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Cost-Effectiveness Analysis Of Proposed Effluent Limitations Guidelines And Standards For The Centralized Waste Treatment Industry

Cost-Effectiveness Analysis of Proposed Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry

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CHAPTER 1
INTRODUCTION

This analysis, submitted in support of proposed effluent limitations guidelines and standards for the centralized waste treatment (CWT) industry, investigates the cost-effectiveness of 24 regulatory options, representing all possible combinations of nine proposed control options for three subcategories of CWT operations. The measure of effectiveness used for comparing regulatory options is the ratio of nationally aggregated total annualized compliance costs to the estimated total mass in pounds of certain toxic pollutants, each weighted according to its relative toxicity, removed under each regulatory option. These removals include removals of all toxic pollutants for which toxic weighting factors have been developed. Some pollutants removed are specifically addressed by the regulation, and others are pollutants that are incidentally removed from CWT facility discharges as a result of complying with the regulation even though they are not specifically regulated under the proposed guidelines and standards. Pollutant removals are assessed for each regulatory option in terms of the net reduction in toxicity of pollutants discharged to surface waters.

Several factors are of particular importance to understanding the results of the cost-effectiveness comparisons presented in this report. First, the analysis is based on removals of standardized "pound equivalents"—a term used to describe a pound of pollutant weighted for its toxicity. Using pound equivalents reflects the fact that some pollutants are more toxic than others and permits summing removals across pollutants. A mass loading in pounds per year (lbs/yr) of each pollutant removed is multiplied by its corresponding weighting factor to derive the pollutant's "toxic equivalent" loading (lbs-equivalent/yr). The cost-effectiveness (in dollars per pound-equivalent removed) of various treatment options may be compared by summing these weighted load reductions across a group of dischargers and dividing the sum into the total estimated cost to the same group of dischargers. Comparisons may also be made on an incremental basis—by comparing the incremental cost and weighted removals of each regulatory option to those of another regulatory option or to an existing treatment.

This analysis employs two different approaches developed by EPA for weighting different pollutants according to their relative toxicity. Each approach uses a different standardized measure of toxicity. The Agency uses each of these approaches to calculate total pound-equivalent pollutant removals attributable to each regulatory option. The first approach uses the toxic weighting factors (TWFs) previously used for effluent guidelines development. The second approach employs new pollutant weighting factors (PWFs) that were developed following the recommendations of an intra-agency workgroup on PWFs. The results of the cost-effectiveness analysis using the two approaches are similar, but not identical. The results from the TWF approach are summarized in the pages that follow. The results from the PWF approach are included in Appendix A.

No absolute scale can be used to evaluate a cost-effectiveness value; cost-effectiveness is a relative measure. Comparison of cost-effectiveness values is not meaningful unless the costs compared are taken from the same time period, or are adjusted to correct for inflation, and the removals are estimated using a consistent toxic weighting approach. Generally, lower cost-effectiveness values are preferable to higher values, because they indicate lower average unit costs of removals. However, policy-makers may have other selection criteria that would preclude choosing some regulatory options with low cost-effectiveness values. The Agency may decide, for example, that regulatory options with total costs above a certain level or with total removals below a particular level are not suitable for proposal.

Cost-effectiveness values are a useful tool for comparing the relative merits of regulatory options proposed at the same time for the same group of dischargers in a specific industry. They also provide a basis for comparing the efficiency of a regulatory option currently being considered for one industry with the efficiency of effluent limitations guidelines for other industries that have been approved in the past. This type of comparison is only possible using the TWF weighting approach because previous guidelines have used the TWF approach. Even then, the comparison is imperfect, because the TWFs that have been used for effluent guidelines development have been modified for some pollutants.

Chapter 2 of this report discusses the methods used for this cost-effectiveness analysis. It details the pollutants included in calculations of pollutant removals, lists the TWFs and PWFs used to estimate pound-equivalent removals expected under each regulatory option, and lists the subcategory control options that are combined to create the 24 regulatory options. Chapter 2 also includes a discussion of the required differences for estimating pollutant removals from direct-discharging CWT facilities as opposed to indirect-dischargers (facilities whose effluent receives treatment at a publicly owned treatment works [POTW] before it is discharged to surfaces waters). In addition, Chapter 2 describes how compliance costs were annualized, how two different cost-effectiveness values were calculated, and how they can be used to compare the merits of each regulatory option. Chapter 3 presents the findings of this analysis and identifies a subset of the 30 regulatory options that are demonstrably more costly and less effective than other options. Chapter 4 compares the remaining most efficient options to other promulgated rules.

CHAPTER 2
BACKGROUND OF METHODOLOGY

Cost-effectiveness calculations are used in the effluent limitations guidelines and standards development process to compare the efficiency of regulatory options in removing pollutants. The Agency evaluates both overall cost-effectiveness and incremental cost-effectiveness. Incremental cost-effectiveness is defined as the incremental (to another option or to a benchmark, such as existing treatment) annual cost of a pollution control option in an industry or industry subcategory per incremental toxicity-weighted pound of pollutant removed by that control option. In other words, the cost-effectiveness value represents the unit cost of removing the next pound equivalent of pollutant. While not required by the Clean Water Act (CWA), cost-effectiveness analysis offers a useful metric for comparing the efficiency of alternative regulatory options in removing toxic pollutants that are either directly regulated by the guidelines and standards or incidentally removed along with regulated pollutants. EPA's cost-effectiveness assessment does not analyze removal efficiencies for conventional pollutants, such as oil, grease, biological oxygen demand, and total suspended solids; thus the removal of conventional pollutants is not addressed in this report.

A cost-effectiveness calculation is simply a ratio of the annualized cost of a regulatory option for a group of dischargers to the pollutant loading removed from surface waters by the option for the same group of dischargers. EPA's cost-effectiveness analysis includes seven steps:

1. Determine the relevant wastewater pollutants.
2. Estimate relative toxic weights for pollutants.
3. Define pollution control options.
4. Calculate pollutant removals for each control option.
5. Determine annualized cost for each control option.
6. Calculate cost-effectiveness values (and adjust to 1981 dollars).
7. Compare cost-effectiveness values.

These steps are discussed in the following sections.

2.1 POLLUTANT DISCHARGES CONSIDERED IN A COST-EFFECTIVENESS ANALYSIS

In developing the effluent guidelines for the CWT industry, EPA identified 125 pollutants of concern in CWT wastes. These pollutants include pollutants regulated directly by the guidelines and standards as well as selected nonregulated pollutants. Nonregulated pollutants are included when they are removed incidentally as a result of a particular treatment technology, even though they are not specifically limited. Some of the factors considered in selecting nonregulated pollutants of concern include toxicity, frequency of occurrence, and amount of pollutant in the waste stream. Not all pollutants of concern are included in cost-effectiveness analyses, however, because TWFs have yet to be estimated for some of these pollutants. Table 2-1 lists the pollutants of concern for the proposed regulation and identifies 89 pollutants that have been assigned weighting factors and are included in the cost-effectiveness analysis.

2.2 RELATIVE TOXIC WEIGHTS OF POLLUTANTS

EPA's cost-effectiveness analyses account for differences in toxicity among pollutants of concern by using the TWFs and PWFs mentioned in Chapter 1. These weighting factors are necessary because different pollutants have different potential effects on human and aquatic life. In the past, cost-effectiveness analyses relied on a single weighting factor (TWF) for each pollutant to calculate standardized pound-equivalent pollutant removals for each regulatory option. To offer an alternative view of the relative health risks presented by diverse toxic pollutants, EPA has developed a new standardized measure of toxicity with corresponding new weighting factors (PWFs) for each pollutant. This report, therefore, offers two alternative cost-effectiveness analyses of the proposed regulatory options: one based on pollutant removals estimated using the traditional TWFs and another with pollutant removals estimated using PWFs. The following sections describe in greater detail the development of each of these weighting factors and the conceptual differences between them.

2.2.1 The Traditional Toxic Weighting Method

The TWFs that have been used to develop effluent guidelines and standards in the past are derived from chronic aquatic life criteria (or toxic effect levels) and human health criteria (or toxic effects levels) established for the consumption of fish. For carcinogenic substances, the human health risk level is 10^{-5}, that is, protective to a level allowing 1 in 100,000 excess cancer cases over background. These toxicity levels are related to a benchmark value or toxicity level associated with a single pollutant. Copper, a toxic metal pollutant commonly detected and removed from industrial effluent, is the benchmark pollutant (i.e., the basis on which others are

TABLE 2-1. POLLUTANTS OF CONCERN FOR CWT INDUSTRY AND POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS

Pollutant Type and CAS Number	Pollutant Name	Is Pollutant Included in Cost-Effectiveness Analysis?
Classicals		
C-025	Amenable Cyanide	No
7664417	Ammonia as N	No
C-002	Bod 5	No
C-004	Cod	No
57125	Cyanide	Yes
C-004d	D-Cod	No
16984488	Fluoride	No
18540299	Hex Chrom	Yes
14797558	Nitrate-Nitrite as N	No
C-007	Oil + Grease	No
18496258	Sulfide, Total	No
C-012	Toc	No
C-020	Total Phenols	No
14265442	Total Phosphorus	No
59473040	Tox	No
C-009	TSS	No
Metals		
7429905	Aluminum	Yes
7440360	Antimony	Yes
7440382	Arsenic	Yes
7440393	Barium	Yes
7440417	Beryllium	No
7440428	Boron	Yes
7440439	Cadmium	Yes
7440702	Calcium	No

(continued)

TABLE 2-1. POLLUTANTS OF CONCERN FOR CWT INDUSTRY AND POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	Is Pollutant Included in Cost-Effectiveness Analysis?
Metals (continued)		
7440473	Chromium	Yes
7440484	Cobalt	Yes
7440508	Copper	Yes
7440553	Gallium	No
7553562	Iodine	No
7439885	Iridium	No
7439896	Iron	Yes
7439921	Lead	Yes
7439932	Lithium	Yes
7439943	Lutetium	No
7439954	Magnesium	No
7439965	Manganese	Yes
7439976	Mercury	Yes
7439987	Molybdenum	Yes
7440020	Nickel	Yes
7723140	Phosphorus	Yes
7440097	Potassium	No
7440155	Rhenium	No
7782492	Selenium	Yes
7440213	Silicon	No
7440224	Silver	Yes
7440235	Sodium	No
7440246	Strontium	No
7704349	Sulfur	Yes
7440257	Tantalum	Yes
13494809	Tellurium	Yes

(continued)

