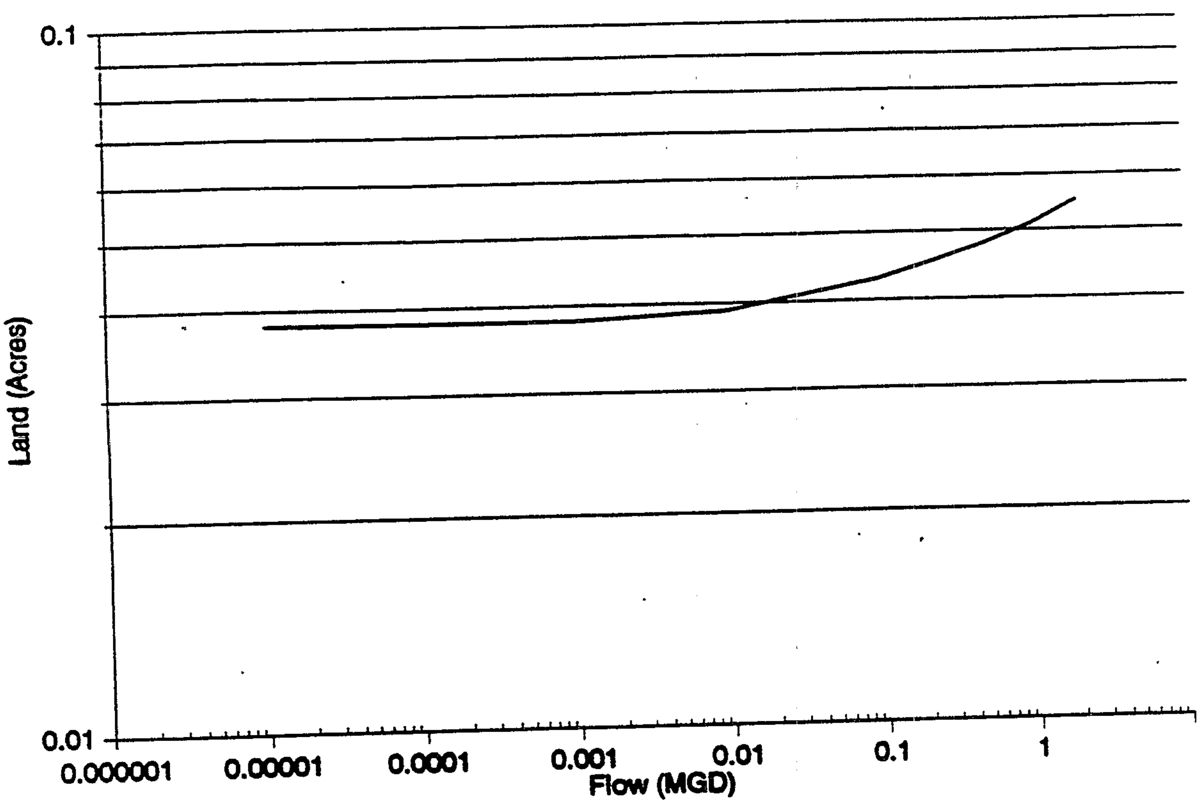

Figure 3-41 Land Requirement Curve for Multi-Media Filtration Systems

3.7 *CARBON ADSORPTION*

Activated carbon adsorption is an effective treatment technology for the removal of organic pollutants from wastewater. It is included in Oils Options 3 and 4 and Organics Option 2. The considered application for the CWT Industry is granular activated carbon (GAC) in column reactors. The equipment consists of two beds operated in series. This configuration allows the beds to go to exhaustion and be replaced on a rotating basis.

The GAC capital costs are based on vendor quotations and are the same for all of the regulatory options considered. The capital costs consist of the adsorber construction cost, initial carbon fill, freight, and supervision. The vendor prices were increased by 35 percent to account for installation costs. Engineering and contingency costs were then added; these were each approximated at 15 percent of the subtotal equipment and installation costs. The 1993 costs were scaled down to 1989 dollars using ENR's Construction Cost Index.

The itemized capital costs for all option GAC systems are presented in Table 3-40.

Table 3-40. Capital Costs for Activated Carbon Systems

Flow (MGD)	Carbon Fill (lb)	Equipment Cost ($1993)	Equipment & Installation	Installation & Eng. & Contingency	Total Capital Cost ($1989)
0.00001	5	500	675	878	799
0.00008	40	500	675	878	799
0.0001	50	500	675	878	799
0.001	500	1,500	2,025	2,633	2,396
0.008	4,000	60,000	81,000	105,300	95,823
0.04	20,000	120,000	162,000	210,600	191,646
0.08	40,000	190,000	256,500	333,450	303,440
0.16	80,000	380,000	513,000	666,900	606,879
0.24	120,000	570,000	769,500	1,000,350	910,319

The capital cost curve for all option GAC systems is presented in Figure 3-42. The GAC capital cost equation for all options is:

$$\ln(Y1) = 15.956 + 1.423\ln(x) + 0.050(\ln(X))^2 \qquad (3\text{-}44)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

The O & M costs are primarily attributed to carbon usage. The key design parameter is adsorption capacity; this is a measurement of the mass of pollutant adsorbed per unit mass of carbon. For each regulatory option system, the pollutants of concern and their associated removals were tabulated. Using the adsorption capacities, the specific carbon requirements were calculated. The carbon usage for each option was scaled down by one-third; this accounts for the series-bed design of the systems. The pollutant performance data and carbon requirements for Oils Options 3 and 4 and Organics Option 2 are presented in Tables 3-41, 3-42, and 3-43, respectively.

The total O & M cost components are electricity, maintenance, labor, freight, and taxes and insurance, in addition to the carbon usage. The electricity requirement is approximated at 0.3 kwhr per 1,000 gallons of wastewater at a cost of $0.08 per kwhr. Maintenance is estimated at five percent of the total capital cost and the taxes and insurance line item is calculated at two percent of the total capital cost. GAC is sold by the vendor in bulk at $0.70 per pound. The freight cost for shipping the carbon is dependent upon the amount of carbon and the distance that it is shipped. The average freight cost used is $3,000 per 20,000 pound shipment. Labor requirements are three hours per day at a rate of $30,000 per man-year. The costs were calculated in 1993 dollars and were scaled down to 1989 dollars using ENR's Construction Cost Index.

The itemized O & M costs for Oils Options 3 and 4 and Organics Option 2 are presented in Tables 3-44, 3-45, and 3-46, respectively. The respective O & M cost curves are shown in Figures 3-43, 3-44, and 3-45. The O & M cost equations for the Oils option 3, Oils Option 4, and Organics Option 2 carbon adsorption systems are presented

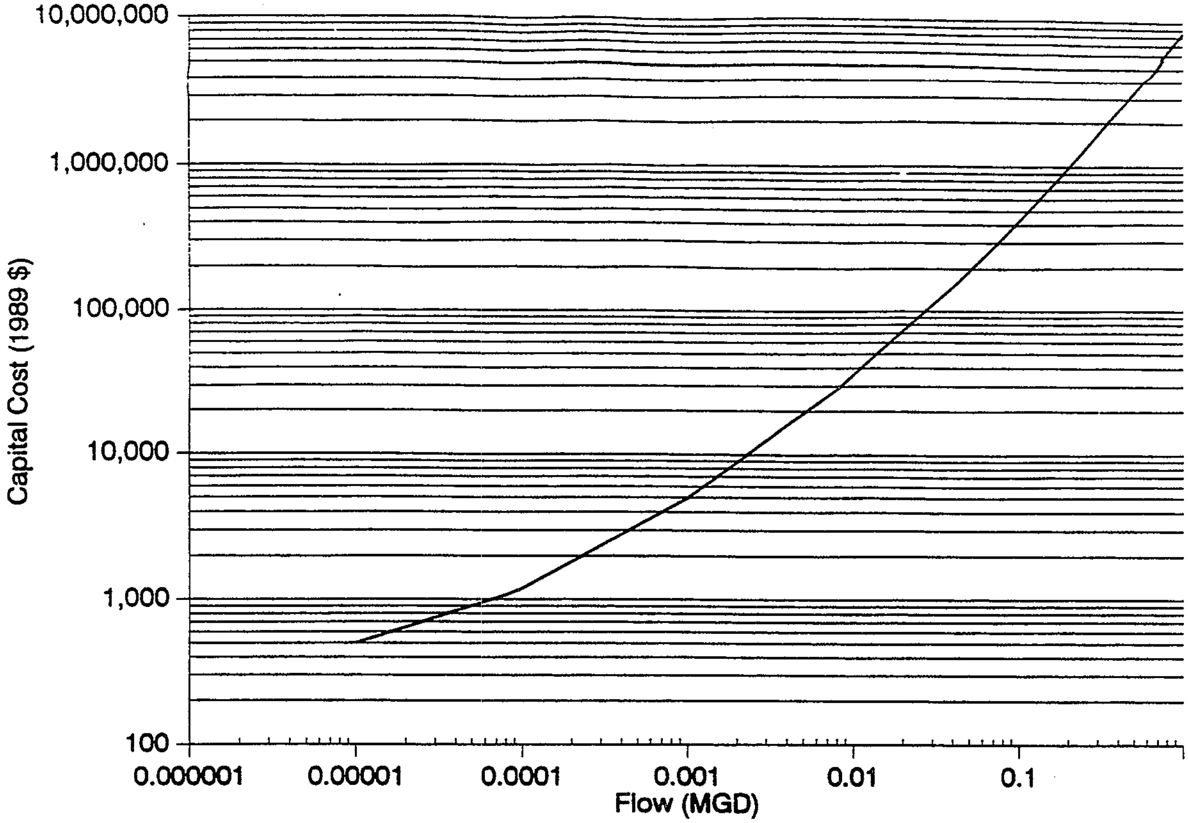

Figure 3-42 Capital Cost Curve for Activated Carbon Systems

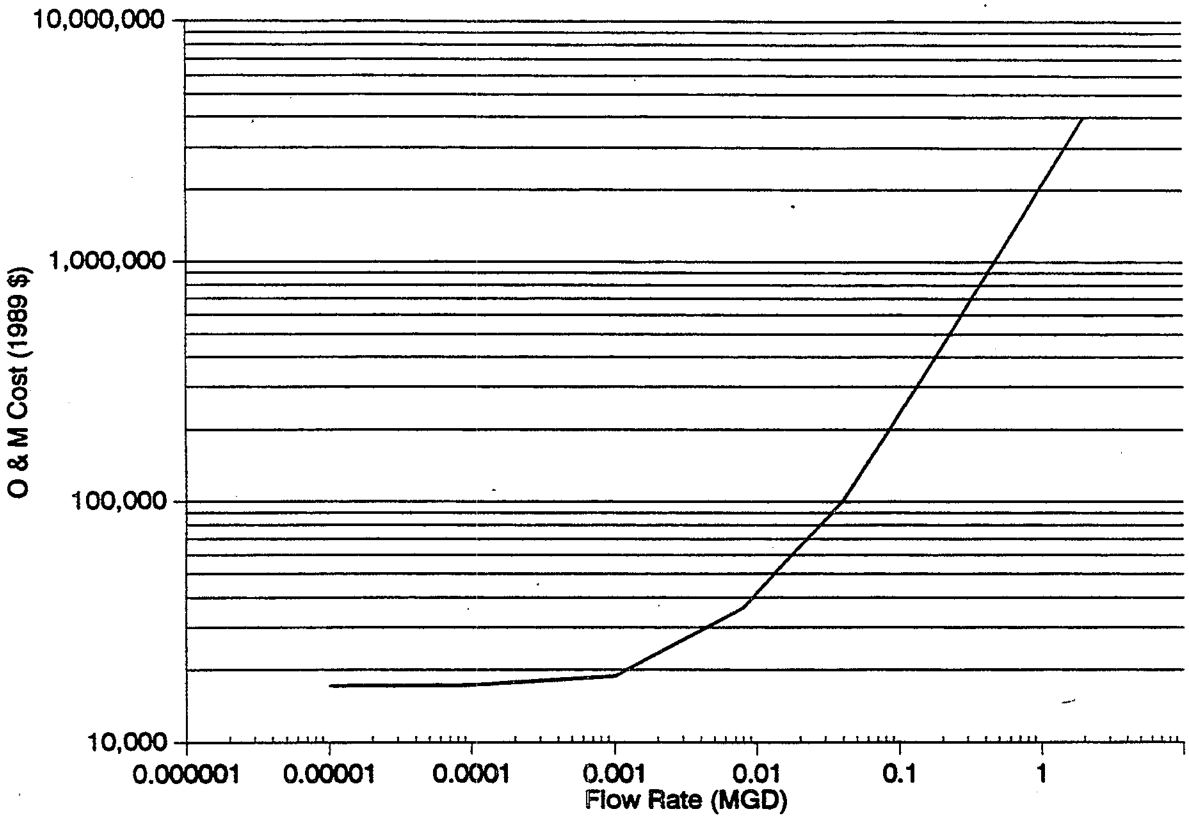

Figure 3-43 O & M Cost Curve for Activated Carbon - Oils Option 3

Table 3-41. Activated Carbon Performance Data - Oils Option 3

Pollutant	Option 3 Influent (µg/l)	Option 3 Effluent (µg/l)	Pollutant Removal (µg/l)	Carbon Usage (g/l)
1,1,1-Trichloroethane	776	252	524	0.338
2-Butanone	1,426	1,469	-	-
2-Propanone	15,724	22,321	-	-
4-Chloro-3-methylphenol	4,025	332	3,693	0.036
Benzene	5,817	2,019	3,799	0.174
Benzoic acid	30,467	15,137	-	-
Ethylbenzene	734	78	656	0.093
Hexanoic Acid	7,595	5,741	1,854	0.017
Methylene Chloride	1,281	1,040	247	0.182
m-Xylene	1,019	69	950	0.019
n-Decane	64 (ND)	28	(ND)	-
n-Docosane	64 (ND)	28	(ND)	-
n-Dodecane	64 (ND)	28	(ND)	-
n-Eicosane	64 (ND)	28	(ND)	-
n-Hexacosane	64 (ND)	28	(ND)	-
n-Hexadecane	64 (ND)	28	(ND)	-
n-Octadecane	64 (ND)	45	(ND)	-
n-Tetradecane	64 (ND)	28	(ND)	-
o+p-Xylene	557	54	503	0.010
Phenol	1,753	1,062	691	0.032
Tetrachloroethene	100	46	54	0.006
Toluene	11,183	2,043	9,140	0.256
Tripropyleneglycol Methyl Ether	99,101	44,915	54,186	0.028
Total	182,070	96,818	76,297	1.191

Table 3-42. Activated Carbon Performance Data - Oils Option 4

Pollutant	Option 4 Influent (µg/l)	Option 4 Effluent (µg/l)	Pollutant Removal (µg/l)	Carbon Usage (g/l)
1,1,1-Trichloroethane	90	8	82	0.171
2-Butanone	1,718	1,866	-	-
2-Propanone	17,529	13,777	16,752	0.002
4-Chloro-3-Methylphenol	331	10	321	0.005
Benzene	1,002	10	992	0.361
Benzoic Acid	2,928	50	2,878	0.199
Ethylbenzene	47	10	37	0.027
Hexanoic Acid	1,796	10	1,786	0.242
Methylene Chloride	497	251	246	0.941
m-Xylene	42	10	32	0.0009
n-Decane	28 (ND)	10	(ND)	-
n-Docosane	28 (ND)	10	(ND)	-
n-Dodecane	28 (ND)	10	(ND)	-
n-Eicosane	28 (ND)	10	(ND)	-
n-Hexacosane	28 (ND)	10	(ND)	-
n-Hexadecane	28 (ND)	10	(ND)	-
n-Octadecane	28 (ND)	10	(ND)	-
n-Tetradecane	28 (ND)	10	(ND)	-
o+p-Xylene	25	10	15	0.0004
Phenol	1,217	10	1,207	0.691
Tetrachloroethene	10 (ND)	6	(ND)	-
Toluene	980	11	969	0.270
Tripropyleneglycol Methyl Ether	23,852	99	23,753	0.795
Total	52,287	16,218	49,070	3.678

Table 3-43. Activated Carbon Performance Data - Organics Option 2

Pollutant	Option 2 Influent (µg/l)	Option 2 Effluent (µg/l)	Pollutant Removal (µg/l)	Carbon Usage (g/l)
1,1,1,2-Tetrachloroethane	10 (ND)	10 (ND)	(ND)	-
1,1,1-Trichloroethane	16 (ND)	10 (ND)	(ND)	-
1,1,2-Trichloroethane	155	10 (ND)	145	0.396
1,1-Dichloroethane	10 (ND)	10 (ND)	(ND)	-
1,1-Dichloroethene	23	10 (ND)	13	0.083
1,2,3-Trichloropropane	12	10 (ND)	2	0.031
1,2-Dibromoethane	10 (ND)	10 (ND)	(ND)	-
1,2-Dichlorobenzene	10 (ND)	10 (ND)	(ND)	-
1,2-Dichloroethane	23	10 (ND)	13	0.166
2,3,4,6-Tetrachlorophenol	3,735	20 (ND)	3,715	0.778
2,3-Dichloroaniline	72	89	-	-
2,4,5-Trichlorophenol	378	10 (ND)	368	0.006
2,4,6-Trichlorophenol	735	10 (ND)	725	0.013
2,4-Dimethylphenol	10 (ND)	10 (ND)	(ND)	-
2-Butanone	745	65	680	1.250
2-Chlorophenol	28 (ND)	10 (ND)	(ND)	-
2-Hexanone	50 (ND)	50 (ND)	(ND)	-
2-Picoline	68	58	10	na
2-Propanone	1,130	1,183	-	-
4-Methyl-2-Pentanone	65	50 (ND)	15	0.002
Acetophenone	10 (ND)	10 (ND)	(ND)	-
Benzene	10 (ND)	10 (ND)	(ND)	-
Benzoic Acid	140 (ND)	50 (ND)	(ND)	-
Benzyl Alcohol	10 (ND)	10 (ND)	(ND)	-
Bromodichloromethane	10 (ND)	10 (ND)	(ND)	-
Carbon Disulfide	82	77	5	na
Chlorobenzene	10 (ND)	10 (ND)	(ND)	-

Table 3-43 (Cont.) Activated Carbon Performance Data - Organics Option 2

Pollutant	Option 2 Influent (µg/l)	Option 2 Effluent (µg/l)	Pollutant Removal (µg/l)	Carbon Usage (g/l)
Chloroform	439	10	429	4.759
Diethyl Ether	50 (ND)	50 (ND)	(ND)	-
Ethylbenzene	10 (ND)	10 (ND)	(ND)	-
Hexanoic Acid	146	141	5	0.0002
Isophorone	10 (ND)	10 (ND)	(ND)	-
Methylene Chloride	887	130	757	6.208
m-Xylene	10 (ND)	10 (ND)	(ND)	-
Naphthalene	10 (ND)	10 (ND)	(ND)	-
n,n-Dimethylformamide	50	69	-	-
o+p-Xylene	10 nd)	10 (ND)	(ND)	-
o-Cresol	15	16	-	-
Pentachlorophenol	1,716	50 (ND)	1,666	0.021
Phenol	243	10 (ND)	233	0.133
Pyridine	117	25	92	0.010
p-Cresol	28 (ND)	10 (ND)	(ND)	-
Tetrachloroethene	472	12	460	0.108
Tetrachloromethane	10 (ND)	10 (ND)	(ND)	-
Toluene	10 (ND)	10 (ND)	(ND)	-
trans-1,2-Dichloroethene	92	10 (ND)	82	0.282
Trichloroethene	721	12	709	0.393
Trichlorofluoromethane	20	19	1	0.0005
Vinyl Chloride	43	10 (ND)	33	0.212
Total	12,665	2,465	10,290	14.856

Table 3-44. O & M Costs for Activated Carbon Systems - Oils Option 3

Flow (MGD)	Energy (1993 $)	Mainten. (1993 $)	Labor (1993 $)	Taxes & Insurance (1993 $)	Carbon Usage (1993 $)	Carbon Shipping (1993 $)	Total O & M Cost (1993 $)	Total O & M Cost (1989 $)
0.00001	1	44	15,793	18	17	3,000	18,873	17,174
0.00008	1	44	15,793	18	135	3,000	18,991	17,282
0.0001	1	44	15,793	18	169	3,000	19,025	17,313
0.001	9	132	15,793	53	1,693	3,000	20,680	18,818
0.008	70	5,265	15,793	2,106	13,544	3,000	39,778	36,198
0.04	350	10,530	15,793	4,212	67,717	12,000	110,602	100,648
0.08	701	16,673	15,793	6,669	135,435	30,000	205,271	186,797
0.16	1,402	33,345	15,793	13,338	270,870	60,000	394,748	359,221
0.24	2,102	50,018	15,793	20,007	406,305	87,000	581,225	528,915