TABLE 2-1. POLLUTANTS OF CONCERN FOR CWT INDUSTRY AND POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	Is Pollutant Included in Cost-Effectiveness Analysis?
Metals (continued)		
7440280	Thallium	Yes
7440315	Tin	Yes
7440326	Titanium	Yes
7440337	Tungsten	Yes
7440611	Uranium	No
7440622	Vanadium	Yes
7440666	Zinc	Yes
7440677	Zirconium	No
Organics		
630206	1,1,1,2-Tetrachloroethane	Yes
71556	1,1,1-Trichloro Ethane	Yes
79005	1,1,2-Trichloroethane	Yes
75343	1,1-Dichloroethane	Yes
75354	1,1-Dichloroethene	Yes
96184	1,2,3-Trichloropropane	Yes
106934	1,2-Dibromoethane	Yes
95501	1,2-Dichlorobenzene	Yes
107062	1,2-Dichloroethane	Yes
123911	1,4-Dioxane	Yes
58902	2,3,4,6-Tetrachlorophenol	Yes
608275	2,3-Dichloroaniline	Yes
95954	2,4,5-Trichlorophenol	Yes
88062	2,4,6-Trichlorophenol	Yes
105679	2,4-Dimethylphenol	Yes
78933	2-Butanone	Yes

(continued)

TABLE 2-1. POLLUTANTS OF CONCERN FOR CWT INDUSTRY AND POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	Is Pollutant Included in Cost-Effectiveness Analysis?
Organics (continued)		
95578	2-Chlorophenol	Yes
591786	2-Hexanone	Yes
91576	2-Methylnaphthalene	Yes
109068	2-Picoline	Yes
67641	2-Propanone	Yes
59507	4-Chloro-3-Methylphenol	Yes
108101	4-Methyl-2-Pentanone	Yes
98862	Acetophenone	Yes
71432	Benzene	Yes
65850	Benzoic Acid	Yes
100516	Benzyl Alcohol	Yes
92524	Biphenyl	Yes
117817	Bis (2-Ethylhexyl) Phthalate	Yes
75274	Bromodichloromethane	Yes
75150	Carbon Disulfide	Yes
108907	Chlorobenzene	Yes
67663	Chloroform	Yes
60297	Diethyl Ether	Yes
101848	Diphenyl Ether	Yes
100414	Ethyl Benzene	Yes
96457	Ethylene Thiourea	No
142621	Hexanoic Acid	Yes
78591	Isophorone	Yes
75092	Methylene Chloride	Yes
108383	M-Xylene	Yes
91203	Naphthalene	Yes

(continued)

TABLE 2-1. POLLUTANTS OF CONCERN FOR CWT INDUSTRY AND POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	Is Pollutant Included in Cost-Effectiveness Analysis?
Organics (continued)		
124185	N-Decane	Yes
629970	N-Docosane	Yes
112403	N-Dodecane	No
112958	N-Eicosane	No
630013	N-Hexacosane	No
544763	N-Hexadecane	No
593453	N-Octadecane	No
629594	N-Tetradecane	No
68122	N.N-Dimethylformamide	Yes
NA	O+P Xylene	Yes
95487	O-Cresol	Yes
87865	Pentachlorophenol	Yes
108952	Phenol	Yes
110861	Pyridine	Yes
106445	P-Cresol	Yes
100425	Styrene	Yes
127184	Tetrachloroethene	Yes
56235	Tetrachloromethane	Yes
108883	Toluene	Yes
156605	Trans-1,2-Dichloroethene	Yes
75252	Tribromomethane	No
79016	Trichloroethene	Yes
75694	Trichlorofluoromethane	Yes
20324338	Tripropyleneglycol Methyl Ether	Yes
75014	Vinyl Chloride	Yes

Total number of pollutants of concern for CWT industry: 125
Number of CWT pollutants of concern included in cost-effectiveness analysis: 89

compared). Although the water quality criterion for copper has been revised (to 12.0 µg/L), the Agency continues to estimate TWF-weighted pollutant removals using the former water quality criterion (5.6 µg/L) to facilitate comparisons with the cost-effectiveness values calculated for other regulations. This is why the current TWF for copper is 0.467 rather than 1, the weighting factor that one would normally expect for a benchmark pollutant.

In the traditional method, a TWF for aquatic life effects and a TWF for human health effects are added for pollutants of concern. The TWF is calculated by dividing aquatic life and human health criteria (or toxic effect levels) for each pollutant, expressed as a concentration in micrograms per liter (µg/L), into the former copper criterion of 5.6 µg/L and summing the resulting values:

$$TWF = 5.6/AQ + 5.6/HHOO$$

where;

TWF = original toxic weighting factor,
AQ = chronic aquatic life value (µg/L), and
HHOO = human health (ingesting organisms only) value (µg/L).

Some examples of the effects of different aquatic and human health criteria on weighting factors are shown in Table 2-2.

As indicated in Table 2-2, the TWF is the sum of two criteria-weighted ratios: the former copper criterion divided by the human health criterion for the particular pollutant and the former copper criterion divided by the aquatic chronic criterion. For example, using the values reported in Table 2-2, 11.04 pounds of copper pose the same relative hazard in surface waters as one pound of cadmium because cadmium has a TWF 11.04 times as large (5.158/0.467=11.04) as the TWF of copper. Similarly, by the TWF method, 97.22 pounds of benzene present the same net risk as a single pound of lead, because the TWF for lead is 97.22 as large (1.75/0.018=97.22) as the TWF for benzene. By multiplying the reduction in industry loadings (lbs/yr) of each pollutant by each pollutant's corresponding copper-based TWF and summing this product across all pollutants of concern, the Agency can derive the total TWF-weighted pollutant removals (lbs-equivalent/yr) attributable to each proposed regulatory option.

TWFs and the alternative PWFs for all 89 pollutants of concern included in the cost-effectiveness analysis are presented in Table 2-3. The logic and methods used to calculate the PWFs are explained in the following section.

TABLE 2-2. TWFs BASED ON COPPER FRESHWATER CHRONIC CRITERIA

Pollutant	Human Health Criteria[a] (µg/L)	Aquatic Chronic Criteria (µg/L)	Weighting Calculation	Toxic Weighting Factor
Copper[b]	–	12.0	5.6/12.0	0.467
Lead	–	3.2	5.6/3.2	1.750
Nickel	4,600	160.0	5.6/4,600 + 5.6/160	0.036
Cadmium	84	1.1	5.6/84 + 5.6/1.1	5.158
Benzene	710	530.0	5.6/710 + 5.6/530	0.018

[a]Based on ingestion of 6.5 grams of fish per day. The human health risk level set for carcinogenic substances in TWF calculations is 10^{-5}.

[b]Although the water quality criterion for copper has been revised (to 12.0 µg/L), the cost-effectiveness analysis uses the old criterion (5.6 µg/L) to facilitate comparisons with cost-effectiveness values for other effluent limitations guidelines. The revised higher criteria for copper results is a TWF for copper not equal to 1.0 but equal to 0.467.

Note: Criteria are maximum contamination thresholds. Using the above calculation, the greater the values for the criterion used, the lower the TWF. Units for criteria are micrograms of pollutant per liter of water.

2.2.2 The New Pollutant Weighting Method

A slightly different approach is used for the alternative method for weighting pollutant removals in terms of their toxicity. PWFs are derived from either chronic aquatic life criteria, or human health criteria established for the consumption of water and fish. For carcinogenic substances, the human health risk level is 10^{-6}, that is, protective to a level allowing 1 in 1,000,000 excess cancer cases over background. In contrast to TWFs, PWFs are not related to a benchmark pollutant. PWFs are calculated in the following manner:

$$PWF = 1/AQ, \text{ if } AQ < HHWO$$

or

$$PWF = 1/HHWO, \text{ if } HHWO < AQ$$

TABLE 2-3. TWFs AND PWFs FOR POLLUTANTS CONSIDERED IN THE COST-EFFECTIVENESS ANALYSIS

Pollutant Type and CAS Number	Pollutant Name	TWF Traditional Approach	PWF Alternative Approach
Classicals			
57125	Cyanide	1.08E+00	1.92E-01
18540299	Hex Chrom	5.11E-01	9.09E-02
Metals			
7429905	Aluminum	6.44E-02	1.15E-02
7440360	Antimony	1.88E-01	7.17E-02
7440382	Arsenic	4.03E+00	5.70E+01
7440393	Barium	1.99E-03	1.00E-03
7440428	Boron	1.77E-01	3.16E-02
7440439	Cadmium	5.16E+00	9.09E-01
7440473	Chromium	2.67E-02	4.76E-03
7440484	Cobalt	1.14E-01	2.04E-02
7440508	Copper	4.67E-01	8.33E-02
7439896	Iron	5.60E-03	1.00E-03
7439921	Lead	1.75E+00	3.13E-01
7439932	Lithium	1.21E-02	2.16E-03
7439965	Manganese	1.44E-02	1.00E-02
7439976	Mercury	5.04E+02	8.33E+01
7439987	Molybdenum	2.01E-01	3.60E-02
7440020	Nickel	3.62E-02	6.25E-03
7723140	Phosphorus	5.60E+01	1.00E+01
7782492	Selenium	1.12E+00	2.00E-01
7440224	Silver	4.67E+01	8.33E+00
7704349	Sulfur	5.60E-06	1.00E-06
7440257	Tantalum	5.96E-02	1.06E-02
13494809	Tellurium	4.48E-02	8.00E-03

(continued)

TABLE 2-3. TWFs AND PWFs FOR POLLUTANTS CONSIDERED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	TWF Traditional Approach	PWF Alternative Approach
Metals (continued)			
7440280	Thallium	1.40E-01	2.50E-02
7440315	Tin	3.01E-01	5.38E-02
7440326	Titanium	2.93E-02	5.24E-03
7440337	Tungsten	5.25E-03	9.38E-04
7440622	Vanadium	6.22E-01	1.11E-01
7440666	Zinc	5.10E-02	9.09E-03
Organics			
630206	1,1,1,2-Tetrachloroethane	2.35E-02	7.84E-01
71556	1,1,1-Trichloro Ethane	4.31E-03	7.69E-04
79005	1,1,2-Trichloroethane	1.38E-02	1.66E+00
75343	1,1-Dichloroethane	3.85E-04	2.58E-04
75354	1,1-Dichloroethene	1.75E-01	1.75E+01
96184	1,2,3-Trichloropropane	1.96E-03	5.05E-03
106934	1,2-Dibromoethane	4.42E+01	2.51E+03
95501	1,2-Dichlorobenzene	1.05E-02	1.82E-03
107062	1,2-Dichloroethane	6.19E-03	2.61E+00
123911	1,4-Dioxane	2.33E-04	3.15E-01
58902	2,3,4,6-Tetrachlorophenol	6.45E-02	1.12E-02
608275	2,3-Dichloroaniline	1.08E-02	1.93E-03
95954	2,4,5-Trichlorophenol	9.88E-02	1.59E-02
88062	2,4,6-Trichlorophenol	3.52E-01	6.31E-01
105679	2,4-Dimethylphenol	5.29E-03	1.87E-03
78933	2-Butanone	3.17E-05	5.73E-04
95578	2-Chlorophenol	3.26E-02	8.20E-03
591786	2-Hexanone	1.28E-04	2.28E-05