Table 3-45. O & M Costs for Activated Carbon Systems - Oils Option 4

Flow (MGD)	Electricity (1993 $)	Maint. (1993 $)	Labor (1993 $)	Taxes & Insurance (1993 $)	Carbon Usage (1993 $)	Carbon Shipping (1993 $)	Total O & M Cost (1993 $)	Total O & M Cost (1989 $)
0.00001	1	44	15,793	18	53	3,000	18,909	17,207
0.00008	1	44	15,793	18	418	3,000	19,274	17,539
0.0001	1	44	15,793	18	523	3,000	19,379	17,635
0.001	9	132	15,793	53	5,228	3,000	24,215	22,036
0.008	70	5,265	15,793	2,106	41,825	9,000	74,059	67,394
0.04	350	10,530	15,793	4,212	209,123	45,000	285,008	259,357
0.08	701	16,673	15,793	6,669	418,245	90,000	548,081	498,754
0.16	1,402	33,345	15,793	13,338	836,491	180,000	1,080,369	983,136
0.24	2,102	50,018	15,793	20,007	1,254,736	270,000	1,612,656	1,467,517

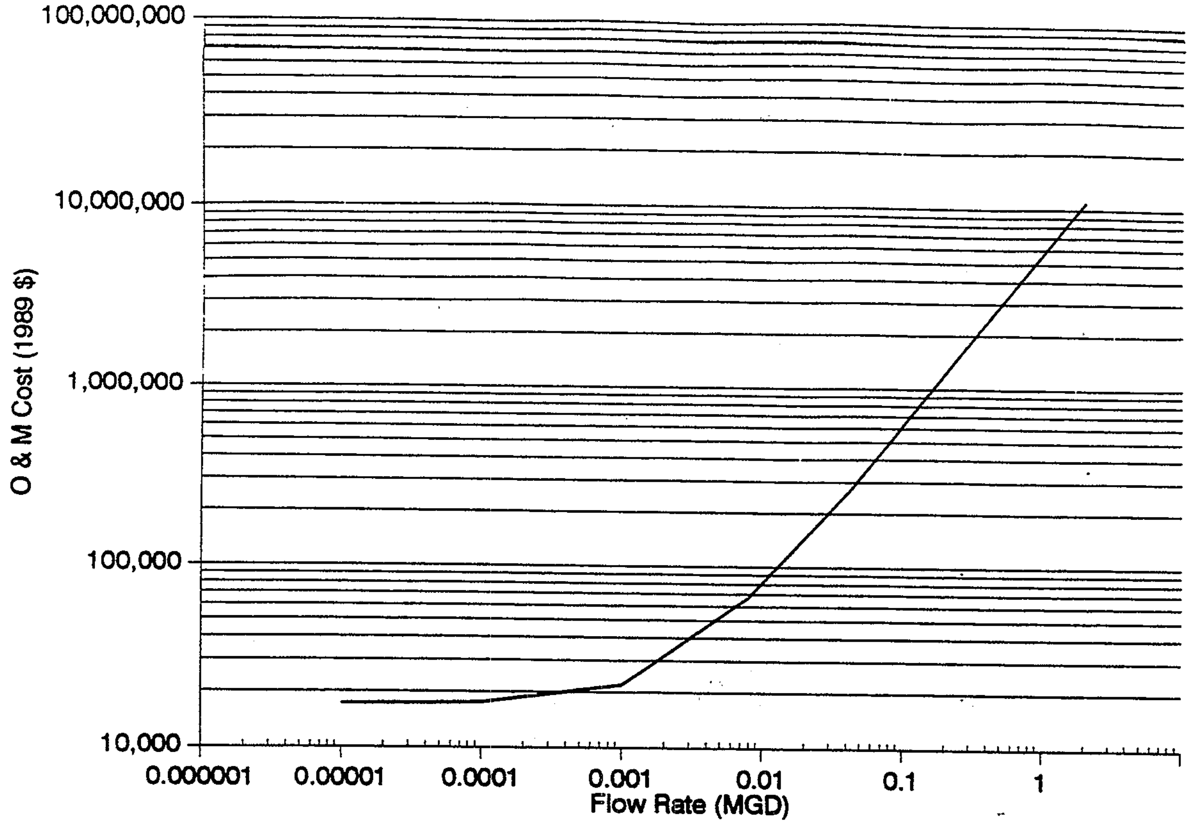

Figure 3-44 O & M Cost Curve for Activated Carbon - Oils Option 4

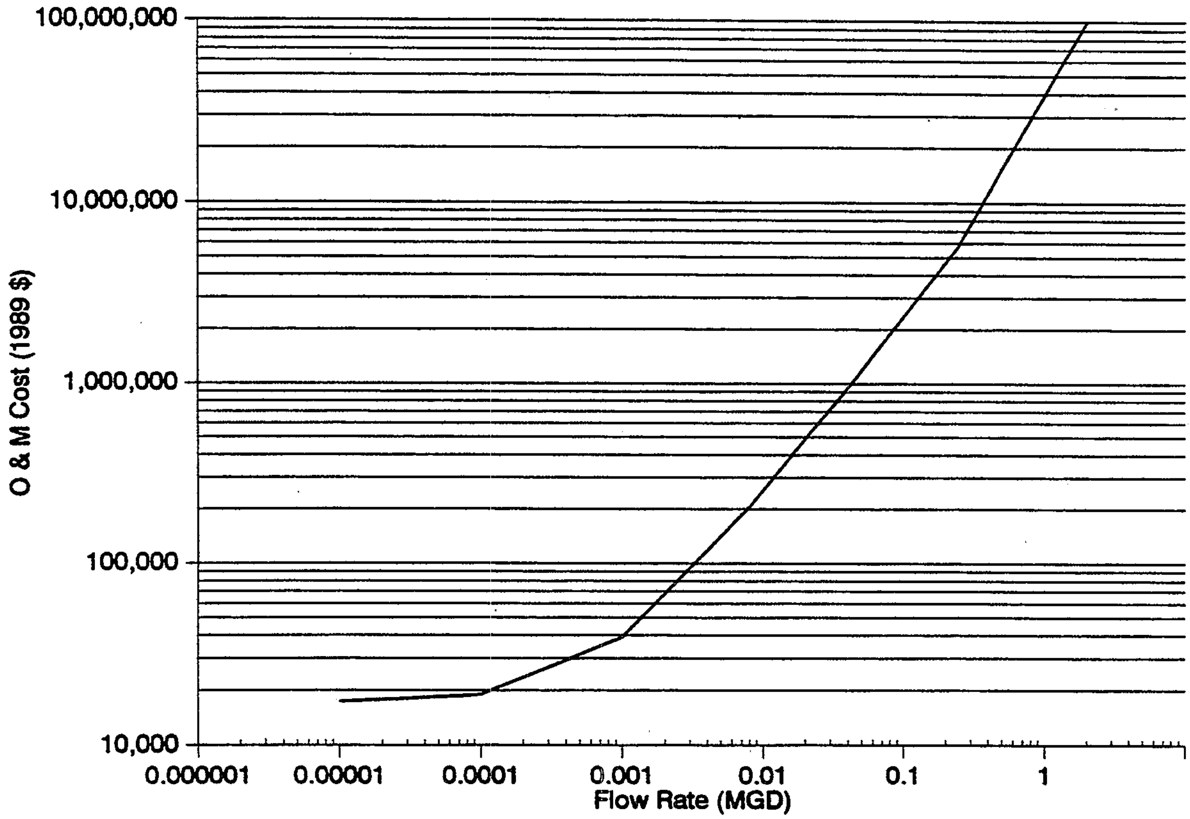

Figure 3-45 O & M Cost Curve for Activated Carbon - Organics Option 2

as Equations 3-45, 3-46, and 3-47, respectively.

$$\ln(Y2) = 14.516 + 1.086\ln(X) + 0.060(\ln(X))^2 \quad (3\text{-}45)$$

$$\ln(Y2) = 15.949 + 1.310\ln(X) + 0.068(\ln(X))^2 \quad (3\text{-}46)$$

$$\ln(Y2) = 17.621 + 1.455\ln(X) + 0.067(\ln(X))^2 \quad (3\text{-}47)$$

where:

X = Flow Rate (MGD) and

Y2 = O & M Cost (1989 $).

Table 3-46. O & M Costs for Activated Carbon Systems - Organics Option 2

Flow (MGD)	Energy (1993 $)	Maint. (1993 $)	Labor (1993 $)	Taxes & Insurance (1993 $)	Carbon Usage (1993 $)	Carbon Shipping (1993 $)	Total O&M Cost (1993 $)	Total O&M Cost (1989 $)
0.00001	1	44	15,793	18	210	3,000	19,066	17,350
0.00008	1	44	15,793	18	1,680	3,000	20,536	18,688
0.0001	1	44	15,793	18	2,100	3,000	20,956	19,070
0.001	9	132	15,793	53	21,000	6,000	42,987	39,118
0.008	70	5,265	15,793	2,106	168,000	36,000	227,234	206,783
0.04	350	10,530	15,793	4,212	840,187	180,000	1,051,072	956,476
0.08	701	16,673	15,793	6,669	1,680,373	360,000	2,080,209	1,892,990
0.16	1,402	33,345	15,793	13,338	3,360,747	720,000	4,144,625	3,771,609
0.24	2,102	50,018	15,793	20,007	5,041,120	1,080,000	6,209,040	5,650,226

The land requirement estimates for the GAC systems are the same for all three regulatory options. The equipment dimensions supplied by the vendor were used to determine the land needed. The itemized land requirements are given in Table 3-47. The resultant GAC land requirement curve is shown in Figure 3-46, and the equation is:

$$\ln(Y3) = -1.780 + 0.319\ln(X) + 0.017(\ln(X))^2 \quad (3\text{-}48)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

Table 3-47. Land Requirements for Activated Carbon Systems

Flow (MGD)	Land Requirement (Acres)
0.00001	0.037
0.00008	0.037
0.0001	0.037
0.001	0.046
0.008	0.0568
0.04	0.0574
0.08	0.075
0.16	0.092
0.24	0.143

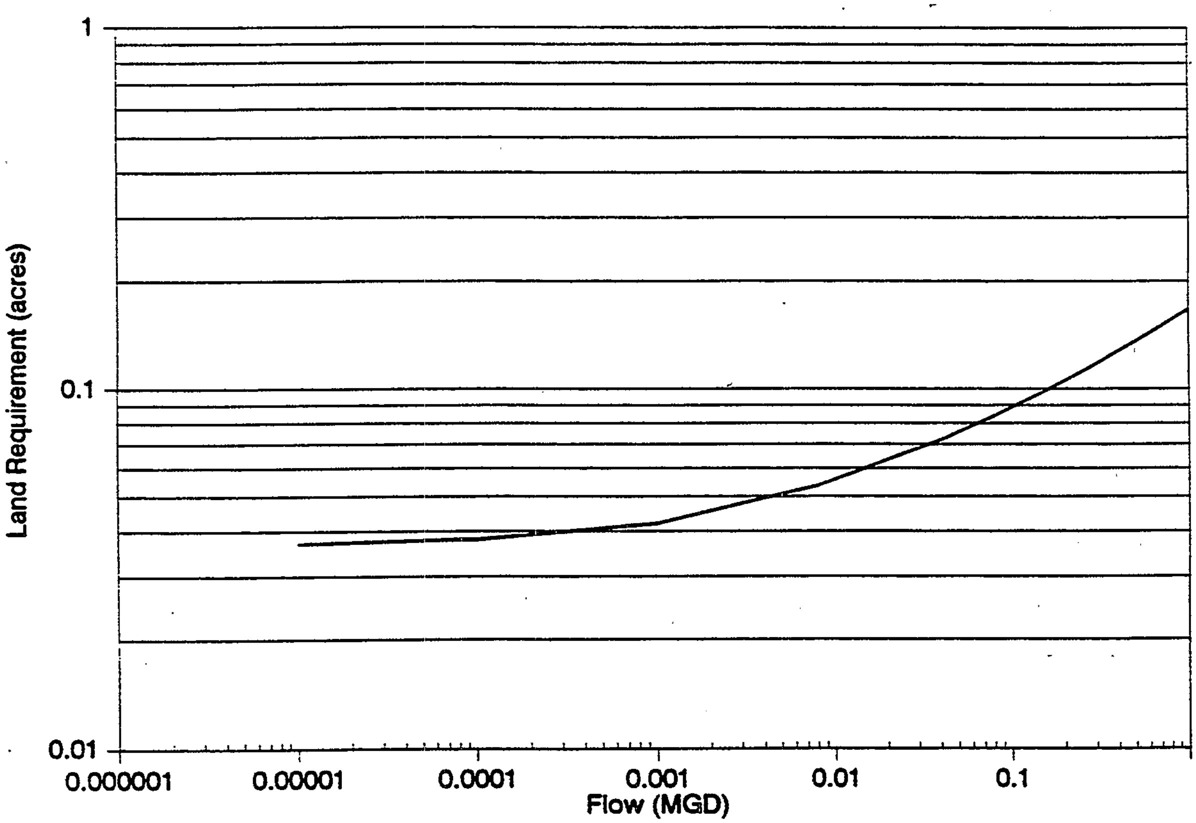

Figure 3-46 Land Requirement Curve for Activated Carbon Systems

3.8 *CYANIDE DESTRUCTION*

Cyanide destruction oxidation is capable of achieving removal efficiencies of 99 percent or greater and to the levels of detection. Chlorine is primarily used as the oxidizing agent in this process, which is called alkaline chlorination, and can be utilized in the elemental or hypochlorite form.

The capital and O & M costs curves for cyanide destruction systems with special operating conditions were obtained from vendor services. The concentration used for influent amenable cyanide was 1,548,000 μg/l and for total cyanides was 4,633,710 μg/l. The effluent for these pollutants was 276,106 μg/l for amenable cyanides and 135,661 μg/l for total cyanides. These rates produce a percent removal of 82 percent for amenable cyanide and 97 percent for total cyanides. These concentrations were taken from the sampling data for CWT QID 105.

The oxidation of cyanide waste using sodium hypochlorite is a two step process. In the first step, cyanide is oxidized to cyanate in the presence of hypochlorite and sodium hydroxide with the base required to maintain a pH range of 9 to 11. The second step oxidizes cyanate to carbon dioxide and nitrogen at a controlled pH of 8.5. The amount of sodium hypochlorite and sodium hydroxide needed to perform the oxidation is 7.5 pounds and 8.0 pounds per pound of cyanide, respectively. At these levels, the total reduction occurs at a retention time of 16 to 20 hours. The application of heat can facilitate the more complete destruction of total cyanide. The system costs were calculated on a batch volume range from 1.0 gallon to 1,000,000 gallons per day and because of the extended retention time, a basis of one batch per day is used.

The capital cost curve for the cyanide destruction system was estimated using the vendor quotes and represent equipment and installation costs. The equipment items include a two-stage reactor with a retention time of 16 hours, feed system and controls, pumps, piping, and foundation. The cost of the reacting tank includes a covered tank, mixer, containment tank, concrete foundation, inlet and outlet pipes, assembly and erection, delivery, manway, vent, and ladder with a cage and platform. The pump costs includes the motor and pump. The total construction cost included the tank costs, instrumentation and controls, pumps, piping, and installation. Installation, installed piping, and instrumentation and controls were estimated based on equipment costs and were 35 percent, 31 percent,and 13 percent of the equipment cost, respectively. The total capital costs included the cost for engineering (15 percent of construction cost) and contingency (15 percent of construction cost). The capital costs were scaled down to 1989 dollars using ENR's Construction Cost Index. The itemized capital costs are listed in Table 3-48.

Table 3-48. Capital Costs for Cyanide Destruction at Special Operating Conditions

Volume per Day (MGD)	System Cost	Installation	Piping	Instrument. & Controls	Total Construction Cost	Total Capital Cost (1993$)	Total Capital Cost (1989 $)
0.000001	500	175	155	65	895	1,164	1,059
0.00001	1,850	648	574	241	3,313	4,307	3,919
0.0001	5,000	1,750	1,550	650	8,950	11,635	10,588
0.001	14,252	4,988	4,418	1,853	25,511	33,164	30,179
0.01	45,875	16,056	14,221	5,964	82,116	106,751	97,143
0.05	106,105	37,137	32,893	13,794	189,929	246,908	224,686
0.10	160,542	56,190	49,768	20,870	287,370	373,581	339,959
0.50	401,320	140,462	124,409	52,172	718,363	933,872	849,824
1.0	560,000	196,000	173,600	72,800	1,002,400	1,303,120	1,185,839

The O & M costs were determined by energy usage, chemical costs, maintenance, labor, and taxes and insurance. Energy was divided into cost for electricity, lighting, and controls. Pumping costs were based on power requirements of 0.5 kwhr per 1,000 gallons per pump, which includes feed, booster, and metering pumps. Lighting and controls were assumed at $1000 per year and electrical usage was $0.08 per kwhr. The chemical costs for sodium hypochlorite and sodium hydroxide at dosages of 7.5 pounds and 8.0 pounds per pound of cyanide destruction were $0.64 per pound and $560 per ton, respectively. The maintenance was approximated at four percent of the total capital cost and taxes and insurance was two percent of the total capital cost. The labor cost for the cyanide destruction system was $31,200 per man-year at three hours per day.

The O & M costs were scaled down to 1989 dollars using ENR's cost index. The itemized O & M costs are presented in Table 3-49. The corresponding capital cost and O & M cost curves are presented in Figures 3-47 and 3-38, respectively. The vendor capital and O & M cost equations for the cyanide destruction systems are presented as Equations 3-49 and 3-50, respectively.

$$\ln(Y1) = 13.977 + 0.546\ln(X) + 0.0033(\ln(X))^{2)} \quad (3\text{-}49)$$

where:

X = Batch Size (MGD) and

Y1 = Capital Cost (1989 $).

$$\ln(Y2) = 18.237 + 1.318\ln(X) + 0.04993(\ln(X))^2 \quad (3\text{-}50)$$

where:

Y2 = O & M Cost (1989 $).

Table 3-49. O & M Costs for Cyanide Destruction at Special Operating Conditions

Flow Rate (MGD)	Energy	Sodium Hypochlorite Cost	Sodium Hydroxide Cost	Labor	Maint.	Taxes & Ins.	Total O & M Cost (1989$)
0.00001	1,000	50	25	16,425	47	24	15,990
0.00001	1,000	482	225	16,425	172	86	16,735
0.0001	1,000	4,826	2,256	16,425	465	233	22,937
0.001	1,100	48,260	22,568	16,425	1,207	604	82,049
0.01	1,600	482,470	225,680	16,425	3,886	1,943	666,124
0.05	1,730	2,412,345	1,128,400	16,425	8,987	4,494	3,250,867
0.10	7,000	4,824,700	2,256,800	16,425	13,598	6,799	6,484,043
0.50	31,200	24,123,450	11,284,000	16,425	33,993	16,997	32,310,519
1.0	70,000	48,246,900	22,568,000	16,425	47,434	23,717	64,584,953

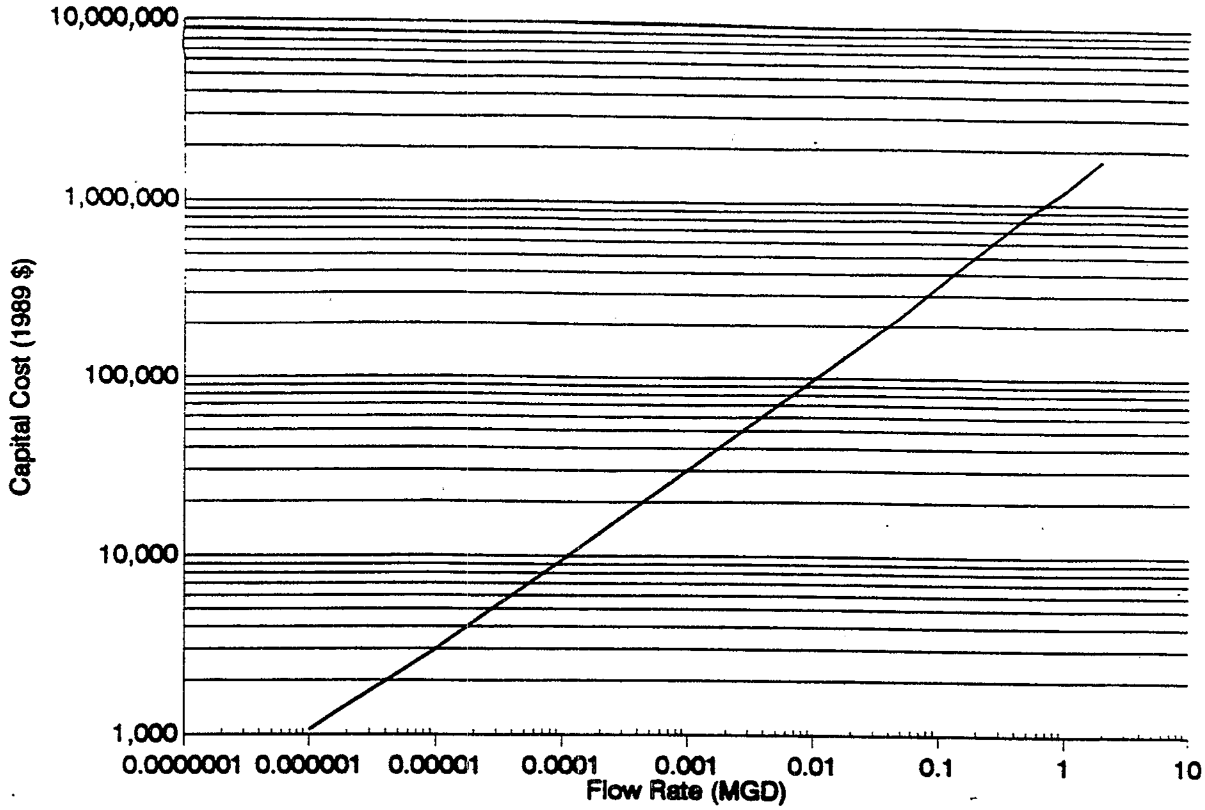

Figure 3-47 Capital Cost Curve for CN Destruction Systems at Special Operating Conditions

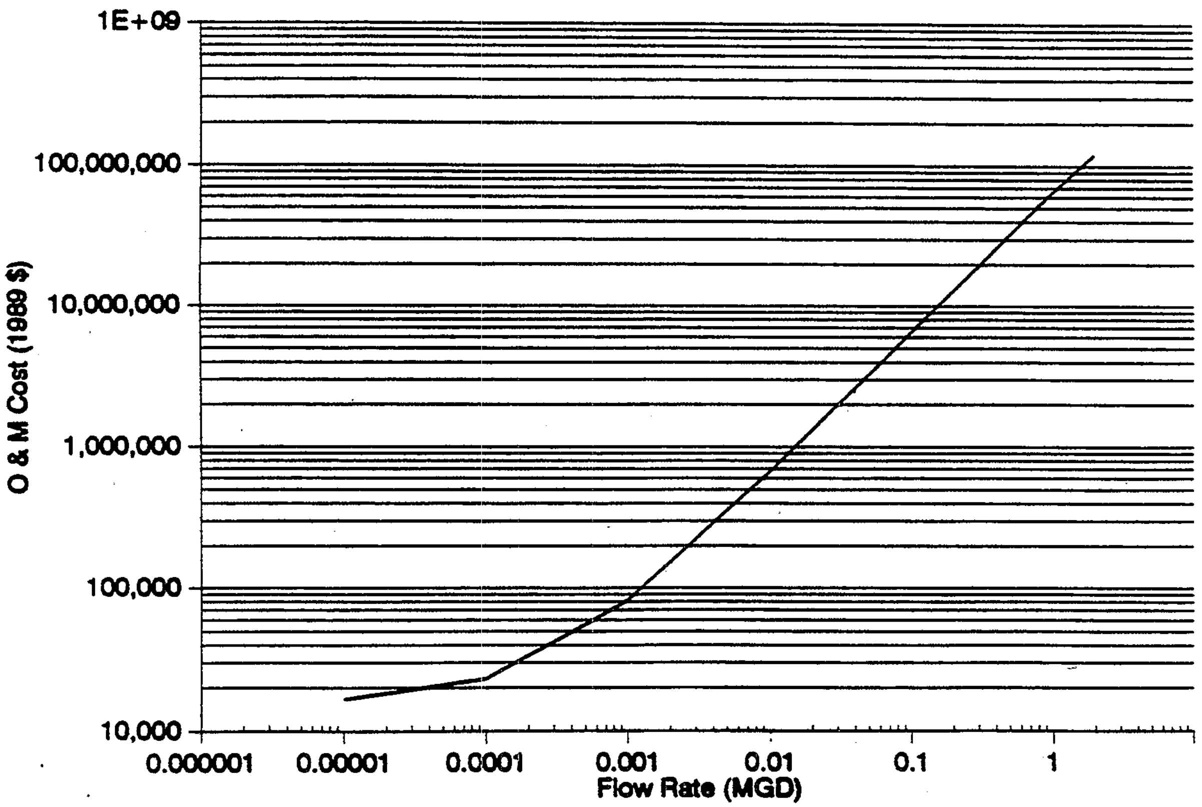

Figure 3-48 O & M Cost Curve for CN Destruction Systems at Special Operating Conditions

To develop land requirements for the cyanide destruction systems, the vendor data was used. The dimensions are scaled up to represent the total land required for the package unit plus peripherals (pumps, controls, access areas, etc.). The equation relating the flow of the cyanide destruction system with the land requirements is:

$$\ln(Y3) = -1.168 + 0.419\ln(X) + 0.021(\ln(X))^2 \qquad (3\text{-}51)$$

where:

X = Flow Rate (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 3-49.

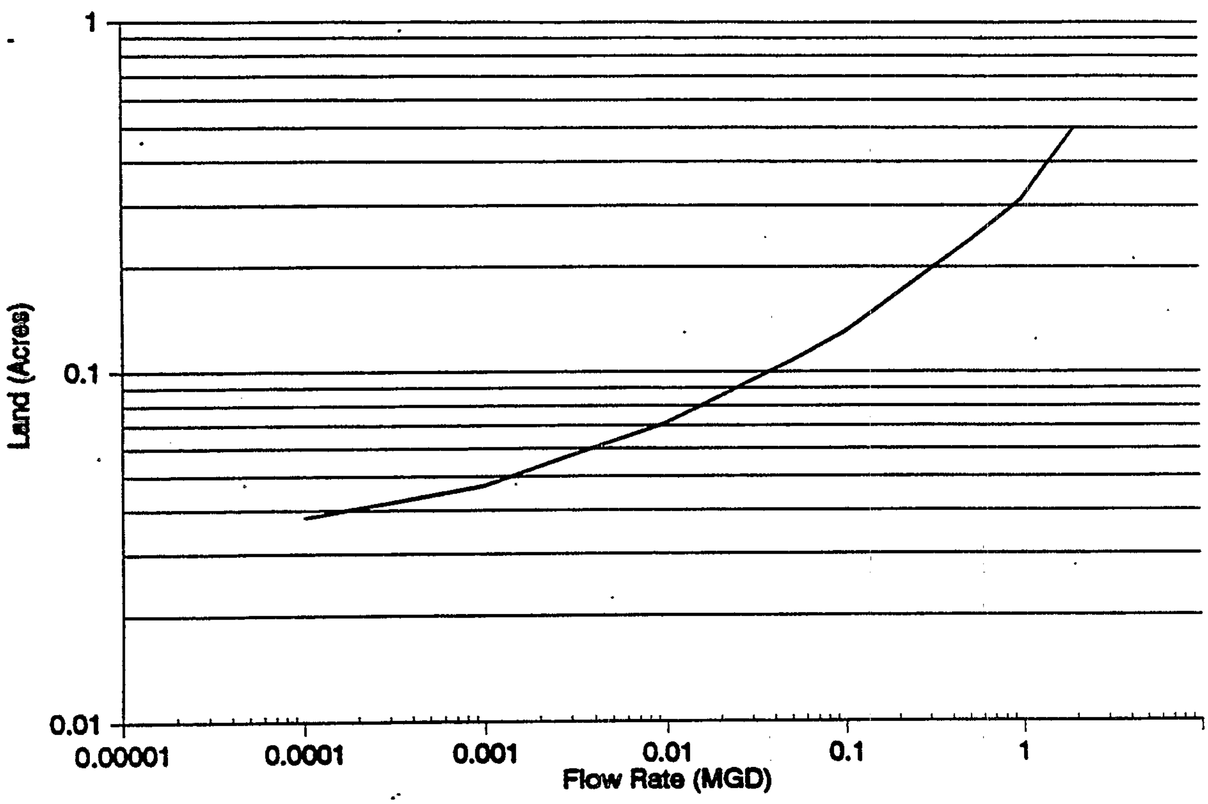

Figure 3-49 Land Requirement Curve for CN Destruction Systems at Special Operating Conditions

3.9 *CHROMIUM REDUCTION*

Reduction is a chemical reaction in which electrons are transferred from one chemical to another. The main application of chemical reduction to the treatment of wastewater is in the reduction of hexavalent chromium to trivalent chromium. The reduction enables the trivalent chromium to be precipitated from solution in conjunction with other metallic salts.

The capital and O & M costs curves for chromium reduction systems using sulfur dioxide were obtained from various vendor services. The average influent hexavalent chromium design concentration used was 752,204 μg/l; the maximum concentration was 3,300,000 μg/l. The average effluent concentration was 30 μg/l. These concentrations were taken from the sampling data for CWT QID 255.

The hexavalent chromium is reduced to trivalent chromium using sulfur dioxide and sulfuric acid. The sulfuric acid is used to lower the pH of the solution and the sulfur dioxide is used for the reduction process. After the reduction process, the trivalent chromium is then removed by precipitation. The amount of sulfur dioxide needed to reduce the hexavalent chromium was reported as 1.9 pounds sulfur dioxide per pound chromium, while the amount of sulfuric acid was 1.0 pound per pound of chromium. At these levels, the total reduction occurs at a retention time of 45 to 60 minutes. The system costs were calculated on a batch volume range from 1,000 gallons to 1,000,000 gallons and a basis of two batches per day.

The capital cost curve for the chromium reduction system was estimated using the vendor quotes and represent equipment and installation costs. The equipment items include a reduction reactor, feed system and controls, pumps, piping, and foundation. The cost of the reacting tank includes a covered tank, mixer, containment tank, concrete foundation, inlet and outlet pipes, assembly and erection, delivery, manway, vent, and ladder with a cage and platform. The pump cost includes the motor and pump. The total construction cost includes the tank costs, instrumentation and controls, pumps, piping, and installation. Installation, installed piping, and instrumentation and controls are estimated at 40 percent, 45 percent, and 30 percent of the equipment cost, respectively.

The total capital costs include the cost for engineering (15 percent of construction cost) and contingency (15 percent of construction cost). The capital costs were scaled down to 1989 dollars using ENR's construction cost index. The itemized capital costs are listed in Table 3-50. The corresponding capital cost curve is presented in Figure 3-50.

Capital costs for system upgrades were developed to estimate the incremental cost required to install a new chemical feed mechanism on an existing chromium reduction system that utilizes a treatment chemical other than sulfur dioxide. For the upgrade costs, the piping and instrumentation and controls equipment items were used to determine the total construction cost. The total capital costs in 1989 dollars are equal to the total construction cost plus engineering and contingency, scaled down using the ENR index. The itemized capital upgrade costs are listed in Table 3-51. The corresponding capital upgrade cost curve is presented in Figure 3-51.

The O & M costs were determined by energy usage, chemical costs, maintenance, labor, and taxes and insurance. Energy was divided into cost for electricity, lighting, and controls. Pumping costs were based on power requirements of 0.5 kwhr per 1,000 gallons per pump, which includes feed, booster, and metering pumps. Lighting and controls were assumed at $1,000 per year and electrical cost was $0.08 per kwhr. The chemical costs for sulfur dioxide and sulfuric acid at dosages of 2.0 pounds and 1.0 pound per pound of chromium were $230 per ton and $79 per ton, respectively. The maintenance was approximated at four percent of the total capital cost and taxes and insurance were two percent of the total capital cost. The labor cost for chromium reduction was $31,200 per man-year at four hours per day. The O & M costs are presented in Table 3-52, with the corresponding O & M curve presented in Figure 3-52.

O & M costs for system upgrades were developed to estimate the incremental cost required to operate an existing chromium reduction system that utilizes a treatment chemical, other than sulfur dioxide, that is a waste product for which a facility does not incur a purchase cost. The chemical cost items were used to determine the total O & M cost. These costs were scaled down to 1989 dollars using the ENR index. The itemized O & M upgrade costs are listed in Table 3-53. The corresponding O & M upgrade cost curve is presented in Figure 3-53.

Table 3-50. Capital Costs for Chromium Reduction Systems using Sulfur Dioxide

Vol/Day (MGD)	System Cost	Installation	Piping	Instrument. & Controls	Engineer. & Conting.	Total Capital Cost (1993$)	Total Capital Cost (1989 $)
0.000001	290	116	131	87	187	811	738
0.00001	1,325	530	596	398	855	3,704	3,371
0.0001	3,600	1,440	1,620	1,080	2,322	10,062	9,156
0.001	11,000	4,400	4,950	3,300	7,095	30,745	27,978
0.01	30,505	12,202	13,727	9,152	19,676	85,262	77,588
0.05	69,056	27,622	31,075	20,717	44,541	193,011	175,640
0.1	96,405	38,562	43,382	28,922	62,181	269,452	245,201
0.5	244,665	97,866	110,099	73,400	157,809	683,839	622,293
1.0	361,320	144,528	162,594	108,396	233,051	1,009,889	918,999

Table 3-51. Capital Upgrade Costs for Chromium Reduction Systems using Sulfur Dioxide

Vol/Day (MGD)	Piping	Instrument. & Controls	Total Construction Cost	Engineering & Contingency	Total Capital Cost (1993$)	Total Capital Cost (1989 $)
0.000001	43	87	130	39	169	154
0.00001	197	398	595	179	774	704
0.0001	535	1,080	1,615	485	2,100	1,911
0.001	1,634	3,300	4,934	1,480	6,414	5,837
0.01	4,530	9,152	13,682	4,105	17,787	16,186
0.05	10,255	20,717	30,972	9,292	40,264	36,640
0.1	14,316	28,922	43,238	12,971	56,209	51,150
0.5	36,333	73,400	109,733	32,920	142,653	129,814
1.0	53,656	108,396	162,052	48,616	210,668	191,708

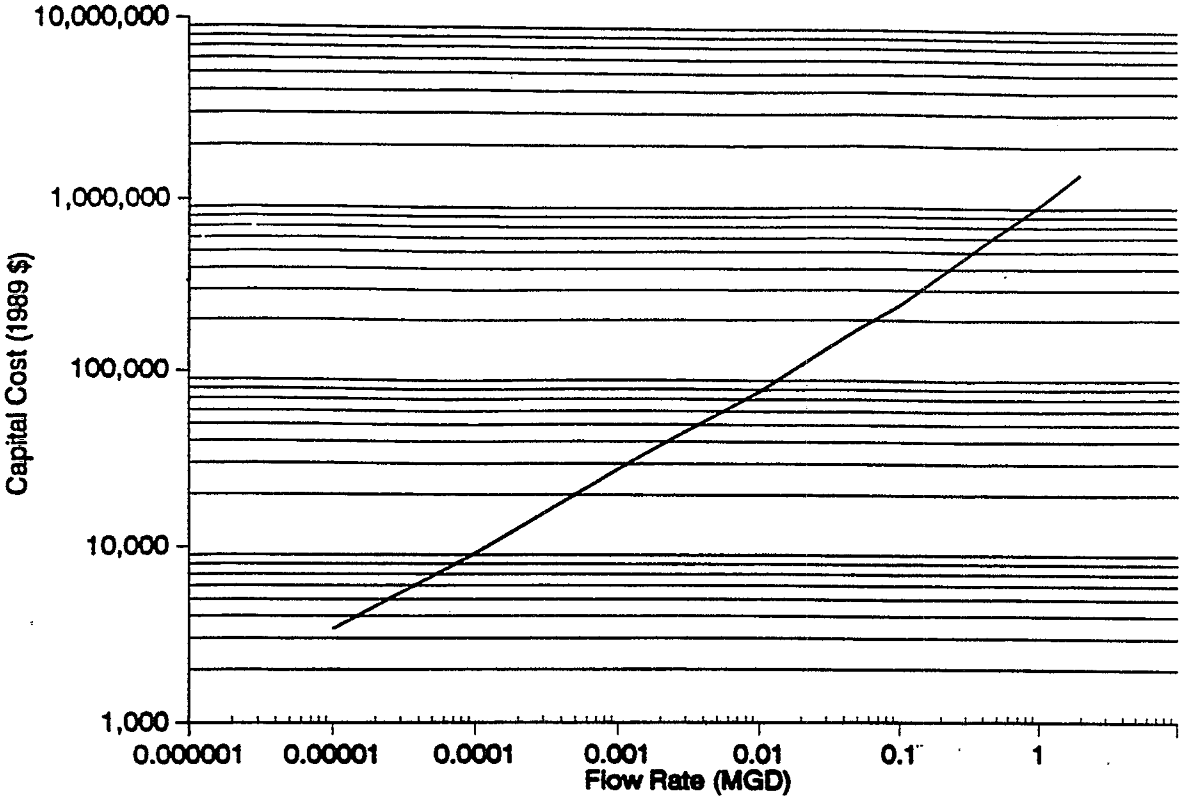

Figure 3-50 Capital Cost Curve for Chromium Reduction Systems

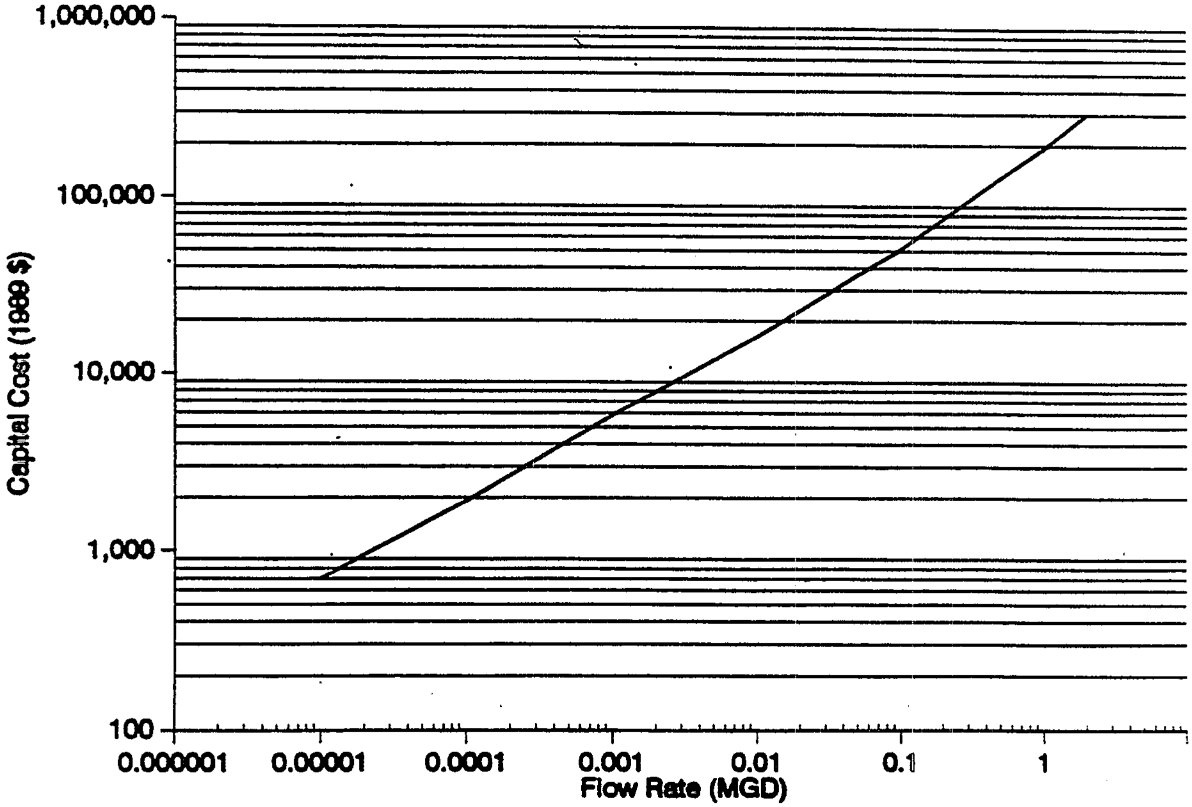

Figure 3-51 Capital Upgrade Cost Curve for Chromium Reduction Systems

Table 3-52. O & M Costs for Chromium Reduction Systems using Sulfur Dioxide

Vol/day (MGD)	Energy	Sulfur Dioxide Cost	Sulfuric Acid Cost	Labor	Mainten ance	Taxes & Insurance	Total O & M Cost (1993$)	Total O & M Cost (1989$)
0.000001	1,000	230	20	21,900	30	15	23,195	21,107
0.00001	1,000	230	20	21,900	135	68	23,353	21,251
0.0001	1,000	230	20	21,900	366	183	23,699	21,566
0.001	1,100	356	65	21,900	1,230	615	25,266	22,992
0.01	1,600	3,560	650	21,900	3,410	1,705	32,825	29,871
0.05	1,730	17,825	3,250	21,900	7,720	3,860	56,285	51,219
0.1	7,000	35,600	6,500	21,900	10,778	5,389	87,167	79,322
0.5	31,200	178,250	32,500	21,900	27,354	13,677	304,881	277,442
1.0	70,000	356,000	65,000	21,900	40,396	20,198	573,494	521,880

Table 3-53. O & M Upgrade Costs for Chromium Reduction Systems using Sulfur Dioxide

Vol/day (MGD)	Sulfur Dioxide Cost	Sulfuric Acid Cost	Total O & M Cost (1993$)	Total O & M Cost (1989$)
0.000001	230	20	250	228
0.00001	230	20	250	228
0.0001	230	20	250	228
0.001	356	65	421	383
0.01	3,560	650	4,210	3,831
0.05	17,825	3,250	21,075	19,178
0.1	35,600	6,500	42,100	38,311
0.5	178,250	32,500	210,750	191,783
1.0	356,000	65,000	421,000	383,110