(continued)

TABLE 2-3. TWFs AND PWFs FOR POLLUTANTS CONSIDERED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	TWF Traditional Approach	PWF Alternative Approach
Organics (continued)			
91576	2-Methylnaphthalene	1.81E-02	3.24E-03
109068	2-Picoline	1.36E-04	2.43E-05
67641	2-Propanone	7.63E-06	2.86E-04
59507	4-Chloro-3-Methylphenol	4.31E-03	7.69E-04
108101	4-Methyl-2-Pentanone	1.25E-04	5.76E-04
98862	Acetophenone	2.37E-04	2.96E-04
71432	Benzene	1.84E-02	8.43E-01
65850	Benzoic Acid	3.28E-04	5.82E-05
100516	Benzyl Alcohol	5.61E-03	1.00E-03
92524	Biphenyl	3.75E-02	5.88E-03
117817	Bis(2-Ethylhexyl)Phthalate	1.10E-01	5.69E-01
75274	Bromodichloromethane	7.42E-02	1.90E+00
75150	Carbon Disulfide	2.80E+00	5.00E-01
108907	Chlorobenzene	2.93E-03	1.48E-03
67663	Chloroform	2.08E-03	1.76E-01
60297	Diethyl Ether	7.74E-05	1.44E-04
101848	Diphenyl Ether	2.63E-02	4.69E-03
100414	Ethyl Benzene	1.41E-03	3.21E-04
142621	Hexanoic Acid	3.41E-04	6.08E-05
78591	Isophorone	7.25E-04	2.75E-02
75092	Methylene Chloride	4.23E-04	2.15E-01
108383	M-Xylene	1.49E-03	2.56E-04
91203	Naphthalene	1.53E-02	2.70E-03
124185	N-Decane	1.12E+00	2.00E-01
629970	N-Docosane	1.06E-03	1.89E-04
68122	N.N-Dimethylformamide	2.36E-06	2.86E-04

(continued)

TABLE 2-3. TWFs AND PWFs FOR POLLUTANTS CONSIDERED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	TWF Traditional Approach	PWF Alternative Approach
Organics (continued)			
NA	O+P Xylene	8.50E-03	1.50E-03
95487	O-Cresol	3.28E-03	6.05E-04
87865	Pentachlorophenol	4.99E-01	3.55E+00
108952	Phenol	2.80E-02	5.00E-03
110861	Pyridine	1.26E-03	2.88E-02
106445	P-Cresol	2.36E-03	6.04E-04
100425	Styrene	8.59E-04	1.49E-04
127184	Tetrachloroethene	7.43E-02	1.25E+00
56235	Tetrachloromethane	1.28E-01	3.94E+00
108883	Toluene	5.63E-03	1.00E-03
156605	Trans-1,2-Dichloroethene	9.25E-05	1.44E-03
79016	Trichloroethene	6.29E-02	3.70E-01
75694	Trichlorofluoromethane	9.58E-04	1.56E-04
20324338	Tripropyleneglycol Methyl Ether	8.19E-06	1.46E-06
75014	Vinyl Chloride	1.29E-03	5.00E-01

Number of CWT pollutants of concern included in cost-effectiveness analysis: 89

where;

PWF = pollutant weighting factor,

AQ = aquatic life chronic value (μg/L), and

HHWO = human health (ingesting water and organisms) value (μg/L).

The resulting PWFs for the 89 pollutants included in the cost-effectiveness analysis are listed in Table 2-3. Some examples of how PWF aquatic and human health criteria influence the weighting factors derived using the alternative PWF weighting approach are shown in Table 2-4. As Table 2-4 shows, the PWF for each pollutant is the inverse of the more stringent of the two criteria-weighted ratios: it is equal to 1 divided by the pollutant's human health criterion when

TABLE 2-4. PWFs, THE ALTERNATIVE WEIGHTING APPROACH

Pollutant	Human Health Criteria[a] (μg/L)	Aquatic Chronic Criteria (μg/L)	Weighting Calculation	Toxic Weighting Factor
Copper	1,300.0	12.0	1/12.0	0.0833
Lead	50.0	3.2	1/3.2	0.3125
Nickel	610.0	160.0	1/160	0.0063
Cadmium	14.0	1.1	1/1.1	0.9091
Benzene	1.2	530.0	1/1.2	0.8333

[a]Based on ingestion of 6.5 grams of fish per day. The human health risk level set for carcinogenic substances in PWF calculations is 10^{-6}.

Note: Criteria are maximum contamination thresholds. Using the above calculation, the greater the values for the criterion used, the lower the TWF. Units for criteria are micrograms of pollutant per liter of water.

the human health criterion is smaller than the chronic aquatic life criterion, and it is equal to 1 divided by the chronic aquatic life criterion when the human health criterion is greater than the chronic aquatic life criterion. Thus, by the PWF weighting approach, 10.91 pounds of copper pose the same relative hazard in surface waters as 1 pound of cadmium, because cadmium has a PWF 10.91 times as large (0.9091/0.0833=10.91) as the PWF of copper. This ratio is roughly equivalent to the ratio of the TWFs of these two pollutants (5.158/0.467=11.04) presented above.

For comparisons between some pollutants, however, switching to the PWF approach yields dramatically different results from those observed using the TWF method. For example, the PWF for benzene is more than 2.5 times greater than the PWF for lead, indicating that 2.5 pounds of lead in surface waters are not as threatening 1 pound of benzene. In the TWF method illustrated in Table 2-2, however, 97.22 pounds of benzene were shown to be about as harmful as 1 pound of lead. This difference is primarily due to differences in the way the human health criteria are set for pollutants in each of the weighting approaches. A major difference is that the PWF method is ten times as stringent in its assessment of the health risk associated with carcinogenic contaminants. A second important difference is that the PWF approach sets the human health criterion for each pollutant based on the potential health effects of the pollutant's presence in drinking water as well as the effect of ingesting organisms that have been exposed to the pollutant. This approach is in contrast to the TWF method, which only considers the health effects of humans eating fish that have been chronically exposed to the pollutants.

Table 2-5 summarizes the conceptual differences between the TWF approach and the PWF approach to weighting pollutant removals with respect to each pollutant's relative toxicity. This report will focus on a discussion of the relative cost-effectiveness of control options as determined using the TWF method. The PWF cost-effectiveness comparison results are presented in Appendix A.

TABLE 2-5. CONCEPTUAL DIFFERENCES BETWEEN TWFs AND PWFs

Feature	Standard TWF	Alternative PWF
Benchmark Value (numerator)	5.6 (former freshwater chronic criterion for copper)	1
Carcinogenic Risk Level	10^{-5} (1 in 100,000 excess cancer cases)	10^{-6} (1 in 1,000,000 excess cancer cases)
Human Health Exposure	Fish consumption only	Drinking water and fish consumption
Aquatic Life Effects vs. Human Health Effects	TWFs are added	More stringent PWF is used

2.3 POLLUTION CONTROL OPTIONS

The proposed Effluent Limitations Guidelines and Standards for the CWT industry are intended to cover discharges generated during the treatment or recovery of hazardous and non-hazardous industrial waste received from off-site. The proposed effluent guidelines and standards were developed for three subcategories;

- metal-bearing waste treatment or recovery,
- oily waste treatment or recovery, and
- organic waste treatment or recovery.

A total of nine control options, each applicable to one of the three subcategories to be regulated, can be combined to present 24 possible regulatory options. Table 2-6 offers a brief description of each control option and identifies the subcategory of treatment to which it applies. Additional information on the control options can be found in the Agency's *Development Document for Proposed Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry* (EPA-821-R-95-006). Each regulatory option combines one control

TABLE 2-6. DESCRIPTIONS OF THE INDIVIDUAL CWT CONTROL OPTIONS

Treatment Subcategory	Control Option Number	Control Option Name	Control Option Description
Metals	1	MET1	Chemical precipitation, solid-liquid separation, and sludge dewatering. Pretreatment of cyanide-bearing wastes via alkaline chlorination at specific operating conditions.
	2	MET2	Selective metals precipitation, pressure filtration, secondary precipitation, solid-liquid separation, and tertiary precipitation. Pretreatment of cyanide-bearing wastes via alkaline chlorination at specific operating conditions.
	3	MET3	Selective metals precipitation, pressure filtration, secondary precipitation, solid-liquid separation, and tertiary precipitation. Pretreatment of cyanide-bearing wastes via alkaline chlorination at specific operating conditions.
Oils	1	OIL1	Emulsion breaking.
	2	OIL2	Ultrafiltration.
	3	OIL3	Ultrafiltration, carbon adsorption, and reverse osmosis.
	4	OIL4	Ultrafiltration, carbon adsorption, reverse osmosis, and carbon adsorption.
Organics	1	ORG1	Equalization, air-stripping, biological treatment, and multimedia filtration.
	2	ORG2	Equalization, air-stripping, biological treatment, and multimedia filtration, followed by carbon adsorbtion.

option for each of the treatment subcategories. Thus, for example, ORG1MET3OIL4 combines Control Option 1 for the Organics subcategory, Control Option 3 for the Metals subcategory, and Control Option 4 for the Oils subcategory.

2.4 CALCULATION OF POLLUTANT REMOVALS

The reduction in pollutant loadings released by each CWT facility to receiving waters has been calculated for each control option. These *at-stream* pollutant removals are equal to *end-of-pipe* (i.e., at the edge of the facility) pollutant removals for direct dischargers. For indirect dischargers, however, at-stream and end-of-pipe removals may differ because of treatment at the POTW. Calculation of removals for direct and indirect dischargers is discussed below.

2.4.1 Direct Dischargers

Current and post-treatment end-of-pipe annual pollutant loadings for each facility and each control option have been estimated. Removals are calculated as the difference between current and post-treatment discharges. Removals are then weighted using each of the TWFs and are reported in pound equivalents.

2.4.2 Indirect Dischargers

Indirect dischargers are treated differently from direct dischargers in the cost-effectiveness analysis. A portion of the end-of-pipe pollutant loadings for indirect dischargers may be removed by the POTW where the CWT facility's sewage receives some wastewater treatment before it is ultimately discharged to surface waters. Therefore at-stream loadings from an indirect discharging facility may be less than end-of-pipe loadings. The comparison of removals across control options in this analysis is based on removals at-stream.