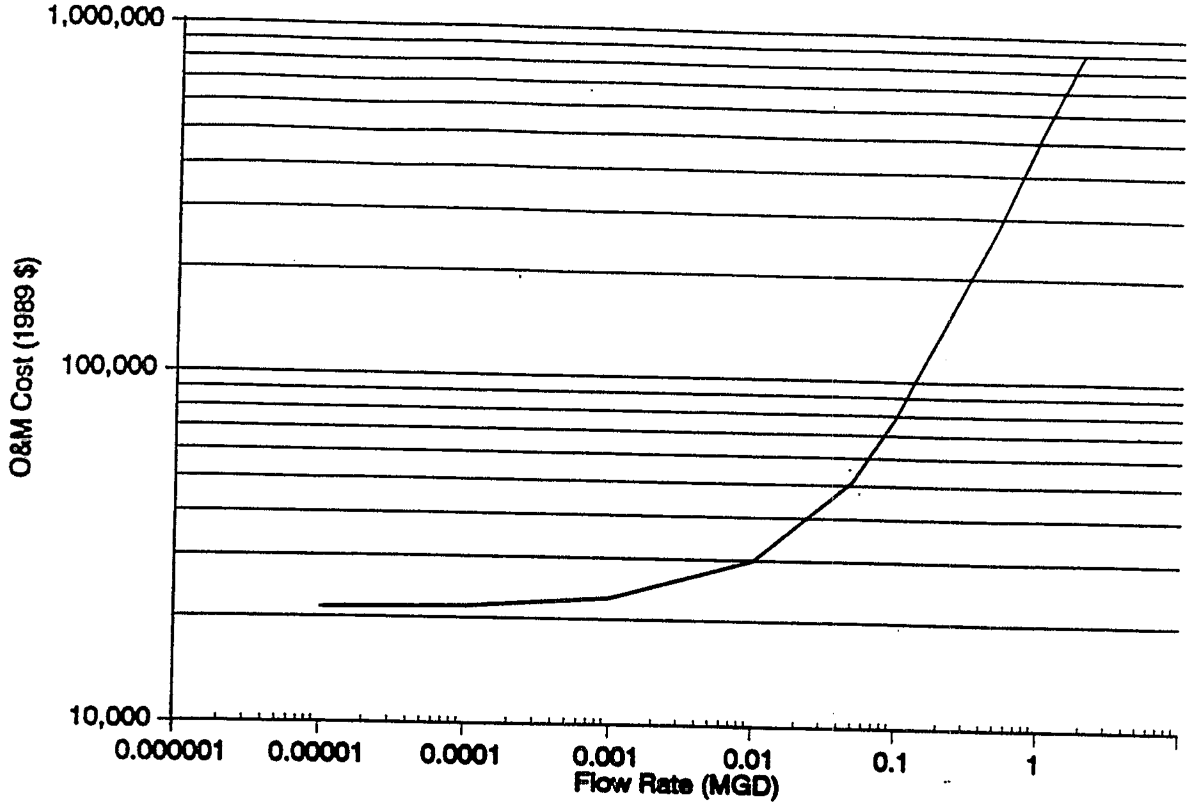

Figure 3-52 O & M Cost Curve for Chromium Reduction Systems

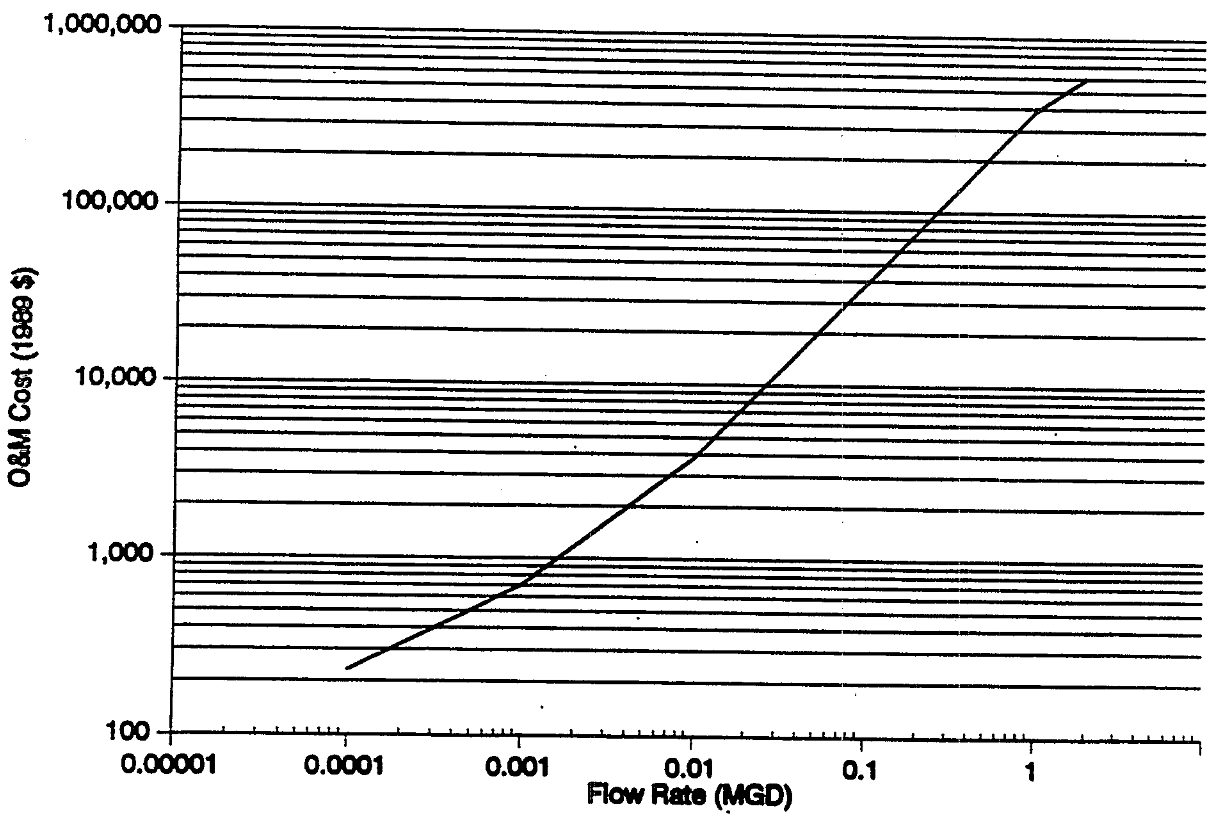

Figure 3-53 O & M Upgrade Cost Curve for Chromium Reduction Systems

The capital cost, capital upgrade cost, O & M cost, and O & M upgrade cost equations for the chromium reduction systems using sulfur dioxide are presented as Equations 3-52, 3-53, 3-54, and 3-55, respectively.

$$\ln(Y1) = 13.737 + 0.600\ln(X) \quad (3\text{-}52)$$

$$\ln(Y1) = 12.068 + 0.492\ln(X) - 0.000496(\ln(X))^2 \quad (3\text{-}53)$$

$$\ln(Y2) = 13.167 + 0.998\ln(X) + 0.079(\ln(X))^2 \quad (3\text{-}54)$$

$$\ln(Y2) = 13.123 + 1.365\ln(X) + 0.059(\ln(X))^2 \quad (3\text{-}55)$$

where:

X = Volume per Day (MGD),

Y1 = Capital Cost (1989 $), and

Y2 = O & M Cost (1989 $).

To develop land requirements for chromium reduction systems, approximate dimensions were calculated using the diameters of the systems. The land was calculated by estimating the size for the reaction tank, storage tanks, and feed system. The dimensions are scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.). The equation relating the flow of the chromium reduction system with the land requirement is:

$$\ln(Y3) = -1.303 + 0.185\ln(X) - 0.036(\ln(X))^2 \quad (3\text{-}56)$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 3-54.

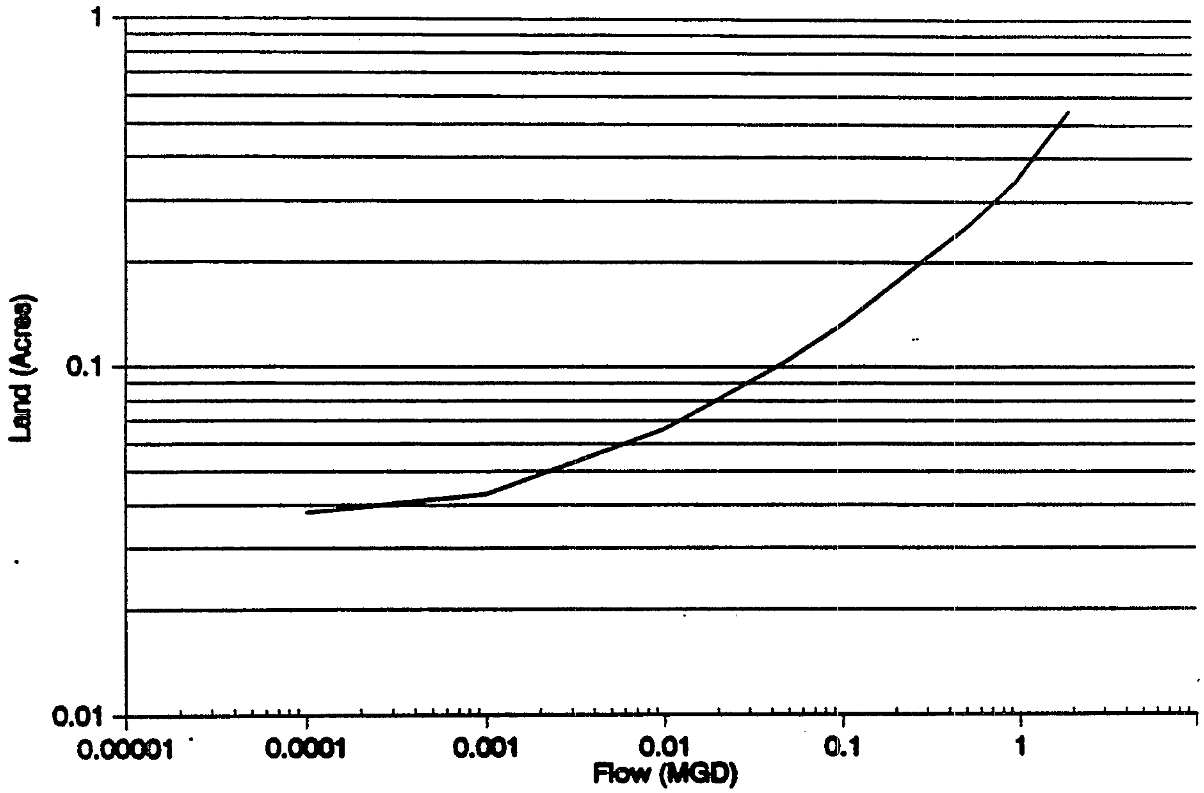

Figure 3-54 Land Requirement Curve for Chromium Reduction Systems

SECTION 4
BIOLOGICAL WASTEWATER TREATMENT TECHNOLOGY COSTS

4.1 *SEQUENCING BATCH REACTORS*

A sequencing batch reactor (SBR) is a suspended growth system in which wastewater is mixed with existing biological floc in an aeration basin. SBRs are unique in that a single tank acts as an equalization tank, an aeration tank, and a clarifier.

The capital and O & M costs curves for the SBR systems were obtained from a vendor service. The average influent BOD_5, ammonia as N, and nitrate-nitrite as N design concentrations used were 4,800 mg/l, 995 mg/l, and 46 mg/l, respectively. The average effluent BOD_5, ammonia as N, and nitrate-nitrite as N concentrations used were 1,600 mg/l, 615 mg/l, and 1.0 mg/l, respectively. These concentrations were obtained from the sampling data from CWT QID 059. The system costs were calculated for a flow range from 0.001 to 1.0 MGD.

The capital costs for the SBR systems were estimated using the vendor quotes and represent equipment and installation costs. The equipment items include a tank system, sludge handling equipment, feed system and controls, pumps, piping, blowers, and valves. The total construction cost includes piping and installation. Installation and installed piping are estimated at 35 percent of the equipment cost and 40 percent of the construction cost, respectively. The total capital costs include the cost for engineering (15 percent of construction cost) and contingency (15 percent of construction cost). The capital costs were scaled down to 1989 dollars using ENR's construction cost index. The itemized capital costs are listed in Table 4-1.

Table 4-1. Capital Costs for Sequencing Batch Reactor Systems

Flow Rate (MGD)	System Cost	Installation	Piping	Total Construction Cost	Engineer. & Conting.	Total Capital Cost (1993$)	Total Capital Cost (1989 $)
0.001	100,000	35,000	54,000	189,000	40,500	229,500	206,550
0.01	360,000	126,000	194,400	680,400	145,800	826,200	743,580
0.05	635,000	222,250	342,900	1,200,150	257,175	1,457,325	1,311,593
0.10	970,000	339,500	523,800	1,833,300	392,850	2,226,150	2,003,535
0.50	2,350,000	822,500	1,269,000	4,441,500	951,750	5,393,250	4,853,925
1.0	3,200,000	1,120,000	1,728,000	6,048,000	1,296,000	7,344,000	6,609,600

The O & M costs were determined by power, maintenance, labor, and taxes and insurance. Power was estimated using the vendor estimates at an electrical cost of $0.08 per kwhr. The maintenance was approximated at four percent of the total capital cost and taxes and insurance were two percent of the total capital cost. The labor cost was $31,200 per man-year at four hours per day. The O & M costs were scaled down to 1989 dollars using ENR's cost index. The itemized O & M costs are presented in Table 4-2.

Table 4-2. O & M Costs for Sequencing Batch Reactor Systems

Flow Rate (MGD)	Power	Labor	Maintenance	Taxes & Insurance	Total O & M Cost
0.001	65	14,600	8,260	4,130	27,055
0.01	392	14,600	29,744	14,872	59,608
0.05	1,852	29,200	52,540	26,270	109,862
0.10	3,703	29,200	80,140	40,070	153,113
0.50	18,298	58,400	194,156	97,078	367,932
1.0	36,596	58,400	264,384	132,192	491,572

The capital cost curve and O & M cost curve are presented in Figures 4-1 and 4-2, respectively. The vendor capital and O & M cost equations for the sequencing batch reactor systems are presented as Equations 4-1 and 4-2, respectively.

$$\ln(Y1) = 15.707 + 0.512\ln(X) + 0.0022(\ln(X))^2 \quad (4\text{-}1)$$

where:

X = Flow Rate (MGD) and

Y1 = Capital Cost (1989 $).

$$\ln(Y2) = 13.139 + 0.562\ln(X) + 0.020(\ln(X))^2 \quad (4\text{-}2)$$

where:

Y2 = O & M Cost (1989 $).

To develop land requirements for SBR systems, overall system dimensions were provided by the vendor. The land dimensions were scaled up to represent the total land required for the system plus peripherals (pumps, controls, access areas, etc.). The rule-of-thumb used to scale the dimensions adds a 20-foot perimeter around the unit. The equation relating the flow of the SBR system with the land requirement is:

$$\ln(Y3) = -2.971 + 0.097\ln(X) + 0.008(\ln(X))^2 \quad (4\text{-}3)$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

The land requirement curve is presented in Figure 4-3.

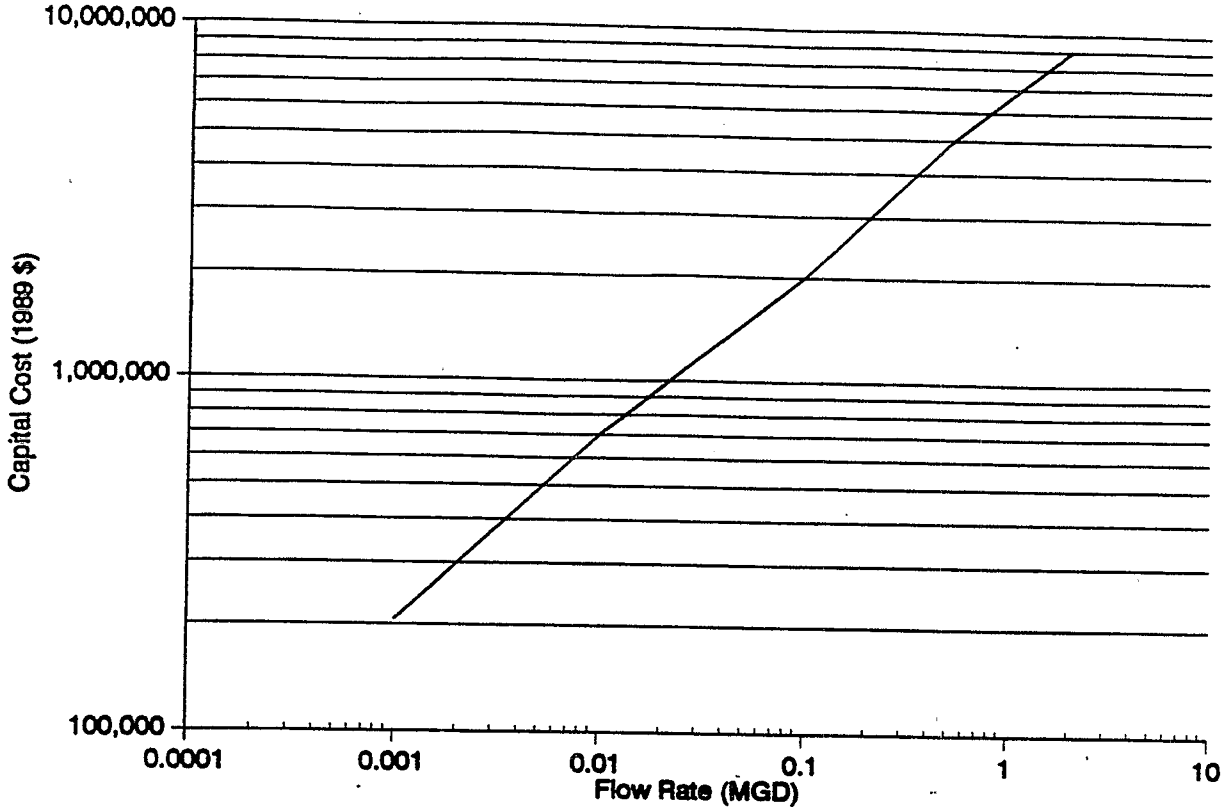

Figure 4-1 Capital Cost Curve for Sequencing Batch Reactor Systems

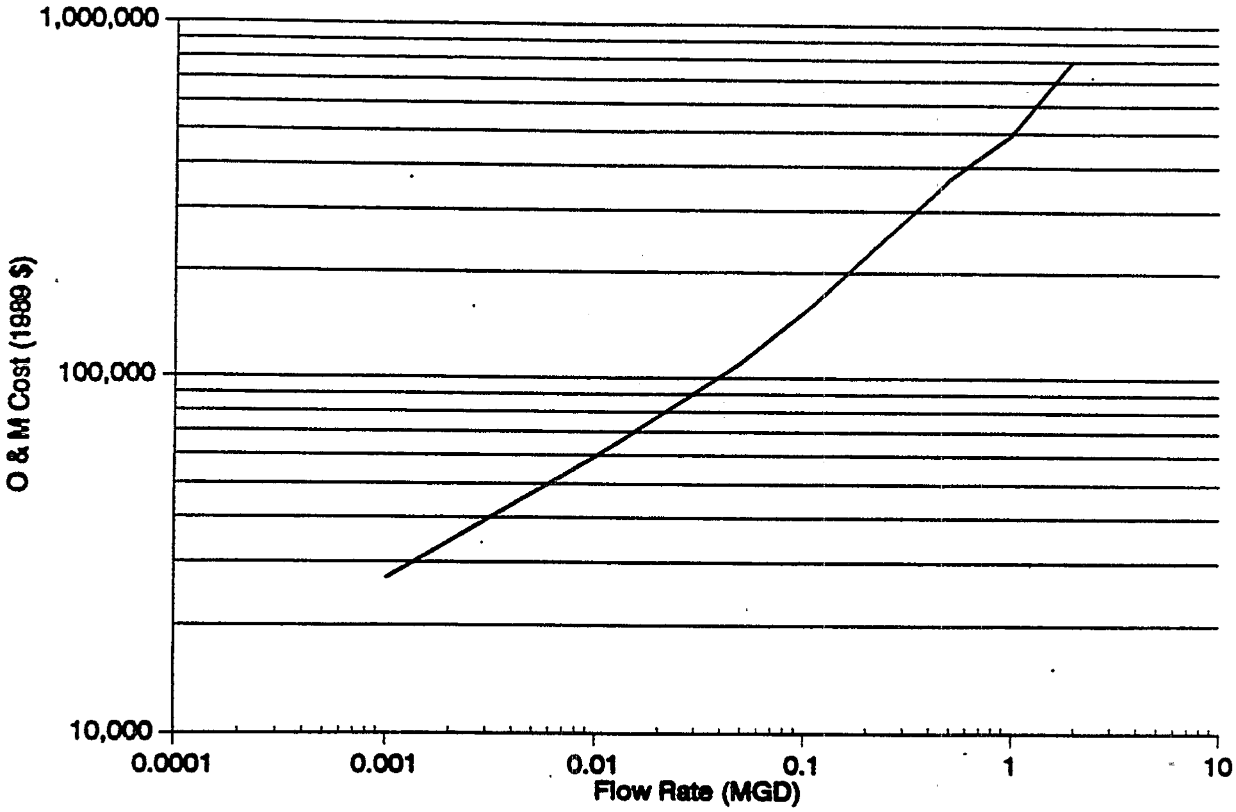

Figure 4-2 O & M Cost Curve for Sequencing Batch Reactor Systems

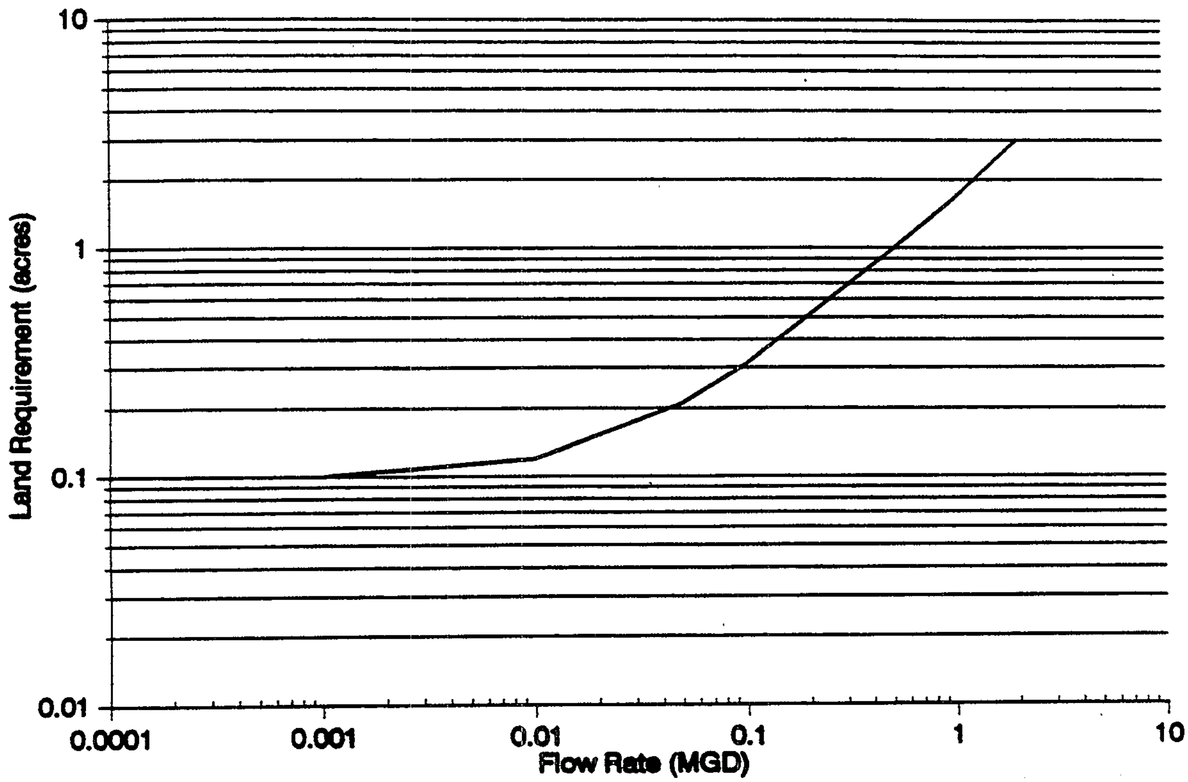

Figure 4-3 Land Requirement Curve for Sequencing Batch Reactor Systems

SECTION 5
ADVANCED WASTEWATER TREATMENT TECHNOLOGY COSTS

5.1 *ULTRAFILTRATION*

Ultrafiltration (UF) systems are used by industry for the treatment of metal-finishing wastewater, textile industry effluent, and oily wastes. In the CWT industry, UF is applied for the treatment of oil/water emulsions.

The components of the UF system include: booster pumps; cartridge prefilters; control units; high pressure pump and motor assembly; membrane/pressure vessel assembly; and reject holding tanks. Capital equipment and operational costs were obtained from manufacturers' quotations. The capital cost equation was developed by adding installation, engineering, and contingency costs to the vendors' equipment cost. The installation cost was estimated at 35 percent of the equipment cost. Contingency and engineering fees were estimated to be 15 percent of the equipment and installation costs. The vendor cost information has been converted to 1989 dollars using ENR's Construction Index. The capital costs are presented in Table 5-1 with the subsequent cost curve presented in Figure 5-1. The UF capital cost equation is:

$$\ln(Y1) = 14.672 + 0.8789\ln(X) + 0.044(\ln(X))^2 \qquad (5\text{-}1)$$

where:

X = Flow (MGD) and

Y1 = Capital Cost (1989 $).

The O & M costs were based on estimated electricity usage, maintenance, labor, taxes, and insurance. The electricity usage and costs were provided by the vendors. Maintenance was approximated at four percent of the capital cost. Taxes and insurance were approximated at two percent of the capital cost. The labor cost for the UF system was approximated at $31,200 per man-year at two hours per day. Concentrate disposal

Table 5-1. Capital Costs for Ultrafiltration Systems

Flow (MGD)	Average Vendor Capital Cost	Installation Cost	Total Capital & Installation Cost	Engineering & Contingency	Total Capital Cost (1989$)
0.00005	17,557	6,145	23,702	7,111	30,813
0.0001	17,730	6,206	23,936	7,181	31,117
0.0005	21,377	7,482	28,859	8,658	37,517
0.0010	25,280	8,848	34,128	10,238	44,366
0.0020	31,325	10,964	42,289	12,687	54,976
0.0100	60,667	21,233	81,900	24,570	106,470
0.0480	142,036	49,713	191,749	57,525	249,274
0.1000	226,365	79,228	305,593	91,678	397,271
1.0000	1,319,323	461,763	1,781,086	534,326	2,315,412

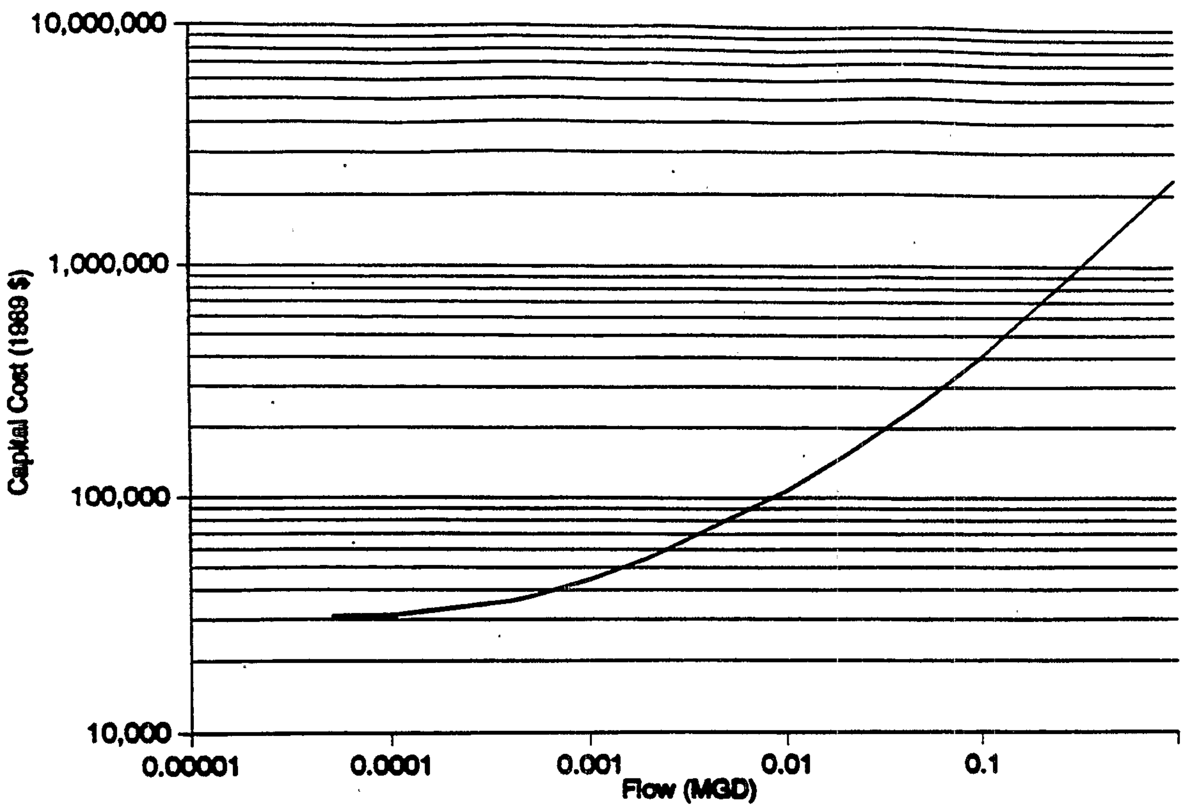

Figure 5-1 Capital Cost Curve for Ultrafiltration Systems

costs were based on a concentrate generation rate of two percent of influent flow. The cost of concentrate disposal was quoted as $0.50 per gallon by CWT QID 409. The O & M costs were converted from 1992 dollars to 1989 dollars using ENR's cost index. The itemized annual O & M costs are presented in Table 5-2 and the subsequent cost curve is presented in Figure 5-2. The UF O & M cost equation is:

$$\ln(Y2) = 15.043 + 1.164\ln(X) + 0.057(\ln(X))^2 \quad (5\text{-}2)$$

where:

Y2 = O & M Cost (1989 $).

Land requirements were calculated for UF systems. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. The land requirement data and curve are presented in Table 5-3 and Figure 5-3, respectively. The UF land requirement equation is:

$$\ln(Y3) = -1.632 + 0.42\ln(X) + 0.035(\ln(X))^2 \quad (5\text{-}3)$$

where:

Y3 = Land Requirement (Acres).

Table 5-2. O & M Costs for Ultrafiltration Systems

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Concentrate Disposal Costs	Total O & M Cost (1989$)
0.000001	1,000	1,232	616	7,607	2	10,457
0.00001	1,000	1,232	616	7,607	25	10,480
0.0001	1,200	1,232	616	7,607	253	10,908
0.001	2,938	1,587	794	7,607	2,536	15,462
0.01	15,068	3,575	1,788	7,607	25,357	53,395
0.05	47,243	7,623	3,812	7,607	126,786	193,071
0.1	77,278	13,398	6,699	7,607	253,571	358,553
1.0	396,329	83,526	41,763	7,607	2,535,714	3,064,939

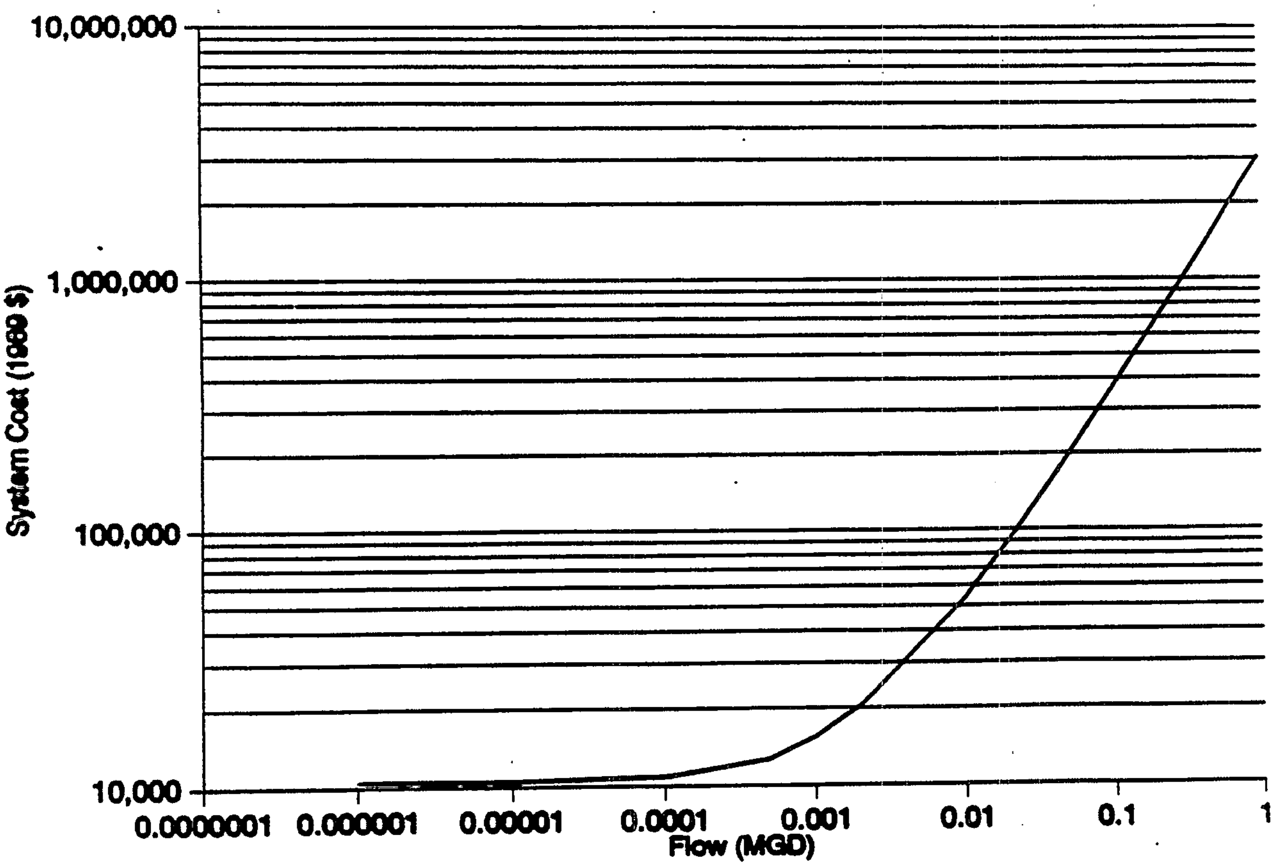

Figure 5-2 O & M Cost Curve for Ultrafiltration Systems

Table 5-3. Land Requirements for Ultrafiltration Systems

Flow (MGD)	Land Requirements (Acres)
0.001375	0.0549
0.003625	0.0555
0.0102	0.0602
0.02115	0.0617
0.0352	0.0725

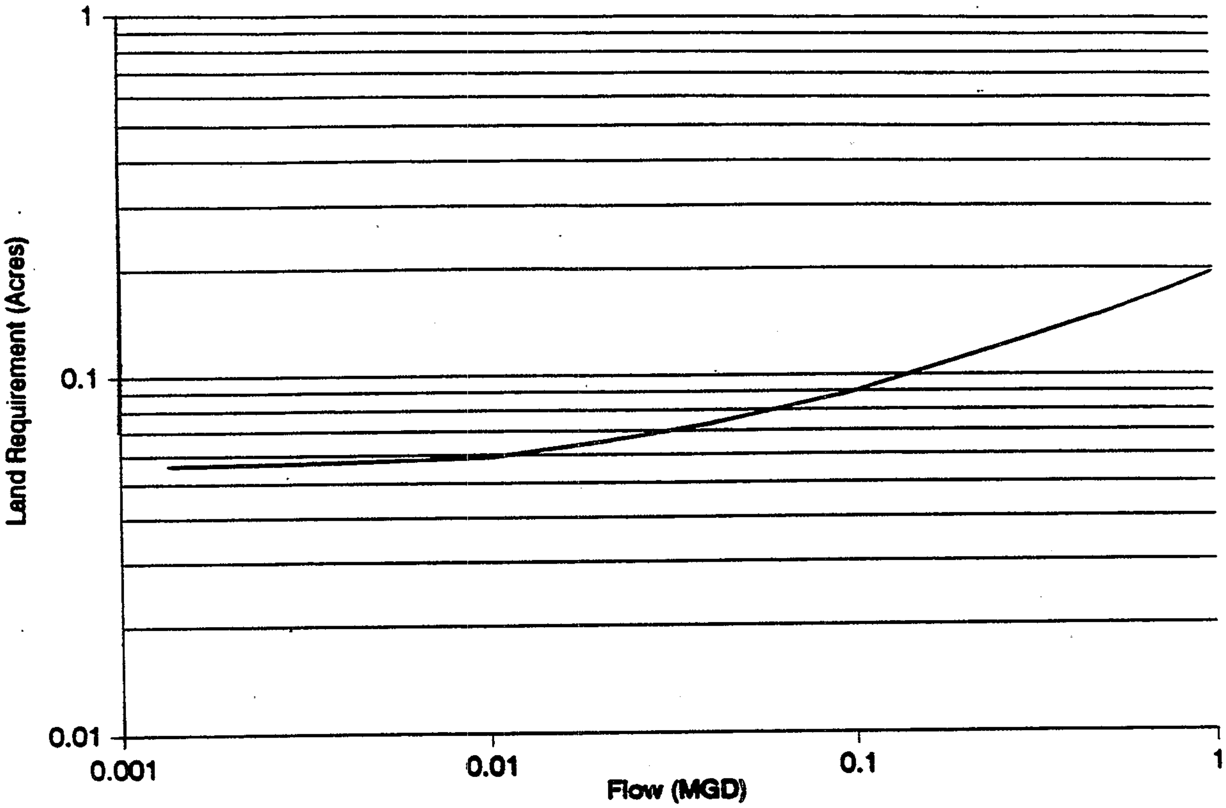

Figure 5-3 Land Requirement Curve for Ultrafiltration Systems

5.2 *REVERSE OSMOSIS*

Reverse osmosis (RO) is a high-pressure, fine membrane process for separating dissolved solids from water. A semi-permeable, microporous membrane and pressure are used to perform the separation. RO systems are typically used as end-of-pipe polishing processes, prior to final discharge of recovered wastewater.

The components of the RO system include a booster pump, cartridge prefilters, RO unit, and a reject holding tank. The capital cost equation was developed by adding installation, engineering, and contingency costs to the vendors' equipment cost. The installation cost was estimated at 35 percent of the equipment cost. Contingency and engineering fees were estimated to be 15 percent of the equipment and installation costs. All vendor cost information has been converted to 1989 dollars using ENR's Construction Index. The capital cost information is presented in Table 5-4, with its subsequent curve in Figure 5-4. The RO capital cost curve equation is:

$$\ln(Y1) = 15.381 + 0.919\ln(X) + 0.04(\ln(X))^2 \qquad (5\text{-}4)$$

where:

X = Flow (MGD) and

Y1 = Capital Cost (1989 $).

Table 5-4. Capital Costs for Reverse Osmosis Systems

Flow (MGD)	Average Vendor Capital Cost	Installation Cost	Total Capital & Installation Cost	Engineering & Contingency	Total Capital Cost (1989$)
0.00001	13,630	4,771	18,401	5,520	23,921
0.0005	25,108	8,788	33,896	10,169	44,065
0.001	31,680	11,088	42,768	12,830	55,598
0.005	65,404	22,891	88,295	26,489	114,784
0.01	94,489	33,071	127,560	38,268	165,828
0.05	246,952	86,433	333,385	100,016	433,401
0.1	394,233	137,982	532,215	159,665	691,880
1.0	2,811,421	983,997	3,795,418	1,138,625	4,934,043