For example, if a facility is discharging 100 pounds of cadmium in its effluent stream to a POTW and the POTW has a removal efficiency for cadmium of 91.47 percent, then 91.47 pounds of the cadmium discharged by the facility would be removed from the facility's effluent when the wastewater is initially treated at the POTW. The amount of cadmium that is ultimately discharged to surface waters would only amount to 8.53 pounds. If the indirect discharging facility then changes its waste treatment operations to comply with the regulation and thereby dramatically reduces the amount of cadmium in its end-of-pipe discharges to the sewer system, only a portion of these end-of-pipe pollutant discharge reductions qualify as at-stream pollutant removals. Thus, if an indirect discharger cut its baseline indirect discharges of cadmium from 100 pounds by 40 percent to 60 pounds, the net reduction in cadmium discharged to surface waters attributable to the regulation is not 40 percent of its baseline discharges to the sewer system (40 pounds), but rather 40 percent of the 8.53 pounds of CWT facility's cadmium that are ultimately discharged to surface waters at baseline (3.412 pounds). The POTW removals factors used in the analysis are shown in Table 2-7.

TABLE 2-7. POTW REMOVAL EFFICIENCIES FOR POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS

Pollutant Type and CAS Number	Pollutant Name	POTW Removal Efficiency (%)
Classical		
57125	Cyanide	70.44
18540299	Hex Chromium	5.68
Metals		
7429905	Aluminum	16.81
7440360	Antimony	71.13
7440382	Arsenic	90.89
7440393	Barium	90.2
7440428	Boron	70.28
7440439	Cadmium	90.05
7440473	Chromium	91.25
7440484	Cobalt	4.81
7440508	Copper	84.11
7439896	Iron	83
7439921	Lead	91.83
7439932	Lithium	26
7439965	Manganese	40.6
7439976	Mercury	90.16
7439987	Molybdenum	52.17
7440020	Nickel	51.44
7723140	Phosphorus	69.42
7782492	Selenium	34.33
7440224	Silver	92.42
7704349	Sulfur	14.33
7440257	Tantalum	55.19
13494809	Tellurium	55.19
7440280	Thallium	53.8

(continued)

TABLE 2-7. POTW REMOVAL EFFICIENCIES FOR POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	POTW Removal Efficiency (%)
Metals (continued)		
7440315	Tin	65.2
7440326	Titanium	68.77
7440337	Tungsten	55.19
7440622	Vanadium	42.28
7440666	Zinc	77.97
Organics		
630206	1,1,1,2-Tetrachloroethane	23
71556	1,1,1-Trichloroethane	90.45
79005	1,1,2-Trichloroethane	55.98
75343	1,1-Dichloroethane	70
75354	1,1-Dichloroethene	75.34
96184	1,2,3-Trichloropropane	5
106934	1,2-Dibromoethane	17
107062	1,2-Dichloroethane	89.03
95501	1,2-Dichlorobenzene	88.98
123911	1,4-Dioxane	73.95
58902	2,3,4,6-Tetrachlorophenol	33
608275	2,3-Dichloroaniline	41
95954	2,4,5-Trichlorophenol	28
88062	2,4,6-Trichlorophenol	65
105679	2,4 Dimethylphenol	51.22
78933	2-Butanone	91.83
95578	2-Chlorophenol	62.03
591786	2-Hexanone	87.82
91576	2-Methylnaphthalene	28
109068	2-Picoline	84.68

(continued)

TABLE 2-7. POTW REMOVAL EFFICIENCIES FOR POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	POTW Removal Efficiency (%)
Organics (continued)		
67641	2-Propanone	83.75
59507	4-Chloro-3-Methylphenol	63
108101	4-Methyl-2-Pentanone	87.87
98862	Acetophenone	95.34
71432	Benzene	94.76
65850	Benzoic Acid	80.5
100516	Benzyl Alcohol	78
92524	Biphenyl	96.28
117817	Bis(2-Ethylhexyl)Phthalate	59.78
75274	Bromodichloromethane	91.93
75150	Carbon Disulfide	84
108907	Chlorobenzene	96.37
67663	Chloroform	73.44
60297	Diethyl Ether	7
101848	Diphenyl Ether	86.53
100414	Ethyl Benzene	93.79
142621	Hexanoic Acid	84
78591	Isophorone	62.13
75092	Methylene Chloride	54.28
108383	M-Xylene	65.4
91203	Naphthalene	94.69
124185	N-Decane	9
629970	N-Docosane	88
68122	N.N-Dimethylformamide	84.75
136777612	O+P Xylene	95.07
95487	O-Cresol	52.5
87865	Pentachlorophenol	13.88

(continued)

TABLE 2-7. POTW REMOVAL EFFICIENCIES FOR POLLUTANTS INCLUDED IN THE COST-EFFECTIVENESS ANALYSIS (CONTINUED)

Pollutant Type and CAS Number	Pollutant Name	POTW Removal Efficiency (%)
Organics (continued)		
108952	Phenol	95.25
110861	Pyridine	95.4
106445	P-Cresol	71.67
100425	Styrene	93.65
127184	Tetrachloroethene	84.61
56235	Tetrachloromethane	87.94
108883	Toluene	96.18
156605	Trans-1,2-Dichloroethene	70.88
79016	Trichloroethene	86.85
75694	Trichlorofluoromethane	75.21
20324338	Tripropyleneglycol Methyl Ether	46.77
75014	Vinyl Chloride	93.49

Table 2-8 presents three different estimates of the annual mass loading of at-stream pollutant removals anticipated from direct and indirect dischargers for each control option. At the top of the table, estimated total pollutant removals (lbs/yr) for each control option are presented for all (conventional, non-conventional, and toxic) pollutants of concern with no effort to weight the individual pollutants removed according to their toxicity. The mass loading reductions presented in this part of the table include expected removals of the 33 CWT pollutants of concern that have been excluded from the cost-effectiveness analysis because information about their relative toxicity is lacking. The middle and lower sections of the table present the weighted mass loading reductions attributable to each control option. These values are based only on weighted removals of the 89 pollutants for which TWFs have been estimated.

2.5 ANNUALIZED COST FOR EACH CONTROL OPTION

The methods used to estimate the costs of complying with the regulatory options can be found in Chapter 8, of the Agency's *Development Document for Proposed Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry* (EPA-821-R-95-006). This section provides a brief summary of the compliance costs.

TABLE 2-8. SUMMARY OF WEIGHTED AND UNWEIGHTED POLLUTANT REMOVALS FOR DIRECT AND INDIRECT DISCHARGERS

Weighting Method	Control Option Name	Total Removals by Direct Dischargers	Total Removals by Indirect Dischargers	Total Removals by All Dischargers
Unweighted		**(lbs./yr)**	**(lbs./yr)**	**(lbs./yr)**
	MET1	9,329,643	3,528,937	12,858,580
	MET2	27,609,319	6,080,565	33,689,883
	MET3	28,739,622	6,322,709	35,062,331
	OIL1	0	0	0
	OIL2	21,004,158	11,263,808	32,267,966
	OIL3	23,108,164	11,586,370	34,694,534
	OIL4	23,300,182	11,619,866	34,920,048
	ORG1	5,372,689	1,458,139	6,830,828
	ORG2	831,011	1,391,288	2,222,299
TWF		**(TWF lb. eq./yr)**	**(TWF lb. eq./yr)**	**(TWF lb. eq./yr)**
	MET1	1,085,922	156,945	1,242,867
	MET2	1,142,279	164,492	1,306,771
	MET3	1,148,324	165,056	1,313,380
	OIL1	0	0	0
	OIL2	113,500	146,606	260,106
	OIL3	119,256	148,780	268,036
	OIL4	117,540	148,264	265,803
	ORG1	843,908	47,409	891,316
	ORG2	25,585	41,227	66,812

Note: lb. eq. = pound equivalent

Three categories of compliance costs were evaluated: capital costs (including RCRA permit-modification costs), land costs, and operating and maintenance costs (including sludge disposal and self-monitoring costs). While the capital and land costs are one-time "lump sum" costs, the operating and maintenance costs were evaluated on an annual basis. Capital and land costs were annualized using the real weighted-average cost of capital.[1] The capital and land are assumed to have a productive life of 20 years; therefore, the capital and land costs are adjusted to account for the cost of financing the investment (through equity and debt) over the 20-year period. The adjusted total capital and land costs are then divided by 20 to arrive at annualized

[1]For details on the weighted average cost of capital see the *Economic Impact Analysis of Proposed Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry* (RTI, 1994).

costs. Total annualized costs are equal to annualized capital and land costs plus operating and maintenance costs. The following formula is used to calculate total annualized costs:

$$TAC = (LAND + CAPITAL) / \frac{1-(1+RWACC)^{-20}}{RWACC} + O\&M$$

where;

TAC	=	total annualized cost of compliance,
LAND	=	total cost of new land,
CAPITAL	=	total capital costs of compliance,
O&M	=	annual operating and maintenance costs of compliance, and
RWACC	=	real weighted average cost of capital.

Table 2-9 presents total 1990-dollar and 1981-dollar annualized costs to direct and indirect dischargers of each of the 10 proposed control options.

2.6 CALCULATION OF COST-EFFECTIVENESS VALUES

Typically, the cost-effectiveness value for a particular control option is calculated as the ratio of incremental annual cost of that option to the incremental pound equivalents removed by that option. The incremental effectiveness may be viewed both in comparison to the baseline scenario and to another regulatory option. Cost-effectiveness values are reported in units of dollars per pound equivalent of pollutant removed. For the purpose of comparing cost-effectiveness values of options under review to those of other promulgated rules, compliance costs used in the cost-effectiveness analysis are adjusted to 1981 dollars using *Engineering News Record's* Construction Cost Index (CCI). This adjustment factor is calculated as follows:

$$\text{Adjustment factor} = \frac{1981\ CCI}{1990\ CCI} = \frac{3535}{4732} = 0.7470$$

The equation used to calculate incremental cost-effectiveness is

$$CE_k = \frac{TAC_k - TAC_{k-1}}{PE_k - PE_{k-1}}$$

where;

CE_k	=	incremental cost-effectiveness of Option k,
TAC_k	=	total annualized cost of compliance under Option k, and
PE_k	=	pound equivalents removed by Option k.