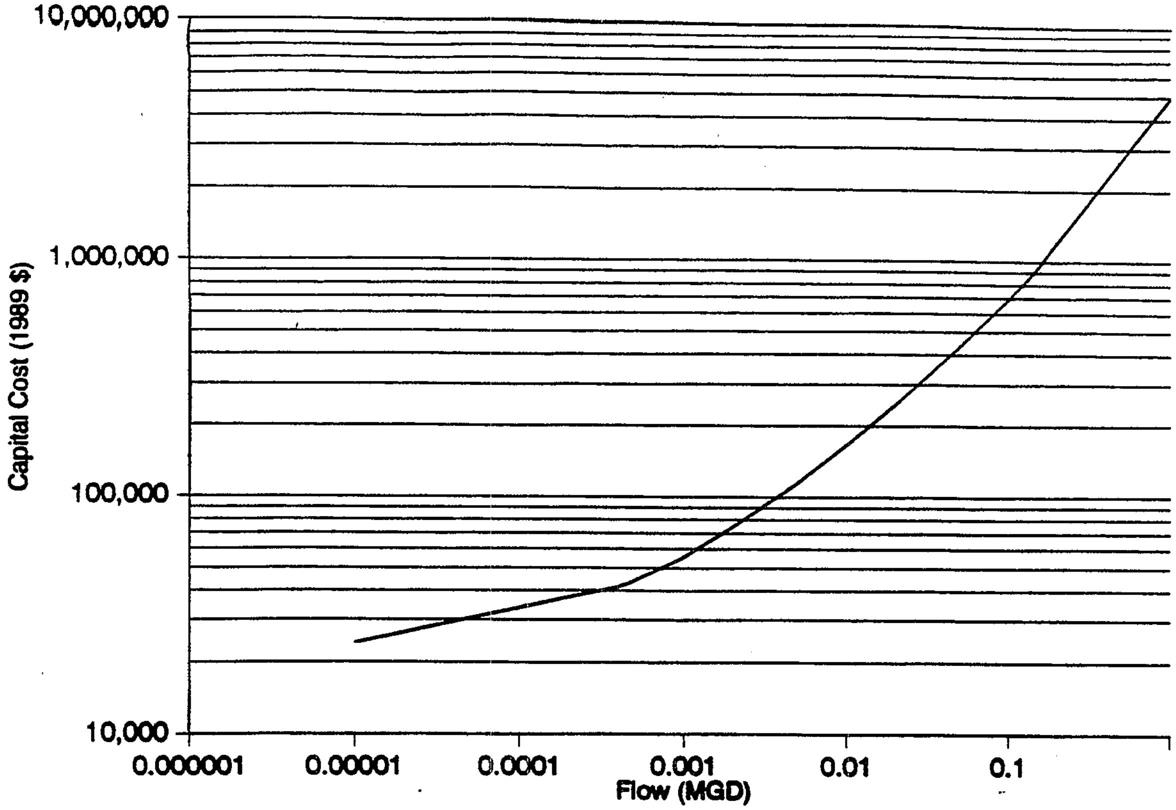

Figure 5-4 Capital Cost Curve for Reverse Osmosis Systems

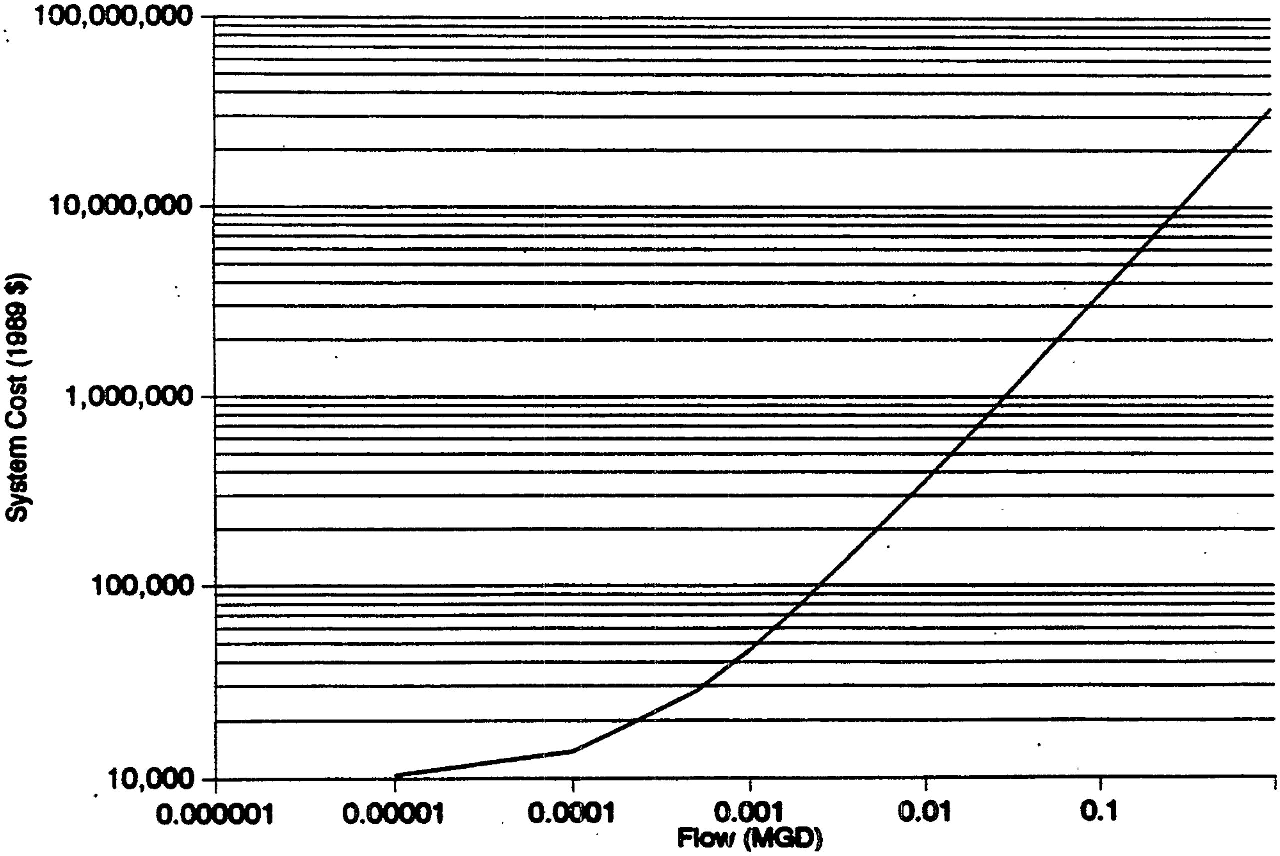

Figure 5-5 O & M Cost Curve for Reverse Osmosis Systems

The O & M costs were based on estimated electricity usage, maintenance, labor, taxes, and insurance. The electricity usage and costs were roughly provided by the vendors. Maintenance was approximated at four percent of the capital cost. Taxes and insurance were approximated at two percent of the capital cost. The labor cost for the reverse osmosis system was approximated at $31,200 per man-year at two hours per day. Concentrate disposal costs were based upon a concentrate generation rate of 28 percent of influent flow (QID 409). The cost of concentrate disposal was quoted as $0.46 per gallon. The O & M costs were converted from 1992 dollars to 1989 dollars using ENR's cost index. The itemized annual O & M costs are presented in Table 5-5 and the subsequent cost curve is presented in Figure 5-5. The RO O & M cost equation is:

$$\ln(Y2) = 17.599 + 1.303\ln(X) + 0.048(\ln(X))^2 \qquad (5\text{-}5)$$

where:

X = Flow (MGD) and

Y2 = O & M Cost (1989 $).

Table 5-5. O & M Costs for Reverse Osmosis Systems

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Concentrate Disposal Costs	Total O & M Cost (1989$)
0.00001	1000	957	479	7,607	327	10,370
0.0001	1076	1,183	592	7,607	3,267	13,725
0.001	2,045	2,235	1,118	7,607	32,660	45,665
0.01	6,670	6,452	3,226	7,607	326,600	350,555
0.05	20,876	17,414	8,707	7,607	1,633,000	1,687,604
0.1	36,960	28,467	14,234	7,607	3,266,000	3,353,268
1.0	348,015	191,976	95,988	7,607	32,660,000	33,303,586

Land requirements were calculated for RO systems. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. This data was plotted and the land area equation was determined. The land requirement data and curve are presented in Table 5-6 and Figure 5-6, respectively. The RO land requirement equation is:

$$\ln(Y3) = -2.346 + 0.166\ln(X) + 0.012(\ln(X))^2 \quad \textbf{(5-6)}$$

where:

X = Flow (MGD) and

Y3 = Land Requirement (Acres).

Table 5-6. Land Requirements for Reverse Osmosis Systems

Flow (MGD)	Land Requirements (Acres)
0.0008	0.0498
0.004	0.0511
0.008	0.0522
0.019	0.0541
0.042	0.0589
0.056	0.0605
0.083	0.0620

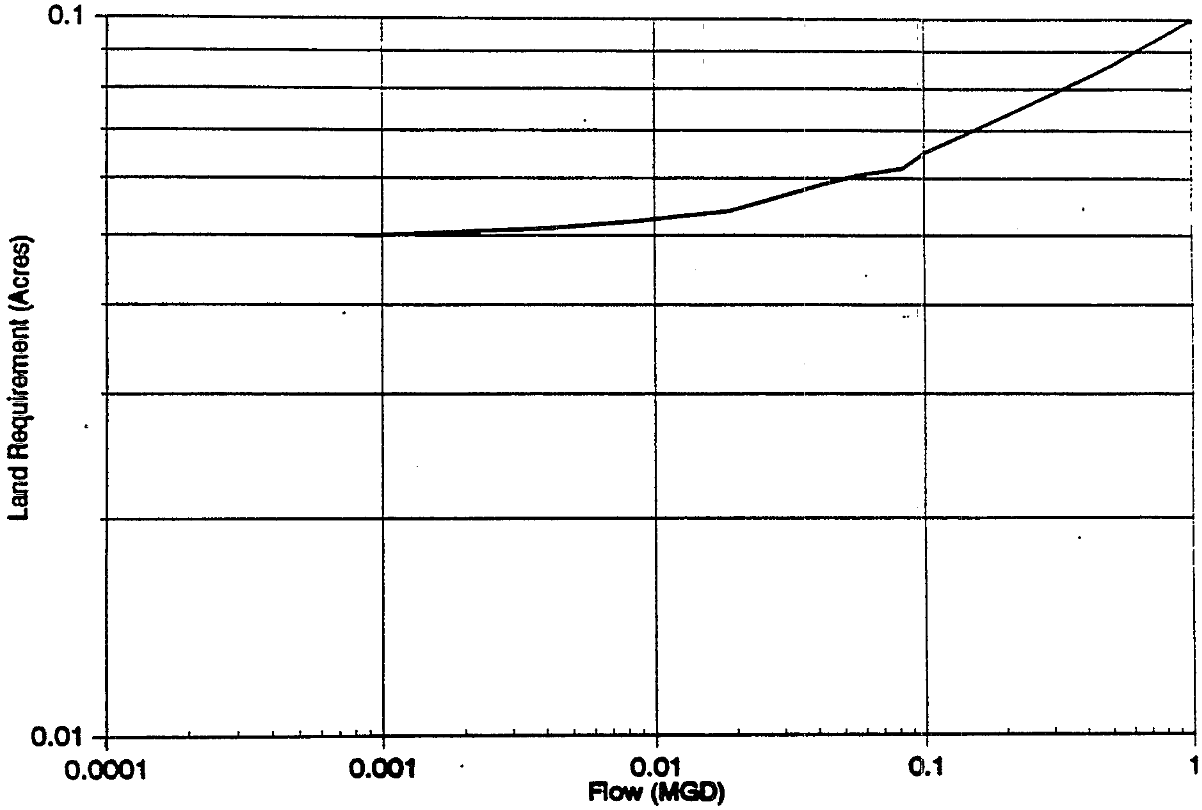

Figure 5-6 Land Requirement Curve for Reverse Osmosis Systems

SECTION 6
SLUDGE TREATMENT AND DISPOSAL COSTS

6.1 *PLATE AND FRAME PRESSURE FILTRATION - SLUDGE STREAM*

Pressure filtration systems are used for the removal of solids from waste streams. These systems typically follow chemical precipitation or clarification.

The plate and frame pressure filtration system costs were estimated for a sludge stream; this consists of the sludge which is collected in the clarification step following some chemical precipitation processes. The sludge stream consists of 80 percent liquid and 20 percent (200,000 mg/l) solids. The influent flow rate used for the sludge stream is 20 percent of the influent flow rate for the liquid wastewater stream. These influent parameters were taken from CWT QID 105.

The components of the plate and frame pressure filtration system include: filter plates; filter cloth; hydraulic pumps; pneumatic booster pumps; control panel; connector pipes; and support platform. Equipment and operational costs were obtained from manufacturers' recommendations. The capital cost equation was developed by adding installation, engineering, and contingency costs to the vendors' equipment costs. The installation cost was estimated at 35 percent of the equipment cost. Engineering and contingency fees were estimated to be 15 percent of the equipment and installation costs. These costs are presented in Table 6-1. All vendor cost information has been converted to 1989 dollars using ENR's Construction Index. The capital cost equation for the Metals Option 1 sludge filtration systems is presented as Equation 6-1, with the subsequent cost curve in Figure 6-1.

$$\ln(Y1) = 14.827 + 1.087\ln(X) + 0.050(\ln(X))^2 \qquad (6\text{-}1)$$

where:

X = Flow (MGD) of Liquid Stream and

Y1 = Capital Cost (1989 $).

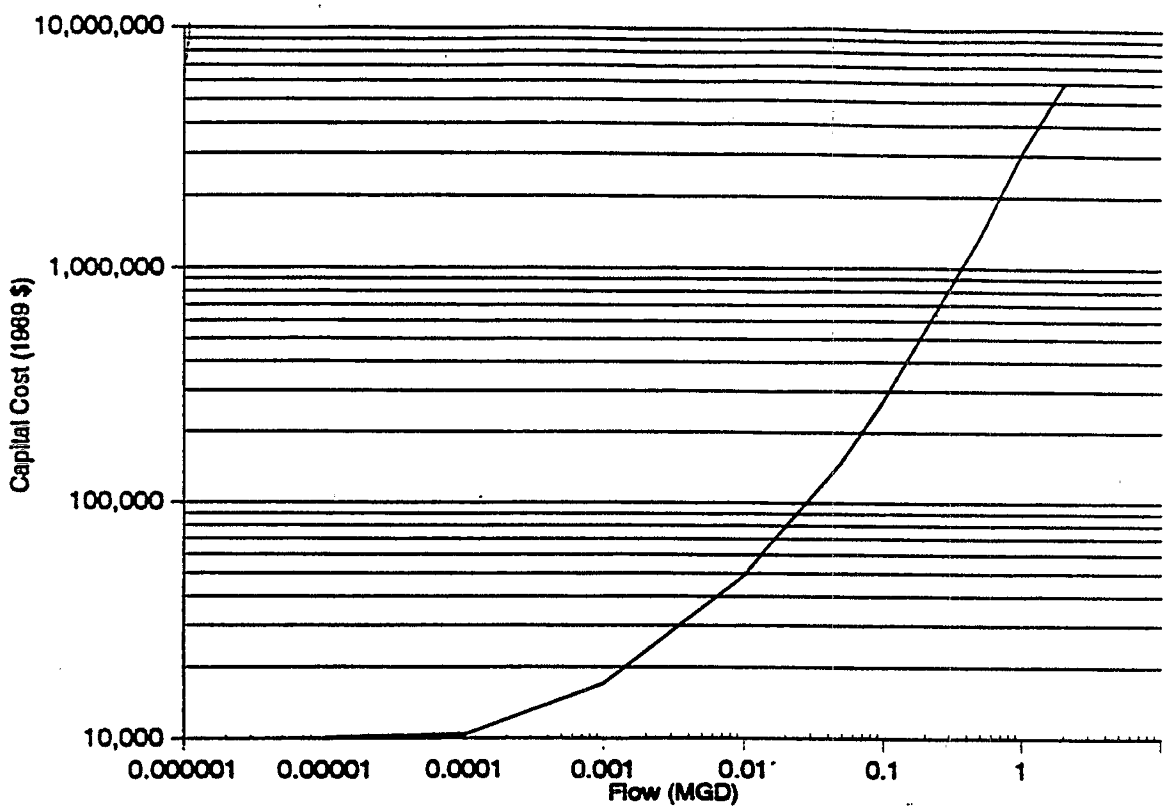

Figure 6-1 Plate & Frame Filtration (Sludge Stream) Capital Cost Curve Metals Option 1

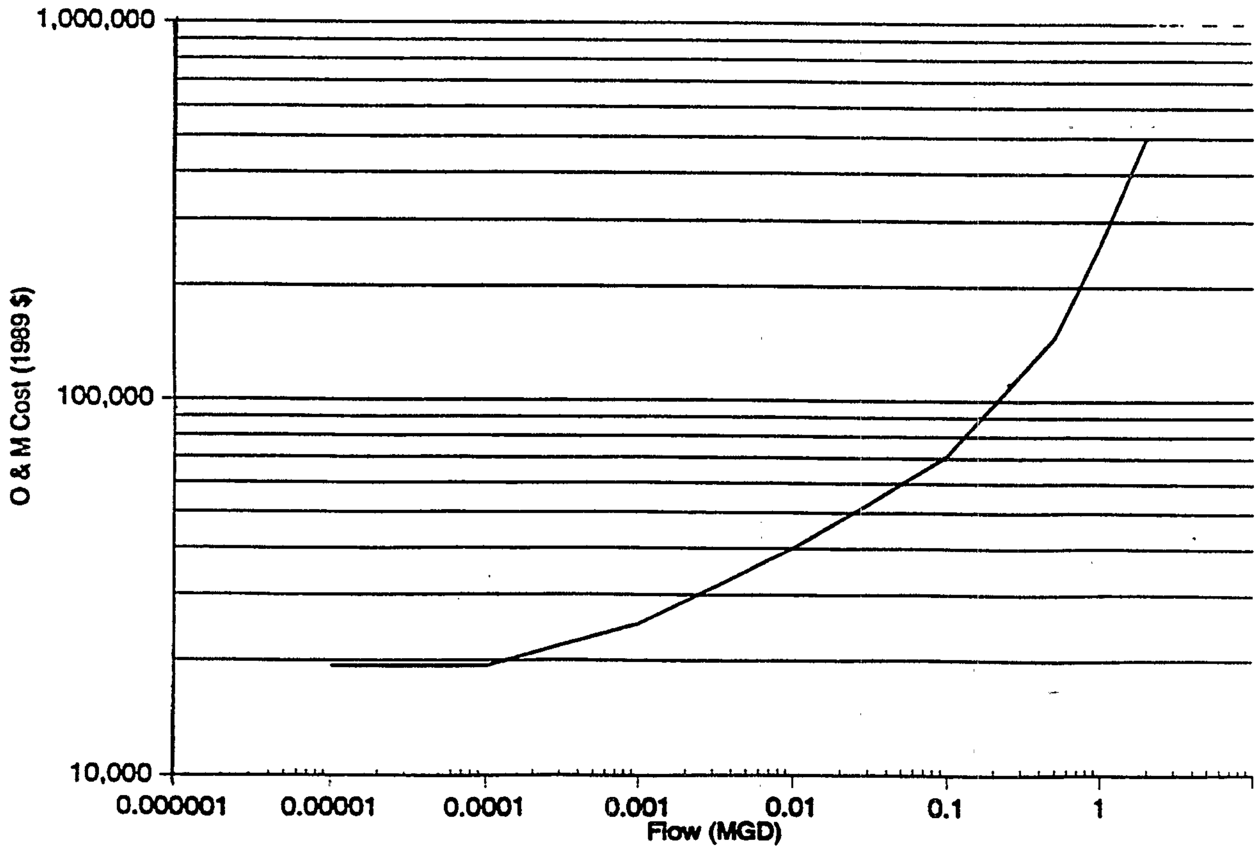

Figure 6-2 Plate & Frame Filtration (Sludge Stream) O & M Cost Curve Metals Option 1

Table 6-1. Capital Costs for Plate and Frame Pressure Filtration - Metals Option 1 (Sludge Stream)

Wastewater Influent Flow (MGD)	Sludge Filtration Flow (MGD)	Average Vendor Equipment Cost	Install. Cost	Total Capital & Installation Cost	Engineering & Contingency Fee	Total Capital Cost (1989 $)
0.000001	0.0000002	6,325	2,214	8,539	2,562	10,102
0.00001	0.000002	6,325	2,214	8,539	2,562	10,102
0.0001	0.00002	6,482	2,269	8,751	2,625	10,352
0.001	0.0002	9,897	3,464	13,361	4,008	15,806
0.01	0.0020	29,474	10,316	39,790	11,937	47,072
0.05	0.0100	93,960	32,886	126,846	38,054	150,059
0.10	0.0200	171,183	59,914	231,097	69,329	273,388
0.50	0.1000	870,475	304,666	1,175,141	352,542	1,390,192
1.00	0.2000	1,939,145	678,701	2,617,846	785,354	3,096,912

The O & M costs were based on estimated electricity usage, maintenance, labor, taxes and insurance, and filter cake disposal costs. The electricity usage and costs were based upon a usage rate of 0.5 kwhr per 1,000 gallons at $0.08 per kwhr, and lighting and control energy costs were estimated at $1,000 per year. Maintenance was approximated at four percent of the capital cost. Taxes and insurance were approximated at two percent of the capital cost. The labor cost for the plate and frame pressure filtration system was approximated at $31,200 per man-year at thirty minutes per cycle per filter press.

Filter cake disposal costs were derived from responses to the WTI Questionnaire. The disposal cost was estimated at $0.74 per gallon of filter cake; this is based on the cost of contract hauling and disposal in a Subtitle C or Subtitle D landfill. A more detailed explanation of the filter cake disposal costs development is presented in Subsection 6.2. To determine the total O & M costs for a plate and frame filtration system, the filter cake disposal costs must be added to the other O & M costs.

The O & M costs were converted to 1989 dollars using ENR's cost index. The itemized annual O & M costs, excluding the filter cake disposal costs, are presented in Table 6-2 with its subsequent cost curve presented in Figure 6-2.

Table 6-2. O & M Costs for Plate & Frame Pressure Filtration - Metals Option 1 (Sludge Stream - Excluding Filter Cake Disposal Costs)

Wastewater Influent Flow (MGD)	Sludge Filtration Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	O & M Cost (1989 $)
0.000001	0.0000002	1,000	404	202	17,730	19,336
0.00001	0.000002	1,000	404	202	17,730	19,336
0.0001	0.00002	1,001	414	207	17,730	19,352
0.001	0.0002	1,005	632	316	35,457	37,410
0.01	0.002	1,010	1,882	941	53,549	57,382
0.10	0.02	1,104	10,935	5,468	53,549	71,056
0.50	0.10	1,520	55,607	27,804	62,504	147,435
1.0	0.2	2,040	123,876	61,938	71,550	259,404

The O & M cost equation for Metals Option 1 sludge filtration is:

$$\ln(Y2) = 12.239 + 0.388\ln(X) + 0.016(\ln(X))^2 \qquad \textbf{(6-2)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O & M Cost (1989 $).

A pressure filtration system upgrade was calculated to estimate the increase in O & M costs for facilities that already have a pressure filtration system in-place. These facilities would need to improve pollutant removals from their current performance levels to Metals Option 1 levels. To determine the incremental percentage increase from current performance to Metals Option 1 levels, the ratio of the current performance to Option 1 levels versus the raw data to current performance levels was calculated. This incremental percentage increase was determined to be three percent, as follows:

$$\text{O \& M Upgrade Increase} = \frac{\text{Current - Metals Option 1}}{\text{Raw - Current}} = 0.03 = 3\% \qquad (6\text{-}3)$$

Therefore, in order for the facilities to perform at Metals Option 1 levels, an O & M cost upgrade of three percent of the total O & M costs (except for taxes and insurance, which are a function of the capital cost) would be realized for each facility. The itemized O & M upgrade costs without the filter cake disposal costs are presented in Table 6-3.

Table 6-3. O & M Upgrade Costs for Plate & Frame Filtration for Metals Option 1 (Sludge Stream - Excluding Filter Cake Disposal Costs)

Wastewater Influent Flow (MGD)	Sludge Filtration Flow (MGD)	Energy	Maintenance	Labor	O & M Cost (1989 $)
0.000001	0.0000002	30	12	531	574
0.00001	0.000002	30	12	531	574
0.0001	0.00002	30	12	531	574
0.001	0.0002	30	18	1,063	1,113
0.01	0.002	30	56	1,606	1,693
0.05	0.01	31	180	1,606	1,818
0.10	0.02	33	328	1,606	1,968
0.50	0.10	45	1,668	1,875	3,589
1.0	0.2	61	3,716	2,146	5,924

The O & M upgrade cost equation for Metals Option 1 sludge filtration system is presented as Equation 6-4, with the subsequent cost curve in Figure 6-3.

$$\ln(Y2) = 8.499 + 0.331\ln(X) + 0.013(\ln(X))^2 \qquad (6\text{-}4)$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O & M Cost (1989 $).

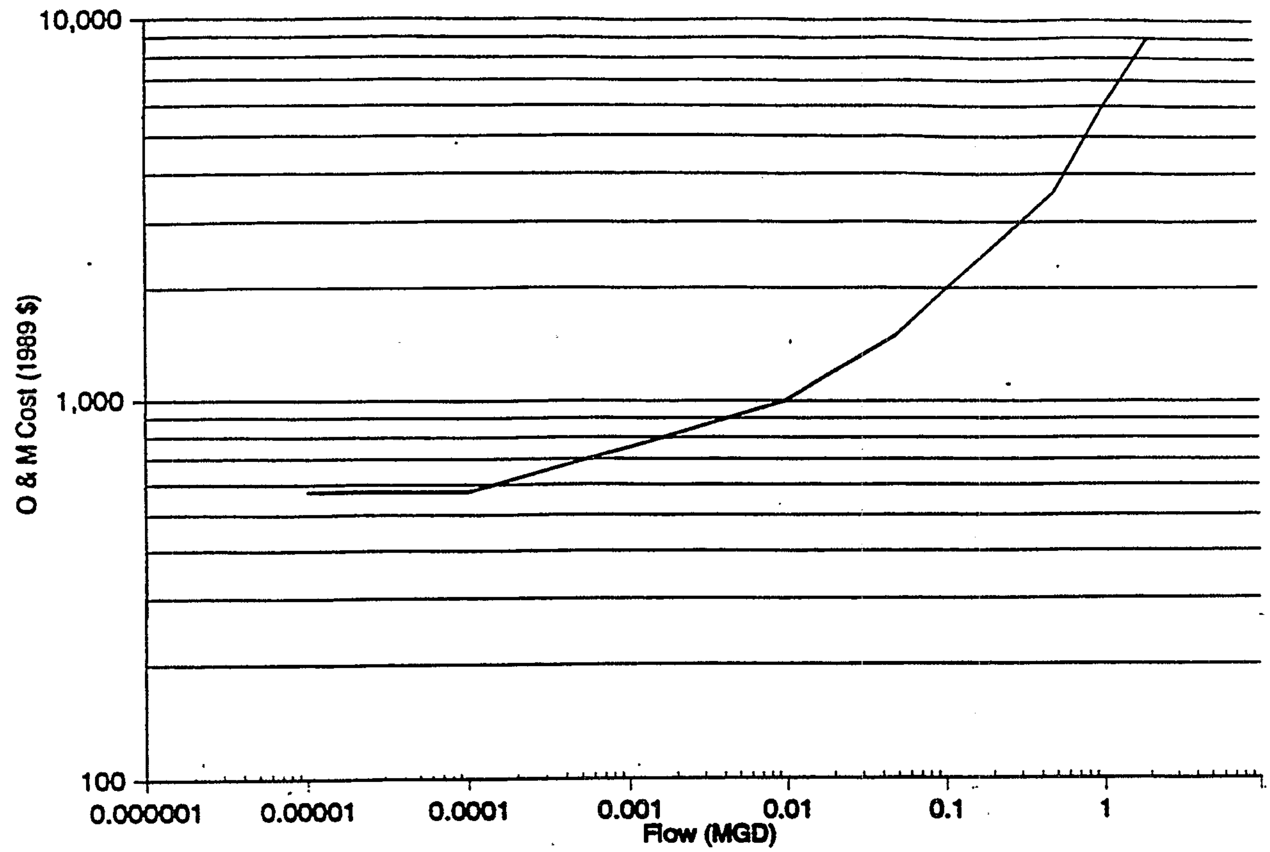

Figure 6-3 Plate & Frame Filtration (Sludge Stream) O & M Upgrade Cost Curve Metals Option 1

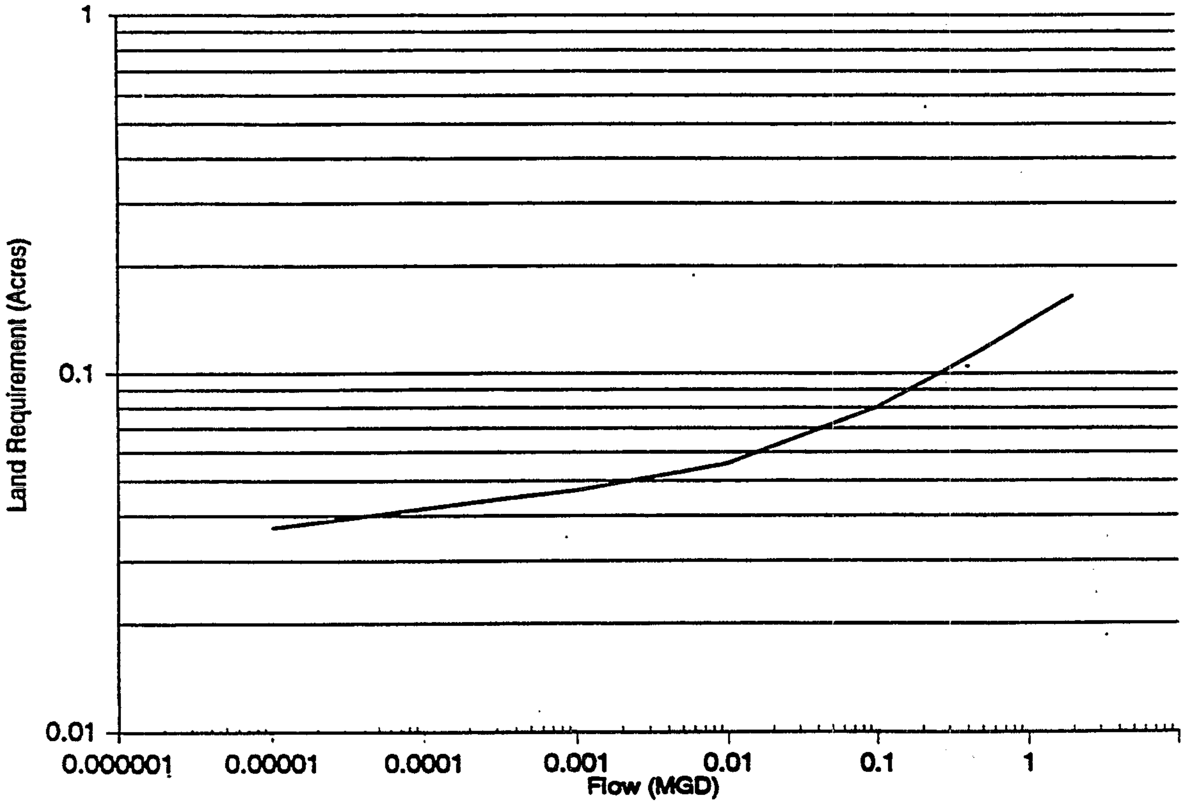

Figure 6-4 Plate & Frame Filtration (Sludge Stream) Land Requirement Curve Metals Option 1

Land requirements were calculated for the plate and frame pressure filtration systems. The land requirements were obtained by adding a perimeter of 20 feet around the equipment dimensions supplied by vendors. The land requirement curve is presented in Figure 6-4. The land requirement equation for Metals Option 1 sludge filtration is:

$$\ln(Y3) = -1.971 + 0.281\ln(X) + 0.018(\ln(X))^2 \qquad (6\text{-}5)$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y3 = Land Area Requirements (Acres).

6.2 *FILTER CAKE DISPOSAL*

The liquid stream and sludge stream pressure filtration systems presented in Subsections 3.3 and 6.1, respectively, generate a filter cake residual. There is an annual O & M cost that is associated with the disposal of this residual. This cost must be added to the pressure filtration equipment O & M costs to arrive at the total O & M costs for the pressure filtration operation.

To determine the cost of transporting filter cake to an off-site facility for disposal, an analysis of the WTI Questionnaire response data base was performed. Data from a subset of questionnaire respondents was pulled for analysis. This subset consisted of Metals Subcategory facilities that are direct and/or indirect dischargers, and would therefore be costed for CWT compliance. From these responses, the reported costs for both the Subtitle C and Subtitle D contract haul/disposal methods of filter cake disposal were tabulated. This information was edited to eliminate incomplete or combined data that could not be used. The resulting data set is presented in Table 6-4.

From this data set, the median cost for both the Subtitle C and Subtitle D disposal options were determined. Then, the weighted average of these median costs was determined. The average was weighted to reflect the ratio of hazardous (67 percent) to nonhazardous (33 percent) waste receipts at these Metals Subcategory facilities. The final disposal cost is $0.74 per gallon of filter cake.

The O & M costs for filter cake disposal for the Metals Options 1 and 2 plate and frame filtration full systems and system upgrades are given in Table 6-5, and the resultant cost curves are shown in Figures 6-5 and 6-6. The filter cake disposal O & M cost and O & M upgrade cost equations are presented as Equations 6-6 and 6-7, respectively.

$$Z = 0.109169 + 7{,}695{,}499.8(X) \qquad (6\text{-}6)$$

$$Z = 0.101186 + 230{,}879.8(X) \qquad (6\text{-}7)$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Z = Filter Cake Disposal Cost (1989 $).

Table 6-4. CWT Metals Subcategory Filter Cake Disposal Costs

CWT QID	Filtercake Quantity (Pounds per Year)	Total Cost (1989 $ per Year)	Unit Cost (1989 $/G Filter Cake)
Subtitle C Landfills			
022	2,632,000	250,000	0.95
072	8,834,801	835,484	0.95
080	6,389,520	711,000	1.11
089	9,456,000	602,471	0.64
100	968,000	125,964	1.30
105	13,230,000	1,164,200	0.88
255	3,030,000	530,250	1.75
257	151,650	12,450	0.82
284	5,850,000	789,000	1.35
288	297,234	36,750	1.24
294	2,628,600	390,000	1.48
449	36,000,000	2,000,000	0.56
MEDIAN			1.03
Subtitle D Landfills			
067	15,393,486	276,160	0.18
072	440,000	24,200	0.55
119	30,410,880	361,000	0.19
132	26,378,000	158,273	0.06
133	36,960,587	780,351	0.21
135	131,451,200	2,768,225	0.21
231	80,000,000	800,000	0.10
294	56,777,760	898,560	0.16
298	2,365,740	18,800	0.08
MEDIAN			0.16
Weighted Average of Subtitle C and D Landfills Median Values			
Weighted Average ($1.03 @ 67% + $0.16 @ 33%)			0.74

Source: WTI Questionnaire Data Base
Note: Pounds = Gallons x 8.34 x Specific Gravity (SG filtercake = 1.2)

Table 6-5. Filter Cake Disposal Costs for Plate and Frame Pressure Filtrations Systems - Metals Options 1 and 2

Wastewater Influent Flow (MGD)	Filter Cake Disposal Costs (1989 $)	Filter Cake Upgrade Disposal Costs (1989 $)
0.000001	8	1
0.00001	77	2
0.0001	770	23
0.001	7,696	231
0.01	76,960	2,309
0.05	384,800	11,544
0.10	769,600	23,088
0.50	3,848,000	115,440
1.0	7,696,000	230,880

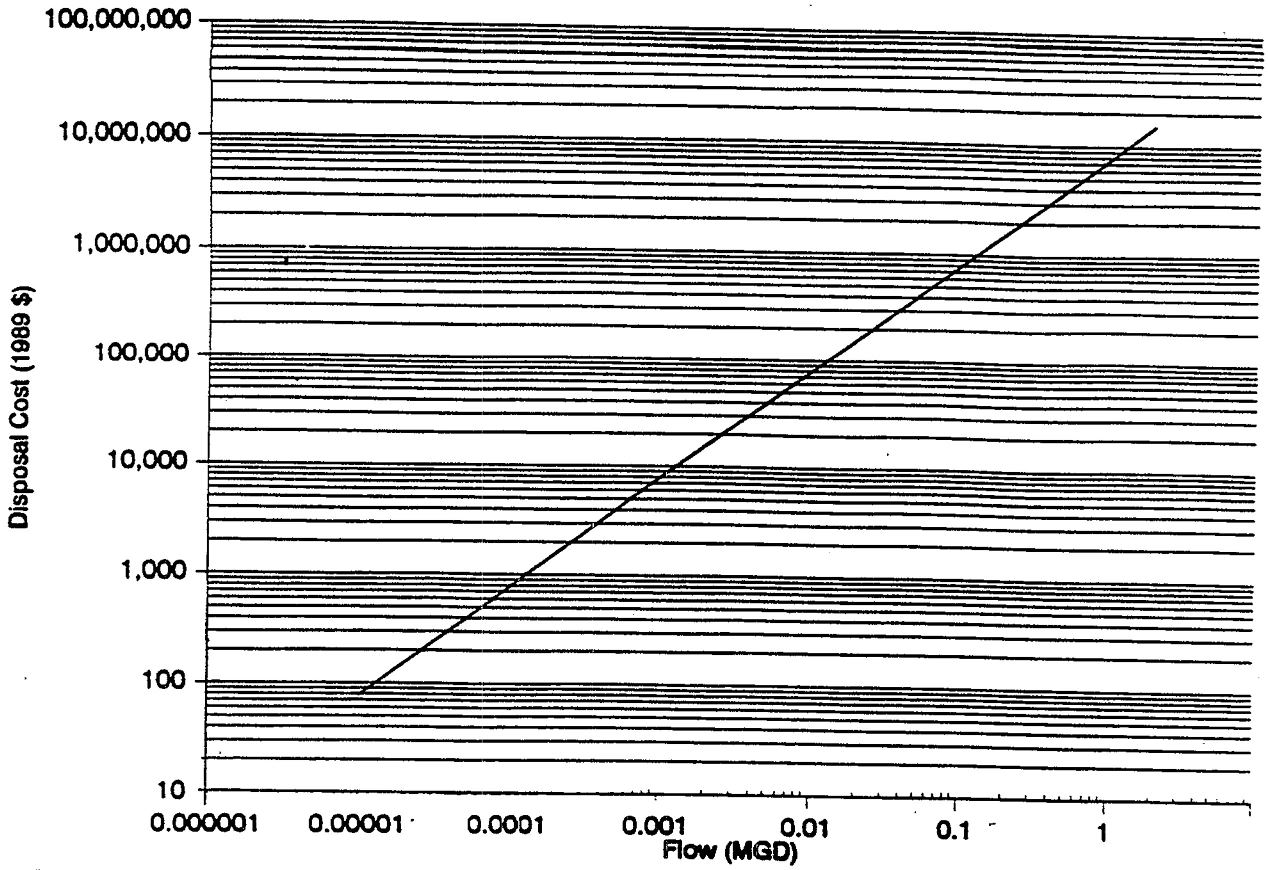

Figure 6-5 Filter Cake Disposal Cost Curve for Plate & Frame Filtration Systems Metals Options 1 & 2

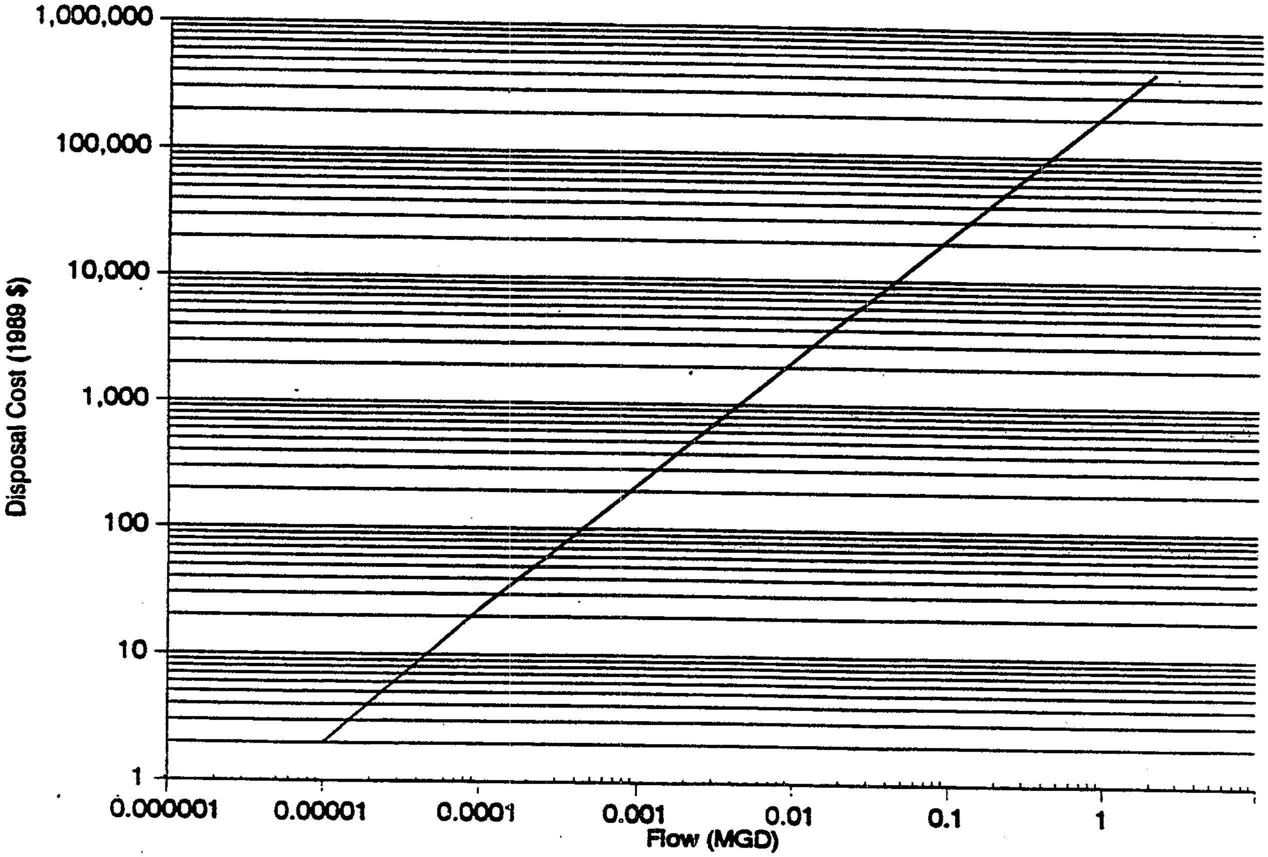

Figure 6-6 Filter Cake Disposal Upgrade Cost Curve for Plate & Frame Filtration Systems Metals Options 1 & 2

SECTION 7
ADDITIONAL COSTS

7.1 *RETROFIT COSTS*

Costs were assigned to the CWT Industry on both an option- and facility-specific basis. The option-specific approach costed a sequence of individual treatment technologies, corresponding to a particular regulatory option, for a subset of facilities defined as belonging to that regulatory subcategory. Within the costing of a specific regulatory option, treatment technology costs were assigned on a facility-specific basis depending upon the technologies determined to be currently in-place at the facility.

Once it was determined that a treatment technology cost should be assigned to a particular facility, there were two design scenarios which were considered. The first was the installation of a new individual treatment technology as a part of a new treatment train. The full capital costs presented in Sections 3 through 6 of this document apply to this scenario. The second scenario was the installation of a new individual treatment technology which would have to be integrated into an existing in-place treatment train. It is in the case of this second scenario that retrofit costs were applied. These retrofit costs cover such items as piping and structural modifications which would be required in an existing piece of equipment to accommodate the installation of a new piece of equipment prior to or within an existing treatment train.

For all facilities which received retrofit costs, a retrofit factor of 20 percent was applied to the total capital cost of the newly-installed or upgraded treatment technology unit that would need to integrated into an existing treatment train.

7.2 *MONITORING COSTS*

Monitoring costs will be realized by CWT facilities who discharge process wastewater directly to a receiving stream or indirectly to a POTW. Direct discharge effluent monitoring requirements are mandated in NPDES permits. Indirect discharge monitoring requirements are mandated by the operating authority of the POTW.