TABLE 2-9. TOTAL ANNUALIZED COSTS OF COMPLIANCE WITH EACH OF THE CONTROL OPTIONS FOR DIRECT AND INDIRECT DISCHARGERS

Treatment Subcategory	Control Option Number	Control Option Name	Direct Dischargers		Indirect Dischargers		All Dischargers	
			Total Annualized Compliance Cost ($1990)	Total Annualized Compliance Cost ($1981)	Total Annualized Compliance Cost ($1990)	Total Annualized Compliance Cost ($1981)	Total Annualized Compliance Cost ($1990)	Total Annualized Compliance Cost ($1981)
Metals	1	MET1	3,050,380	2,278,827	3,227,061	2,410,819	6,277,441	4,689,646
	2	MET2	11,433,921	8,541,863	23,813,521	17,790,208	35,247,442	26,332,072
	3	MET3	11,834,022	8,840,764	24,999,938	18,676,537	36,833,959	27,517,300
Oils	1	OIL1	0	0	0	0	0	0
	2	OIL2	840,930	628,228	2,705,906	2,021,483	3,546,836	2,649,711
	3	OIL3	8,223,696	6,143,622	22,180,332	16,570,113	30,404,028	22,713,735
	4	OIL4	9,721,340	7,262,456	26,590,602	19,864,864	36,311,942	27,127,320
Organics	1	ORG1	392,459	293,191	2,460,162	1,837,897	2,852,621	2,131,088
	2	ORG2	3,052,076	2,280,094	4,982,305	3,722,098	8,034,382	6,002,192

Note: Costs were adjusted to 1981 dollars using the *Engineering News Record's* Construction Cost Index (1981 through 1992).

The numerator of the equation, TAC_k minus TAC_{k-1}, is simply the incremental annualized treatment cost in going from Option k-1 to Option k. The denominator is similarly the incremental removals achieved in going from Option k-1 to Option k. Thus, the incremental cost-effectiveness of Option k represents the unit cost of additional pound-equivalent removals (beyond what is achievable by Option k-1), assuming that the removals achievable by Option k-1 can be removed for the average unit cost of Option k-1. In other words, incremental cost-effectiveness values show how much more it would cost per incremental pound-equivalent of pollutant removed to raise the effluent guideline from one level of stringency to the next higher level of stringency.

The method of comparing total cost-effectiveness values of options to current treatment uses the same formula and sets the benchmark costs (TAC_{k-1}) equal to zero. For the total cost-effectiveness method, the benchmark pollutant loadings (PE_{k-1}) are set equal to the current at-stream loading.

2.7 COMPARISONS OF COST-EFFECTIVENESS VALUES

Two types of comparisons are typically done using cost-effectiveness values. Compliance costs (y axis) and pollutant removals (x axis) may be plotted in a scatter graph to determine which options form the cost-effectiveness frontier by offering the most cost-effective regulatory control. Alternatively, a comparison of total cost-effectiveness values can be used to assess the cost-effectiveness of controls relative to previously promulgated effluent limitations guidelines for other industries.

Cost-effectiveness values for individual control options alone do not provide enough information to guide the Agency in selecting an optimal regulatory option because each proposed control option only applies to one of the three subsets of wastes treated in CWT operations covered by these (Phase I) guidelines. Three individual control options (one addressing each subcategory of waste managed in in-scope CWT operations) must be combined to create each regulatory option capable of meeting the Agency's regulatory responsibilities. The total cost, total TWF removals, and the TWF-cost-effectiveness values associated with approval of each individual control option for direct dischargers are presented in Table 2-10. Table 2-11 presents a parallel comparison for indirect dischargers. A more in-depth investigation of the relative cost-effectiveness of the Agency's regulatory options, options that encompass all areas of CWT operations, is presented in Chapter 3. This investigation involves comparing and presenting both incremental and total cost-effectiveness values calculated for each possible combination of the ten control options that cover all three subcategories of the Centralized Waste Treatment Industry.

TABLE 2-10. COST-EFFECTIVENESS COMPARISON OF CONTROL OPTIONS FOR DIRECT DISCHARGING CWT FACILITIES

Treatment Category	Control Option	Total Costs ($1981)	Total Cost ($1990)	Total Removals (lb. eq.)	TWF Cost-Effectiveness Costs ($//lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)
Metals	1	2,278,827	3,050,380	1,085,922	2.10	
	2	8,541,863	11,433,921	1,142,279	7.48	111.13
	3	8,840,764	11,834,022	1,148,324	7.70	49.45
Oils	1	0	0	0		
	2	628,228	840,930	113,500	5.54	5.54
	3	6,143,622	8,223,696	119,256	51.52	958.19
	4	7,262,456	9,721,340	117,540	61.79	(652.04)
Organics	1	293,191	392,459	843,908	0.35	
	2	2,280,094	3,052,076	25,585	89.12	(2.43)

Note: The shaded area indicates that the option in question has fewer weighted removals than the preceding option. That is, incremental values are not meaningful. These costs do not include RCRA and monitoring costs.

TABLE 2-11. COST-EFFECTIVENESS COMPARISON OF CONTROL OPTIONS FOR INDIRECT DISCHARGING CWT FACILITIES

Treatment Category	Control Option	Total Costs ($1981)	Total Cost ($1990)	Total Removals (lb. eq.)	TWF Cost-Effectiveness Costs ($//lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)
Metals	1	2,410,819	3,227,061	156,945	15.36	
	2	17,790,208	23,813,521	164,492	108.15	2,037.92
	3	18,676,537	24,999,938	165,056	113.15	1,569.66
Oils	1	0	0	0		
	2	2,021,483	2,705,906	146,606	13.79	13.79
	3	16,570,113	22,180,332	148,780	111.37	6,692.49
	4	19,864,864	26,590,602	148,264	133.98	(6,376.47)
Organics	1	1,837,897	2,460,162	47,409	38.77	
	2	3,722,098	4,982,305	41,227	90.28	(304.83)

Note: The shaded area indicates that the option in question has fewer weighted removals than the preceding option. That is, incremental values are not meaningful. These costs do not include RCRA and monitoring costs.

CHAPTER 3
COST-EFFECTIVENESS RESULTS

There are 24 possible combinations of the nine control options described in Table 2-6 that include a control option for each waste subcategory covered by these guidelines. As described earlier, two parallel cost-effectiveness analyses were performed on all 24 regulatory options. In each case the cost-effectiveness of the 24 regulatory options is analyzed separately for direct and indirect dischargers. Each analysis first investigates the relative cost-effectiveness of all 24 regulatory options and presents in tabular form total costs, total removals, and cost-effectiveness and incremental cost-effectiveness values for each regulatory option. The relative removals of the regulatory options are also displayed graphically. This chapter concludes with tabular and graphic comparisons of regulatory options for direct and indirect dischargers combined.

Calculating incremental cost-effectiveness values involves sorting the regulatory options in order of increasing removals. Incremental cost-effectiveness values are calculated by dividing the incremental (to the regulatory option with the next lowest level of removals) total annualized cost of compliance by the incremental removals, as described in Section 2.6. Regulatory options that are cost-effective (superior) can be identified at this stage, because the total costs associated with these options are lower than the total costs of all options with lower levels of removals. When the costs and removals for each regulatory option are plotted in a scatter graph, the superior regulatory options form a cost-effectiveness efficiency frontier along the lower right-hand edge of the cluster of points.

Similar comparisons are made in a second set of tables that include only those options forming the respective efficiency frontiers. The incremental cost-effectiveness values presented in the tables comparing only the regulatory options along each efficiency frontier are more meaningful than in the tables that compare all 24 regulatory options, because the values reflect the incremental unit cost of removals (in pound equivalents) to the *superior* regulatory option with the next lowest level of removals.

3.1 RESULTS OF COST-EFFECTIVENESS ANALYSIS

Tables 3-1 and 3-2 compare the relative cost-effectiveness of all 24 regulatory options for direct and indirect discharging facilities, respectively. In each case, the Agency's preferred control option combinations, Regulatory Option 1 and Regulatory Option 2, are identified. The names in Column 2 identify the control options from the three treatment subcategories that were

TABLE 3-1. TWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR DIRECT DISCHARGING CWT FACILITIES

TWF	Regulatory Option	Total Costs ($1981)	Total TWF Removals (lb. eq.)	TWF Cost-Effectiveness ($/lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG2MET1OIL1	5,092,902	1,111,506	4.58	4.58	Drop
	ORG2MET2OIL1	11,355,938	1,167,864	9.72	111.13	Drop
	ORG2MET3OIL1	11,654,838	1,173,909	9.93	49.45	Drop
	ORG2MET1OIL2	5,721,129	1,225,006	4.67	(116.13)	Drop
	ORG2MET1OIL4	12,355,358	1,229,046	10.05	1,642.09	Drop
	ORG2MET1OIL3	11,236,524	1,230,762	9.13	(652.04)	Drop
	ORG2MET2OIL2	11,984,166	1,281,363	9.35	14.78	Drop
	ORG2MET2OIL4	18,618,394	1,285,404	14.48	1,642.09	Drop
	ORG2MET2OIL3	17,499,560	1,287,119	13.60	(652.04)	Drop
	ORG2MET3OIL2	12,283,066	1,287,408	9.54	(18,054.45)	Drop
	ORG2MET3OIL4	18,917,295	1,291,449	14.65	1,642.09	Drop
	ORG2MET3OIL3	17,798,460	1,293,164	13.76	(652.04)	Drop
	ORG1MET1OIL1	**3,105,999**	**1,929,829**	**1.61**	**(23.08)**	**Keep**
	ORG1MET2OIL1	9,369,035	1,986,187	4.72	111.13	Drop
	ORG1MET3OIL1	9,667,936	1,992,231	4.85	49.45	Drop
	ORG1MET1OIL2	**3,734,226**	**2,043,329**	**1.83**	**(116.13)**	**Keep**
	ORG1MET1OIL4	10,368,455	2,047,369	5.06	1,642.09	Drop
	ORG1MET1OIL3	**9,249,621**	**2,049,085**	**4.51**	**(652.04)**	**Keep**
	ORG1MET2OIL2	**9,997,263**	**2,099,686**	**4.76**	**14.78**	**Keep**
	ORG1MET2OIL4	16,631,491	2,103,726	7.91	1,642.09	Drop
	ORG1MET2OIL3	15,512,657	2,105,442	7.37	(652.04)	Drop
Reg Opt 1	**ORG1MET3OIL2**	**10,296,163**	**2,105,731**	**4.89**	**(18,054.45)**	**Keep**
	ORG1MET3OIL4	16,930,392	2,109,771	8.02	1,642.09	Drop
Reg Opt 2	**ORG1MET3OIL3**	**15,811,557**	**2,111,487**	**7.49**	**(652.04)**	**Keep**

Note: Costs for each option include annualized $1,981 RCRA and monitoring costs of $533,980.