The method developed for the OCPSF Industry was used as the basis for the CWT monitoring cost estimation. The following generalizations have been used to estimate compliance monitoring costs:

1) Monitoring costs are based on the number of outfalls through which process wastewater is discharged. The cost for a single outfall is multiplied by the number of outfalls to arrive at the total costs for a facility.

2) Flow monitoring equipment costs are included in the capital costs for the specific treatment technologies.

3) Sample collection costs (labor and equipment) and sample shipping costs are not included and.

4) The monitoring costs (based on frequency and analytical methods) are incremental to the monitoring currently being incurred by the CWT facility.

Respondents to the WTI Questionnaire reported their POTW discharge monitoring requirements. For direct discharger, NPDES permits were reviewed. This information shows that most facilities are currently required to monitor for several classical pollutant parameters (e.g. BOD_5, TSS, pH, and cyanide). And, for the parameters that are not addressed, these analyses are relatively inexpensive. Therefore, costs for classical pollutant analyses are not included in the cost estimation.

Many facilities are required to monitor for commonly-regulated metals (e.g. lead, copper, and nickel); however, the CWT list of pollutants includes many more metals than any facility currently quantifies. Therefore, costs for metals monitoring are included in the cost estimation.

Very few facilities are required to monitor for organic compounds, so costs are included for these analyses. EPA method 1624 is used for the quantification of volatile organic compounds, and Method 1625 is used for the quantification of semivolatile organic compounds.

The frequency of monitoring currently required in the CWT Industry varies widely for any specific parameter from daily to semi-annually. An estimated weekly frequency was used for the cost estimation. This frequency includes a full scan as one of the analyses each month.

The OCPSF methodology assumes that larger discharges would be required to monitor for more parameters within a pollutant group. As such, the analytical cost would increase based on the number of parameters to be quantified. The monitoring costs, adjusted to 1989 dollars, are presented in Table 7-1.

Table 7-1. Monitoring Costs for the CWT Industry

Flow (MGD)	Annual Monitoring Cost per Outfall (1989$)
≤ 0.5	40,680
0.5-4.99	61,725
5-9.99	68,100
≥ 10	134,525

7.3 *RCRA PERMIT MODIFICATION COSTS*

Respondents to the 1991 WTI Questionnaire whose RCRA Part B permits were modified were asked to report the following information pertaining to the cost of obtaining the modification:

- Legal fees;
- Administrative costs;
- Public relations costs;
- Other costs; and
- Total costs.

The purpose of the permit modification was also asked. Anticipated changes to a facility's RCRA permit as a result of the implementation of CWT regulations include the upgrades to existing equipment and/or the installation of new treatment technologies to achieve effluent limitations. These changes correlate with the purposes identified by the WTI Questionnaire respondents as "new tanks", "new units", "new technologies", and "other - modification of existing equipment". The applicable costs are summarized in Table 7-2.

Table 7-2. RCRA Permit Modification Costs Reported in WTI Questionnaire

Modification	QID	Year	Total Cost (Reported $)	Total Cost (1989 $)
New Units	081	1990	26,000	25,357
	255	1990	7,000	6,827
New Technology	081	1990	82,000	79,793
	090	1990	6,300,000*	6,144,231
Modify Existing Equipment	402	1991	14,080	13,440
Average	-	-	-	31,400

* This cost includes equipment/installation costs; no cost breakdown is given. Therefore, this cost was not used in calculating the average cost.

7.4 *LAND COSTS*

An important factor in the calculation of treatment technology costs is the value of the land needed for the installation of the technology. Due to continuing development, the availability and therefore the cost of land can prove to be a significant part of the capital cost. To determine the amount of land required for costing purposes, the land requirements for each treatment technology were calculated for the range of system sizes. These land requirements were fitted to a curve so that a land requirement, in acres, could be calculated for every treatment system costed. The individual land requirements are then multiplied by the corresponding land cost estimates to obtain facility-specific cost estimates. Since land costs may vary widely across the country, a nationwide average figure would not be representative. Therefore, the average land costs for suburban sites of each state were obtained from the 1990 Guide to Industrial Real Estate Office Markets survey.

Table 7-3 shows the estimated unit land prices for the unimproved suburban sites of major cities and the averages for each state and region. According to the survey, the unimproved sites are the most desirable of the existing inventory and are zoned for industrial use; therefore, improved land costs were used in this analysis. Table 7-4 is a summary of the estimated land prices for each state. For states that have no land prices available, the regional average figures were used. In calculating the regional average costs for the western region, Hawaii was not included because of Hawaii's disproportionately high land cost, which would have skewed the regional average.

The survey report data is broken down by site size ranges; these are zero to 10 acres, 10 to 100 acres, and greater than 100 acres. The respondents to the WTI Questionnaire reported total facility areas ranging from less than one acre to 2,700 acres and undeveloped facility areas from zero to 1,775 acres. Since the CWT facilities fall into all three size ranges covered by the report data, the three size-specific land costs for each state were averaged to arrive at the final costs for the industry. Table 7-5 indicates that the least expensive state is Kansas with a land cost of $7,042 per acre. The most expensive state is Hawaii with a land cost of $1,089,000 per acre.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: Northeast

State	City	Land Costs ($/ft²)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Connecticut	Hartford	1.37	0.92	0.58
	New Haven	1.85	1.60	1.15
	State Average Cost	1.61	1.26	0.87
	Estimated State Cost/Acre($)	70,132	54,886	37,679
Maine	Portland	0.60	0.40	0.35
	State Average Cost	0.60	0.40	0.35
	Estimated State Cost/Acre($)	26,136	17,424	15,246
Massachusetts	Boston	-	2.00	1.50
	Springfield	1.45	1.10	0.75
	State Average Cost	1.45	1.55	1.13
	Estimated State Cost/Acre($)	63,162	67,518	49,005
New Hampshire	Nashua	1.50	1.15	1.00
	State Average Cost	1.50	1.15	1.00
	Estimated State Cost/Acre($)	65,340	50,094	43,560
New Jersey	Central	2.00	1.50	1.00
	Northern	4.00	3.50	2.50
	Southern	1.15	1.10	-
	State Average Cost	2.38	2.03	1.75
	Estimated State Cost/Acre($)	103,673	88,426	76,230

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: Northeast

State	City	Land Costs ($/ft²)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
New York	Albany	1.20	1.00	0.40
	Buffalo	0.25	0.15	0.12
	Rochester	0.75	0.50	0.25
	Rockland/Westchester Counties	20.00	12.00	-
	Syracuse	0.40	0.35	0.25
	State Average Cost	4.52	2.80	0.26
	Estimated State Cost/Acre($)	196,891	121,968	11,180
Pennsylvania	Philadelphia	0.90	0.80	0.80
	Pittsburgh	1.00	0.60	0.35
	State Average Cost	0.95	0.70	0.58
	Estimated State Cost/Acre($)	41,382	30,492	25,047
Rhode Island		*	*	*
Vermont		*	*	*
REGIONAL	AVERAGE REGIONAL COST	1.86	1.41	0.85
	ESTIMATED REGIONAL COST/ACRE($)	80,959	61,544	36,964

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: North Central

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Illinois	Chicago	1.65	1.50	1.25
	Quad Cities	0.25	0.20	0.15
	State Average Cost	0.95	0.85	0.70
	Estimated State Cost/Acre($)	41,382	37,026	30,492
Indiana	Gary-Hammond	0.60	0.60	0.50
	Indianapolis	2.30	-	-
	South Bend	0.34	0.20	0.10
	Terre Haute	0.50	0.10	0.05
	State Average Cost	0.94	0.30	0.22
	Estimated State Cost/Acre($)	40,728	13,068	9,438
Iowa	Des Moines	0.30	0.25	0.20
	Quad Cities	0.25	0.20	0.15
	Sioux City	0.25	0.15	0.10
	State Average Cost	0.27	0.20	0.15
	Estimated State Cost/Acre($)	11,616	8,712	6,534
Kansas	Kansas City	-	0.20	0.20
	Wichita	0.23	0.09	0.02
	State Average Cost	0.23	0.15	0.11
	Estimated State Cost/Acre($)	10,019	6,316	4,792

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: North Central

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Michigan	Grand Rapids	0.85	0.40	0.18
	Jackson	0.20	0.15	0.10
	State Average Cost	0.53	0.28	0.14
	Estimated State Cost/Acre($)	22,869	11,979	6,098
Minnesota	Minneapolis/ St. Paul	1.00	0.25	0.20
	State Average Cost	1.00	0.25	0.20
	Estimated State Cost/Acre($)	43,560	10,890	8,712
Missouri	Kansas City	-	0.20	0.20
	St Louis	1.50	1.10	1.00
	State Average Cost	1.50	0.65	0.60
	Estimated State Cost/Acre($)	65,340	28,314	26,136
Ohio	Akron	0.80	0.25	0.20
	Cincinnati	0.75	0.50	0.55
	Cleveland	0.40	0.30	0.17
	Columbus	0.25	0.18	0.12
	Dayton	0.25	0.20	0.15
	State Average Cost	0.49	0.29	0.23
	Estimated State Cost/Acre($)	21,344	12,458	9,932

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: North Central

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Nebraska	Omaha	0.70	0.60	0.40
	State Average Cost	0.70	0.60	0.40
	Estimated State Cost/Acre($)	30,492	26,136	17,424
North Dakota		*	*	*
South Dakota		*	*	*
Wisconsin	Milwaukee	0.60	0.35	0.25
	State Average Cost	0.60	0.35	0.25
	Estimated State Cost/Acre($)	26,136	15,246	10,890
REGIONAL	AVERAGE REGIONAL COST	0.72	0.89	0.30
	ESTIMATED REGIONAL COST/ACRE($)	31,407	16,988	13,068

* No data available for state, use regional average.

\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: South

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Alabama	Birmingham	1.00	0.50	0.30
	Mobile	0.75	0.50	0.50
	State Average Cost	0.88	0.50	0.40
	Estimated State Cost/Acre($)	38,115	21,780	17,424
Arkansas	Fort Smith	0.75	0.60	0.50
	Little Rock	0.15	0.10	0.10
	State Average Cost	0.45	0.35	0.30
	Estimated State Cost/Acre($)	19,602	15,028	13,068
Delaware	Wilmington	1.50	1.25	1.00
	State Average Cost	1.50	1.25	1.00
	Estimated State Cost/Acre($)	65,340	54,450	43,560
Florida	Jacksonville	1.00	1.00	0.75
	Ft Lauderdale	4.50	3.50	3.50
	Lakeland	0.45	0.45	0.30
	Melbourne/ South Brevard Cty	0.80	0.80	0.80
	Miami	3.00	1.60	-
	Orlando	1.25	0.50	0.50
	Sarasota/Bradenton	0.85	0.65	0.50
	Tampa	1.75	1.25	1.25
	West Palm Beach	3.10	2.25	1.75
	State Average Cost	1.86	1.33	1.17
	Estimated State Cost/Acre($)	80,828	58,080	50,911

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: South

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Georgia	Atlanta	2.00	1.75	1.25
	State Average Cost	2.00	1.75	1.25
	Estimated State Cost/Acre($)	87,120	76,230	54,450
Kentucky	Louisville	0.80	0.70	0.50
	State Average Cost	0.80	0.70	0.50
	Estimated State Cost/Acre($)	34,848	30,492	21,780
Louisiana	New Orleans	2.00	2.00	2.00
	Shreveport	1.00	0.50	0.30
	State Average Cost	1.50	1.25	1.15
	Estimated State Cost/Acre($)	65,340	54,450	50,094
Maryland	Baltimore	3.00	3.00	1.75
	State Average Cost	3.00	3.00	1.75
	Estimated State Cost/Acre($)	130,680	130,680	76,230
Mississippi	Jackson	0.50	0.20	0.20
	State Average Cost	0.50	0.20	0.20
	Estimated State Cost/Acre($)	21,780	8,712	8,712
North Carolina	Charlotte	0.50	0.40	0.30
	Greensboro	0.90	0.75	-
	Raleigh	1.00	1.50	1.00
	State Average Cost	0.80	0.88	0.65
	Estimated State Cost/Acre($)	34,848	38,478	28,314

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: South

State	City	Land Costs ($/ft²)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Oklahoma	Oklahoma City	0.70	0.75	0.50
	Tulsa	0.50	0.50	0.40
	State Average Cost	0.60	0.63	0.45
	Estimated State Cost/Acre($)	26,136	27,225	19,602
South Carolina	Charleston	0.75	0.50	0.30
	Columbia	0.70	0.40	0.25
	Greenville	0.65	0.45	0.40
	State Average Cost	0.70	0.45	0.32
	Estimated State Cost/Acre($)	30,492	- 19,602	13,794
Tennessee	Chattanooga	0.40	0.60	0.50
	Knoxville	0.45	0.25	0.15
	Memphis	1.00	0.75	0.55
	Nashville	0.80	0.50	0.50
	State Average Cost	0.66	0.43	0.35
	Estimated State Cost/Acre($)	28,859	18,513	15,246
Texas	Austin	0.75	0.60	0.50
	Corpus Christi	1.25	0.50	0.20
	Dallas	2.50	2.00	1.50
	Fort Worth	1.00	0.75	0.50
	Houston	2.50	2.00	1.00
	San Antonio	0.85	0.65	0.65
	State Average Cost	1.48	1.08	0.73
	Estimated State Cost/Acre($)	64,251	47,190	31,581

* No data available for state, use regional average.

\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: South

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Virginia	Richmond	0.75	1.00	0.75
	Roanoke	1.25	1.00	0.75
	State Average Cost	1.00	1.00	0.75
	Estimated State Cost/Acre($)	43,560	43,560	32,670
District of Columbia	Washington	4.50	3.50	-
	State Average Cost	4.50	3.50	-
	Estimated State Cost/Acre($)	196,020	152,460	-
West Virginia		*	*	*
REGIONAL	AVERAGE REGIONAL COST	1.39	1.14	0.73
	ESTIMATED REGIONAL COST/ACRE($)	60,521	49,658	31,857

* No data available for state, use regional average.
\- No data available for city or area indicated.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: West

State	City	Land Costs ($/ft^2)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Alaska		*	*	*
Arizona	Phoenix	2.25	1.50	0.75
	Tucson	1.00	0.60	0.25
	State Average Cost	1.63	1.05	0.50
	Estimated State Cost/Acre($)	70,785	45,738	21,780
California	Contra Costa	3.00	1.50	-
	Orange County	12.00	11.00	-
	San Fernando Valley	7.00	6.00	5.00
	San Gabriel Valley	7.50	4.50	-
	South Bay	18.00	18.00	18.00
	Marin & Sonoma Counties	4.00	2.50	-
	San Diego	6.00	6.00	5.00
	Stockton	1.20	0.60	0.50
	State Average Cost	7.34	6.26	7.13
	Estimated State Cost/Acre($)	319,622	272,795	310,365
Colorado	Denver	1.25	1.00	0.75
	State Average Cost	1.25	1.00	0.75
	Estimated State Cost/Acre($)	54,450	43,560	32,670
Hawaii**	Honolulu	30.00	20.00	-
	State Average Cost	30.00	20.00	-
	Estimated State Cost/Acre($)	1,306,800	871,200	-

* No data available for state, use regional average.
\- No data available for city or area indicated.
** Hawaii was not included in the regional average calculations.

Table 7-3. Unimproved Land Costs for Suburban Areas - Region: West

State	City	Land Costs ($/ft²)		
		0 - 10 Acres	10 - 100 Acres	>100 Acres
Idaho		*	*	*
Montana		*	*	*
Nevada	Reno	1.25	0.75	0.50
	State Average Cost	1.25	0.75	0.50
	Estimated State Cost/Acre($)	54,450	32,670	21,780
New Mexico	Albuquerque	1.00	0.50	0.35
	State Average Cost	1.00	0.50	0.35
	Estimated State Cost/Acre($)	43,560	21,780	15,246
Oregon	Portland	2.00	1.00	0.50
	State Average Cost	2.00	1.00	0.50
	Estimated State Cost/Acre($)	87,120	43,560	21,780
Utah		*	*	*
Washington	Seattle - Eastside	4.50	3.50	-
	Spokane	0.35	0.20	0.11
	State Average Cost	2.43	1.85	0.11
	Estimated State Cost/Acre($)	105,633	80,586	4,792
Wyoming		*	*	*
REGIONAL	AVERAGE REGIONAL COST	2.41	1.77	1.41
	ESTIMATED REGIONAL COST/ACRE($)	104,980	77,101	61,233

* No data available for state, use regional average.
\- No data available for city or area indicated.
** Hawaii was not included in the regional average calculations.

Table 7-4. Summary of Land Costs for Unimproved Suburban Areas - Region: Northeast

State	Land Costs per Acre ($)		
	0 - 10 Acres	10 - 100 Acres	>100 Acres
Connecticut	70,132	54,886	37,679
Maine	26,136	17,424	15,246
Massachusetts	63,162	67,518	49,005
New Hampshire	65,340	50,094	43,560
New Jersey	103,673	88,426	76,230
New York	196,891	121,968	11,180
Pennsylvania	41,382	30,492	25,047
Rhode Island	*	*	*
Vermont	*	-*	*
ESTIMATED REGIONAL COST/ACRE($)	80,959	61,544	36,964

* No data available for state, use regional average.

Table 7-4. Summary of Land Costs for Unimproved Suburban Areas - Region: North Central

State	Land Costs per Acre ($)		
	0 - 10 Acres	10 - 100 Acres	>100 Acres
Illinois	41,382	37,026	30,492
Indiana	40,728	13,068	9,438
Iowa	11,616	8,712	6,534
Kansas	10,019	6,316	4,792
Michigan	22,869	11,979	6,098
Minnesota	43,560	10,890	8,712
Missouri	65,340	28,314	26,136
New Mexico	*	*	*
Ohio	21,344	12,458	9,932
Nebraska	30,492	26,136	17,424
North Dakota	*	*	*
South Dakota	*	*	*
Wisconsin	26,136	15,246	10,890
ESTIMATED REGIONAL COST/ACRE($)	31,407	16,988	13,068

* No data available for state, use regional average.

Table 7-4. Summary of Land Costs for Unimproved Suburban Areas - Region: South

State	Land Costs per Acre ($)		
	0 - 10 Acres	10 - 100 Acres	>100 Acres
Alabama	38,115	21,780	17,424
Arkansas	19,602	15,028	13,068
Delaware	65,340	54,450	43,560
Florida	80,828	58,080	50,911
Georgia	87,120	76,230	54,450
Kentucky	34,848	30,492	21,780
Louisiana	65,340	54,450	50,094
Maryland	130,680	130,680	76,230
Mississippi	21,780	8,712	8,712
North Carolina	34,848	38,478	28,314
Oklahoma	26,136	27,225	19,602
South Carolina	30,492	19,602	13,794
Tennessee	28,859	18,513	15,246
Texas	64,251	47,190	31,581
Virginia	43,560	43,560	32,670
District of Columbia	196,020	152,460	-
West Virginia	*	*	*
ESTIMATED REGIONAL COST/ACRE($)	60,521	49,658	31,857

* No data available for state, use regional average.

Table 7-4. Summary of Land Costs for Unimproved Suburban Areas - Region: West

State	Land Costs per Acre ($)		
	0 - 10 Acres	10 - 100 Acres	>100 Acres
Alaska	*	*	*
Arizona	70,785	45,738	21,780
California	319,622	272,795	310,365
Colorado	54,450	43,560	32,670
Hawaii**	1,306,800	871,200	*
Idaho	*	*	*
Montana	*	*	*
Nevada	54,450	32,670	21,780
New Mexico	43,560	21,780	15,246
Oregon	87,120	43,560	21,780
Utah	*	*	*
Washington	105,633	80,586	4,792
Wyoming	*	*	*
ESTIMATED REGIONAL COST/ACRE($)**	104,980	77,101	61,233

* No data available for state, use regional average.

** Hawaii was not included in the regional average calculations.

Table 7-5. State Land Costs for the CWT Industry

State	Land Cost per Acre (1989 $)	State	Land Cost per Acre (1989 $)
Alabama	22,773	Nebraska	24,684
Alaska*	81,105	Nevada	36,300
Arizona	46,101	New Hampshire	52,998
Arkansas	15,899	New Jersey	89,443
California	300,927	New Mexico	26,929
Colorado	43,560	New York	110,013
Connecticut	54,232	North Carolina	33,880
Delaware	54,450	North Dakota*	20,488
Florida	63,273	Ohio	14,578
Georgia	72,600	Oklahoma	24,321
Hawaii	1,089,000	Oregon	50,820
Idaho*	81,105	Pennsylvania	32,307
Illinois	36,300	Rhode Island*	59,822
Indiana	21,078	South Carolina	21,296
Iowa	8,954	South Dakota*	20,488
Kansas	7,042	Tennessee	20,873
Kentucky	29,040	Texas	47,674
Louisiana	56,628	Utah*	81,105
Maine	19,602	Vermont*	59,822
Maryland	112,530	Virginia	39,930
Massachusetts	59,895	Washington	63,670
Michigan	13,649	West Virginia*	47,345
Minnesota	21,054	Wisconsin	17,424
Mississippi	13,068	Wyoming*	81,105
Missouri	39,930	Washington DC	174,240
Montana*	81,105		

* No data available for state, use regional average.

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