TABLE 3-2. TWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR INDIRECT DISCHARGING CWT FACILITIES

TWF	Regulatory Option	Total Costs ($1981)	Total TWF Removals (lb. eq.)	TWF Cost-Effectiveness ($/lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG2MET1OIL1	8,887,118	198,173	44.85	44.85	Drop
	ORG1MET1OIL1	**7,002,917**	**204,354**	**34.27**	**(304.83)**	**Keep**
	ORG2MET2OIL1	24,266,507	205,719	117.96	12,643.81	Drop
	ORG2MET3OIL1	25,152,835	206,284	121.93	1,569.66	Drop
	ORG1MET2OIL1	22,382,306	211,900	105.63	(493.28)	Drop
	ORG1MET3OIL1	23,268,634	212,465	109.52	1,569.66	Drop
	ORG2MET1OIL2	10,908,601	344,779	31.64	(93.41)	Drop
	ORG2MET1OIL4	28,751,981	346,436	82.99	10,767.39	Drop
	ORG2MET1OIL3	25,457,230	346,953	73.37	(6,376.47)	Drop
	ORG1MET1OIL2	**9,024,400**	**350,960**	**25.71**	**(4,100.67)**	**Keep**
	ORG2MET2OIL2	26,287,990	352,326	74.61	12,643.81	Drop
	ORG1MET1OIL4	26,867,781	352,617	76.20	1,987.02	Drop
	ORG2MET3OIL2	27,174,318	352,890	77.01	1,123.37	Drop
	ORG1MET1OIL3	**23,573,029**	**353,134**	**66.75**	**(14,769.58)**	**Keep**
	ORG2MET2OIL4	44,131,371	353,983	124.67	24,224.05	Drop
	ORG2MET2OIL3	40,836,619	354,499	115.20	(6,376.47)	Drop
	ORG2MET3OIL4	45,017,699	354,547	126.97	87,182.31	Drop
	ORG2MET3OIL3	41,722,948	355,064	117.51	(6,376.47)	Drop
	ORG1MET2OIL2	**24,403,789**	**358,507**	**68.07**	**(5,030.70)**	**Keep**
Reg Opt 1	**ORG1MET3OIL2**	**25,290,118**	**359,071**	**70.43**	**1,569.66**	**Keep**
	ORG1MET2OIL4	42,247,170	360,164	117.30	15,521.24	Drop
	ORG1MET2OIL3	**38,952,419**	**360,681**	**108.00**	**(6,376.47)**	**Keep**
	ORG1MET3OIL4	43,133,498	360,729	119.57	87,182.31	Drop
Reg Opt 2	**ORG1MET3OIL3**	**39,838,747**	**361,245**	**110.28**	**(6,376.47)**	**Keep**

Note: Costs for each option include annualized RCRA and monitoring costs of 2,754,201.

combined to create each regulatory option. Thus, ORG2MET1OIL1, the regulatory option with the lowest level of removals using the TWFs, combines the following treatment subcategory control options:

- Organics Option 2
- Metals Option 1
- Oils Option 1

The costs in Column 3 represent the total annualized cost of compliance (TAC) of each regulatory option (summed across all three subcategory control options and across all CWT facilities in the given discharge status). These costs include the sum of total annualized RCRA costs and monitoring costs for all facilities in the corresponding discharge status and have been deflated from 1990 dollars to 1981 dollars. The land cost and capital cost components of the compliance costs and the RCRA permit-modification costs were annualized over 20 years for each facility using facility-specific estimates of RWACC, as explained in Section 2.5. RWACC is the effective interest rate, adjusted to correct for inflation, at which companies are able to borrow new investment capital.

The removals in Column 4 are the total TWF-weighted removals achievable by each regulatory option, summed across all CWT facilities in the same discharging categories. The regulatory alternatives have been sorted in ascending order of total weighted removals. The cost-effectiveness values shown in Column 5 were generated by dividing total costs associated with each regulatory alternative by the corresponding level of weighted removals.

The incremental cost-effectiveness values in Column 6 show the incremental cost-effectiveness of each regulatory option. These values were generated by dividing the change in total costs by the change in total removals from one regulatory option to the next (in order of increasing removals). Regulatory options with negative values in this column preclude further considering the options directly above them in the table, because they achieve greater total removals at lower total costs than the preceding option in the table.

The labels in Column 7, "STATUS," indicate whether the regulatory option is on the cost-effectiveness efficiency frontier. Regulatory options with "DROP" in this column have higher total costs for fewer total removals than at least one other option in the table. These options are not on the cost-effectiveness efficiency frontier. The regulatory options with "KEEP" in this column have lower total costs than all options with total removals less than or equal to their level of total removals and are on the cost-effectiveness efficiency frontier.

Figures 3-1 and 3-2 are scatter graphs of the costs and removals values shown for the regulatory options in Tables 3-1 and 3-2. Total costs are measured along the y axis and total removals are measured along the x axis. The cost-effectiveness efficiency frontier is made up of those superior options, symbolized by bold diamonds, plotted in the lower right-hand section of the graph. The Agency's preferred regulatory options, REG OPT 1 and REG OPT 2, are tagged with a 1 and a 2 respectively. There are 6 regulatory options on the efficiency frontier for direct dischargers and 7 regulatory options on the efficiency frontier for indirect dischargers when removals are estimated using the TWFs. Both of EPA's preferred regulatory options are on each of these frontiers.

Tables 3-3 and 3-4 are organized in the same way as Tables 3-1 and 3-2, but Tables 3-3 and 3-4 only include the most cost-effective regulatory options from Table 3-1. The incremental cost-effectiveness values presented in these tables are more meaningful than those shown in Tables 3-1 and 3-2, because they are based on the incremental costs and removals of moving from the superior regulatory option with the next lowest level of removals to the superior option in question.

Figure 3-3 is a close-up image of Figure 3-1 with the omission of all inferior regulatory options. Similarly, Figure 3-4 is a close-up image of Figure 3-2 without any of the inferior regulatory options. In each case the scales of both the y axis, along which costs are measured, and the x axis, along which removals are measured, have been changed to permit a closer look at differences in costs and removals across options.

3.2 RESULTS OF COST-EFFECTIVENESS ANALYSIS FOR DIRECT AND INDIRECT DISCHARGERS TOGETHER

The Agency also investigated the relative cost-effectiveness of each of the 24 regulatory alternatives with the constraint that both direct and indirect dischargers are assumed to face the same regulatory alternative. Table 3-5 compares the relative cost-effectiveness of all options when removals are estimated using the TWF approach, and Table 3-6 compares the cost-effectiveness of seven regulatory options that form the cost-effectiveness efficiency frontier. Figure 3-5 is a scatter graph of the relative cost-effectiveness of all 24 regulatory options. Figure 3-6 is a larger scale image of the relative cost-effectiveness of the seven regulatory options forming the efficiency frontier in Figure 3-5.

It is interesting to note that the same seven regulatory options form the efficiency frontier regardless of weighting approach, when costs and removals for all dischargers are included in the analysis (see tables and figures in Appendix A for comparison). Both of the Agency's preferred options are on each of the efficiency frontiers.

Figure 3-1. TWF Cost-Effectiveness of Regulatory Options for Direct Dischargers

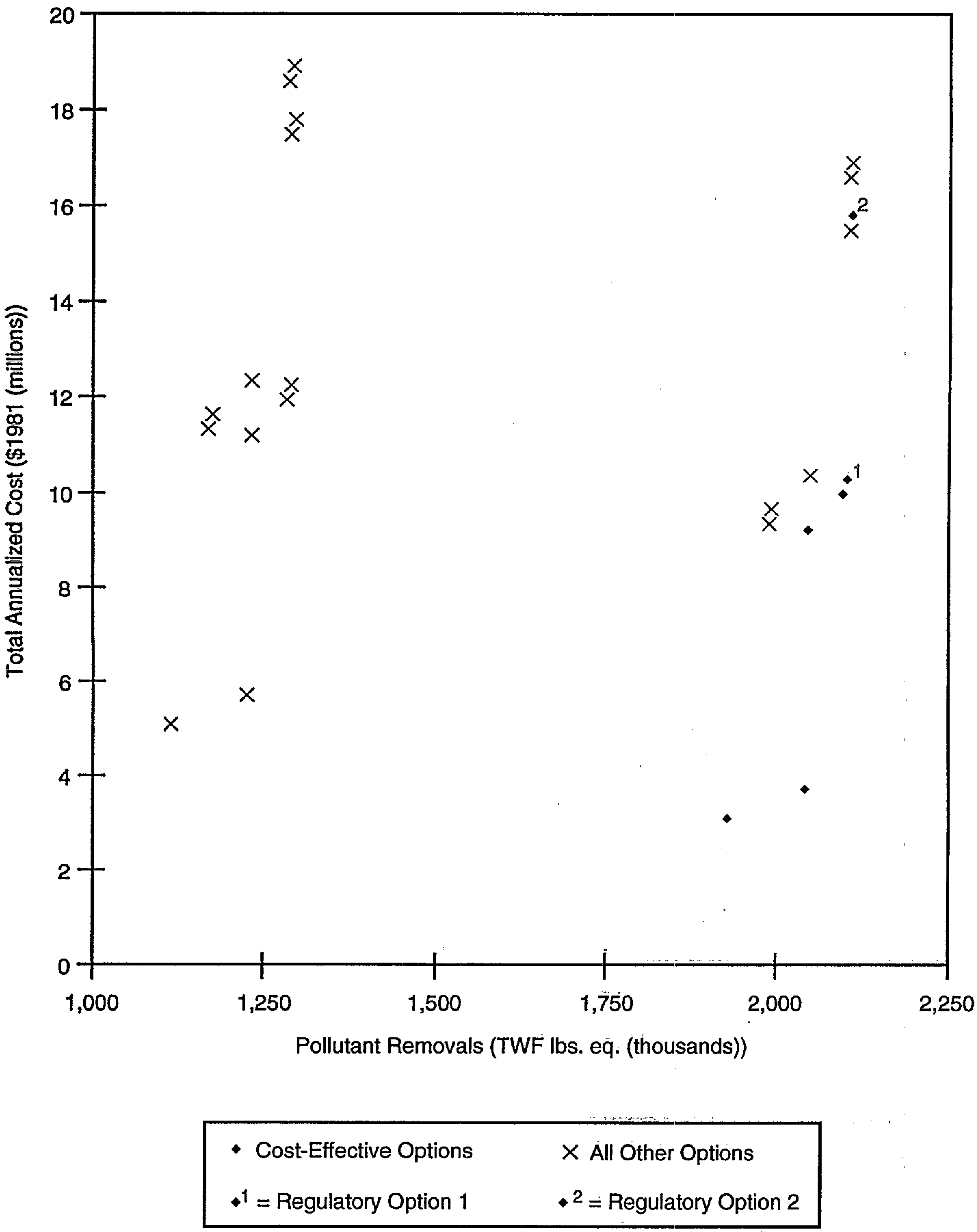


Figure 3-2. TWF Cost-Effectiveness of Regulatory Options for Indirect Dischargers

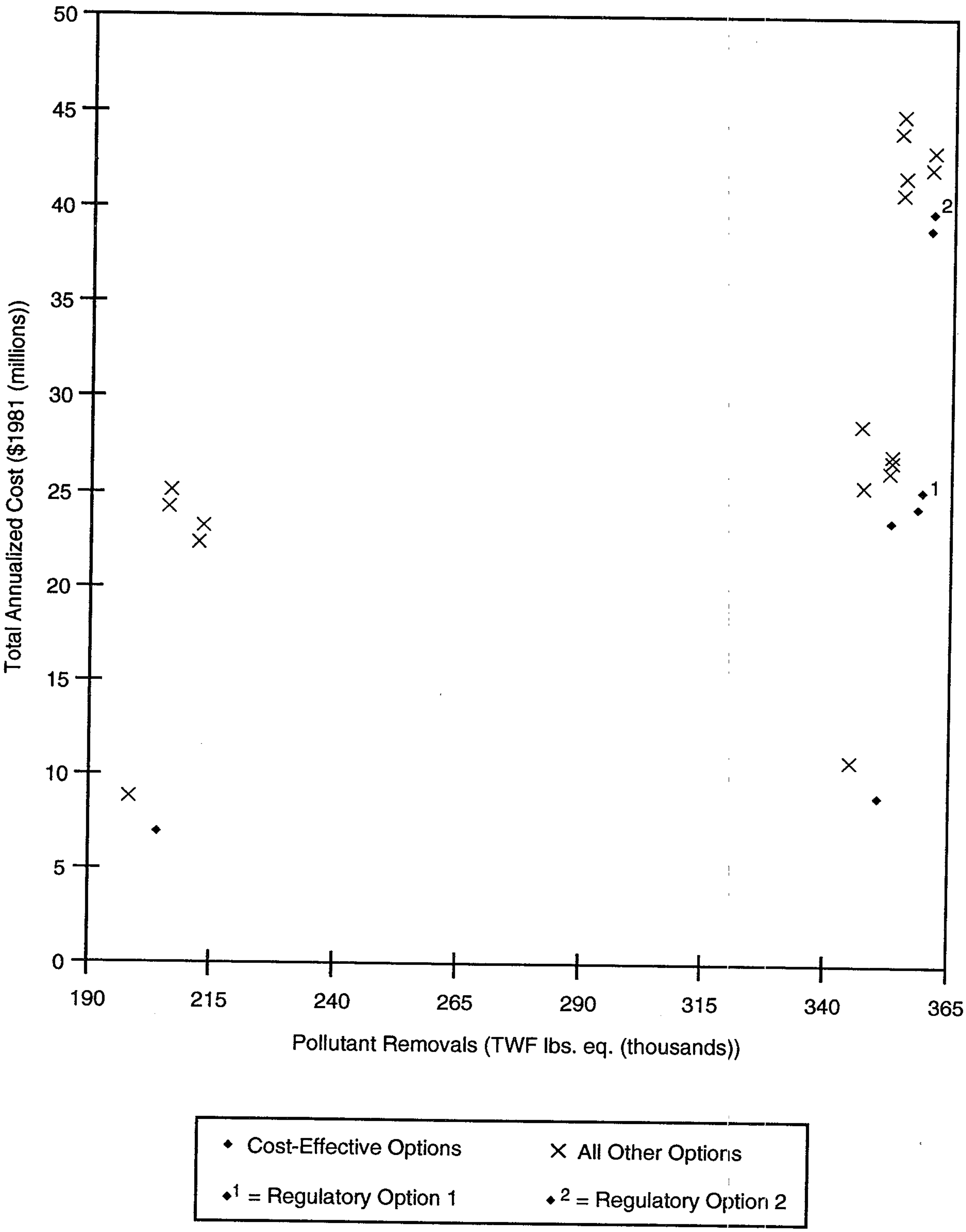


TABLE 3-3. TWF COST-EFFECTIVENESS EFFICIENCY FRONTIER FOR DIRECT DISCHARGING CWT FACILITIES

TWF	Regulatory Option	Total Costs ($1981)	Total TWF Removals (lb. eq.)	TWF Cost-Effectiveness ($/lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	3,105,999	1,929,829	1.61	1.61	Keep
	ORG1MET1OIL2	3,734,226	2,043,329	1.83	5.54	Keep
	ORG1MET1OIL3	9,249,621	2,049,085	4.51	958.19	Keep
	ORG1MET2OIL2	9,997,263	2,099,686	4.76	14.78	Keep
Reg Opt 1	ORG1MET3OIL2	10,296,163	2,105,731	4.89	49.45	Keep
Reg Opt 2	ORG1MET3OIL3	15,811,557	2,111,487	7.49	958.19	Keep

Note: Costs for each option include annualized $1981 RCRA and monitoring costs of $533,980.

TABLE 3-4. TWF COST-EFFECTIVENESS EFFICIENCY FRONTIER FOR INDIRECT DISCHARGING CWT FACILITIES

TWF	Regulatory Option	Total Costs ($1981)	Total TWF (lb. eq.) Removals	TWF Cost-Effectiveness ($/lb. eq.)	Incremental TWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	7,002,917	204,354	34.27	34.27	Keep
	ORG1MET1OIL2	9,024,400	350,960	25.71	13.79	Keep
	ORG1MET1OIL3	23,573,029	353,134	66.75	6,692.49	Keep
	ORG1MET2OIL2	24,403,789	358,507	68.07	154.63	Keep
Reg Opt 1	ORG1MET3OIL2	25,290,118	359,071	70.43	1,569.66	Keep
	ORG1MET2OIL3	38,952,419	360,681	108.00	8,490.06	Keep
Reg Opt 2	ORG1MET3OIL3	39,838,747	361,245	110.28	1,569.66	Keep

Note: Costs shown include $1981 RCRA and monitoring costs of 2,754,201.

Figure 3-3. TWF Cost-Effectiveness Efficiency Frontier for Direct Dischargers

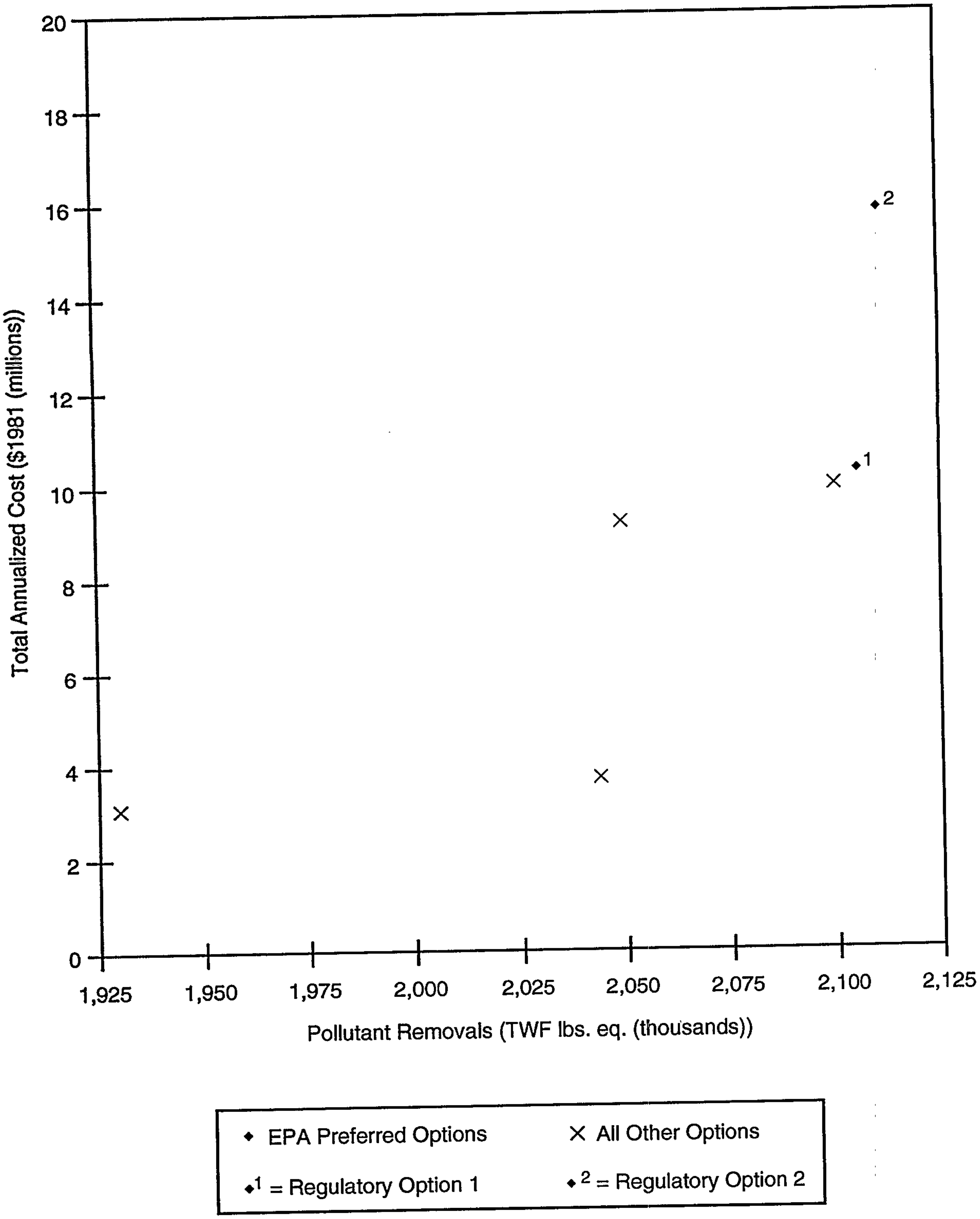


Figure 3-4. TWF Cost-Effectiveness Efficiency Frontier for Indirect Dischargers

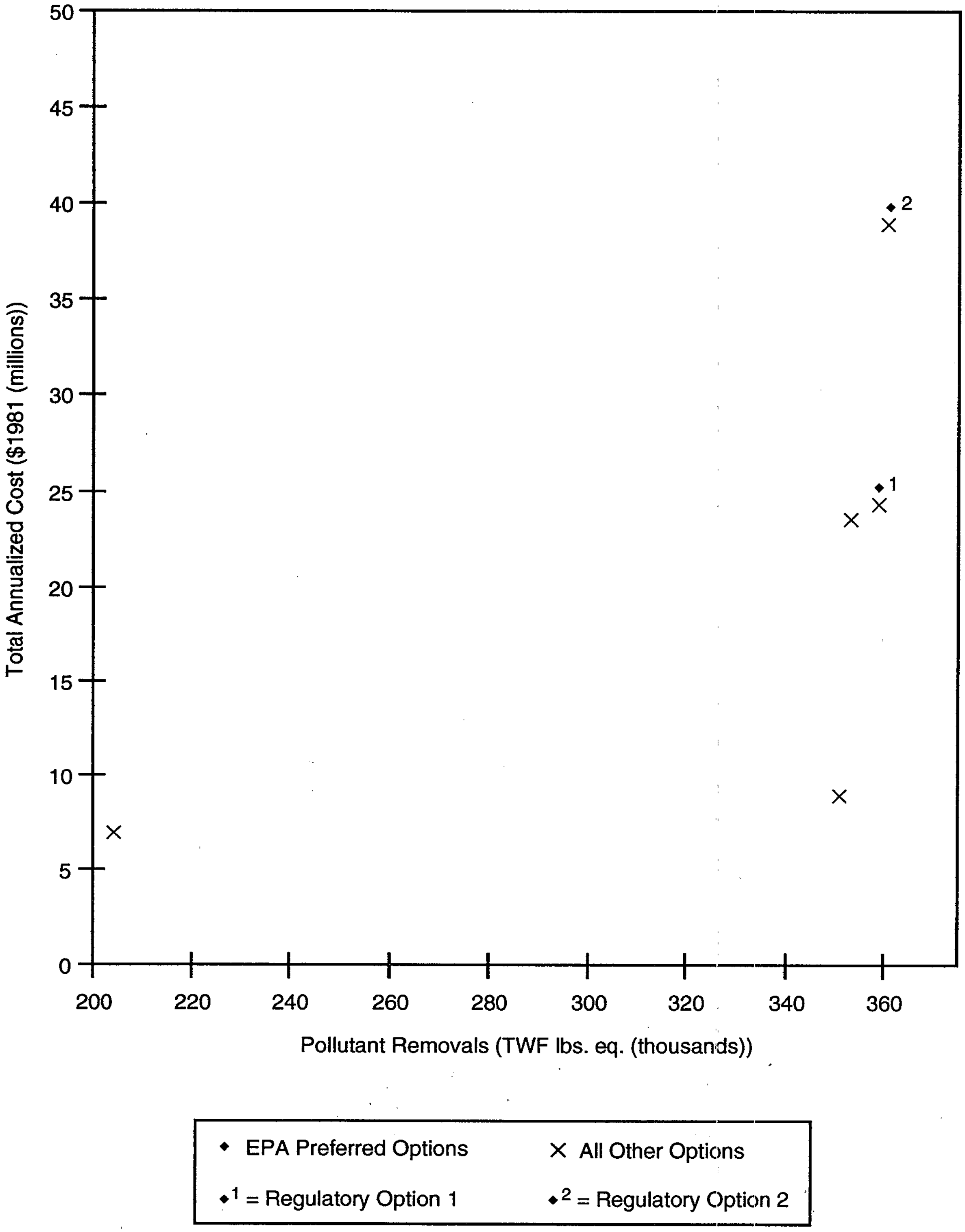


TABLE 3-5. TWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR ALL DISCHARGERS

TWF	Regulatory Option	Total Costs ($1981)	Total TWF Removals (lb. eq.)	TWF Cost-Effectiveness ($/lb. eq.)	TWF Incremental Cost-Effectiveness ($/lb. eq.)	Status
	ORG2MET1OIL1	13,980,019	1,309,679	10.67	10.67	Drop
	ORG2MET2OIL1	35,622,445	1,373,583	25.93	338.67	Drop
	ORG2MET3OIL1	36,807,674	1,380,192	26.67	179.32	Drop
	ORG2MET1OIL2	16,629,730	1,569,785	10.59	(106.43)	Drop
	ORG2MET1OIL4	41,107,339	1,575,482	26.09	4,296.36	Drop
	ORG2MET1OIL3	36,693,754	1,577,715	23.26	(1,976.87)	Drop
	ORG2MET2OIL2	38,272,156	1,633,689	23.43	28.20	Drop
	ORG2MET2OIL4	62,749,765	1,639,386	38.28	4,296.36	Drop
	ORG2MET3OIL2	39,457,385	1,640,299	24.06	(25,530.55)	Drop
	ORG2MET2OIL3	58,336,179	1,641,619	35.54	14,299.09	Drop
	ORG2MET3OIL4	63,934,994	1,645,996	38.84	1,279.14	Drop
	ORG2MET3OIL3	59,521,408	1,648,229	36.11	(1,976.87)	Drop
	ORG1MET1OIL1	**10,108,915**	**2,134,183**	**4.74**	**(101.68)**	**Keep**
	ORG1MET2OIL1	31,751,341	2,198,087	14.44	338.67	Drop
	ORG1MET3OIL1	32,936,570	2,204,697	14.94	179.32	Drop
	ORG1MET1OIL2	**12,758,627**	**2,394,289**	**5.33**	**(106.43)**	**Keep**
	ORG1MET1OIL4	37,236,236	2,399,987	15.52	4,296.36	Drop
	ORG1MET1OIL3	**32,822,650**	**2,402,219**	**13.66**	**(1,976.87)**	**Keep**
	ORG1MET2OIL2	**34,401,052**	**2,458,193**	**13.99**	**28.20**	**Keep**
	ORG1MET2OIL4	58,878,661	2,463,890	23.90	4,296.36	Drop
Reg Opt 1	**ORG1MET3OIL2**	**35,586,281**	**2,464,803**	**14.44**	**(25,530.55)**	**Keep**
	ORG1MET2OIL3	**54,465,076**	**2,466,123**	**22.09**	**14,299.09**	**Keep**
	ORG1MET3OIL4	60,063,890	2,470,500	24.31	1,279.14	Drop
Reg Opt 2	**ORG1MET3OIL3**	**55,650,304**	**2,472,733**	**22.51**	**(1,976.87)**	**Keep**

Note: Costs shown include $1981 RCRA and monitoring costs of $3,288,181.

TABLE 3-6. TWF COST-EFFECTIVENESS EFFICIENCY-FRONTIER FOR ALL DISCHARGERS

TWF	Regulatory Option	Total Costs ($1981)	Total TWF Removals (lb. eq.)	TWF Cost-Effectiveness ($/lb. eq.)	TWF Incremental Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	10,108,915	2,134,183	4.74	(101.68)	Keep
	ORG1MET1OIL2	12,758,627	2,394,289	5.33	(106.43)	Keep
	ORG1MET1OIL3	32,822,650	2,402,219	13.66	(1,976.87)	Keep
	ORG1MET2OIL2	34,401,052	2,458,193	13.99	28.20	Keep
Reg Opt 1	ORG1MET3OIL2	35,586,281	2,464,803	14.44	(25,530.55)	Keep
	ORG1MET2OIL3	54,465,076	2,466,123	22.09	14,299.09	Keep
Reg Opt 2	ORG1MET3OIL3	55,650,304	2,472,733	22.51	(1,976.87)	Keep

Note: Costs shown include $1981 RCRA and monitoring costs of $3,288,181.

Figure 3-5. TWF Cost-Effectiveness of Regulatory Options for All Dischargers

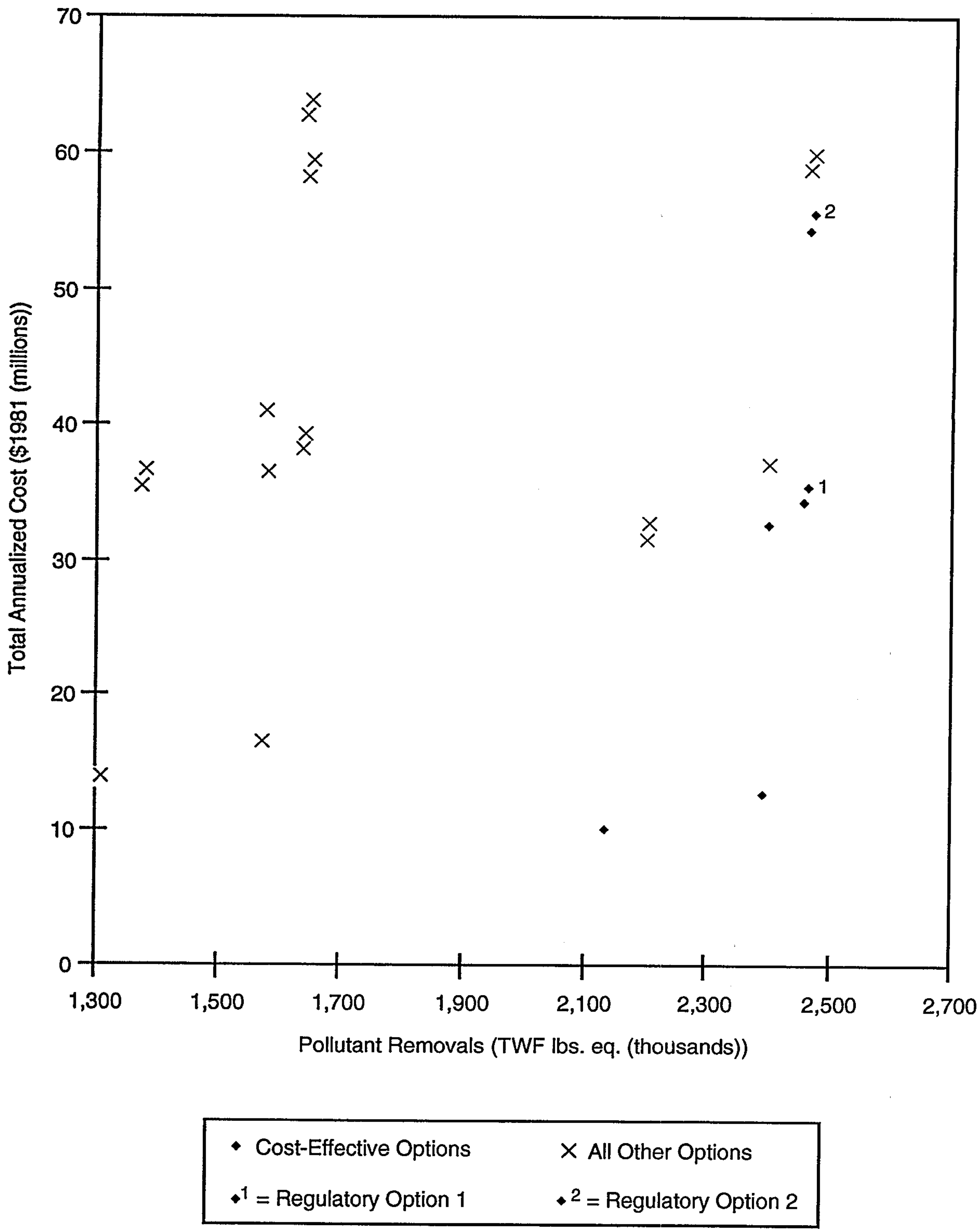
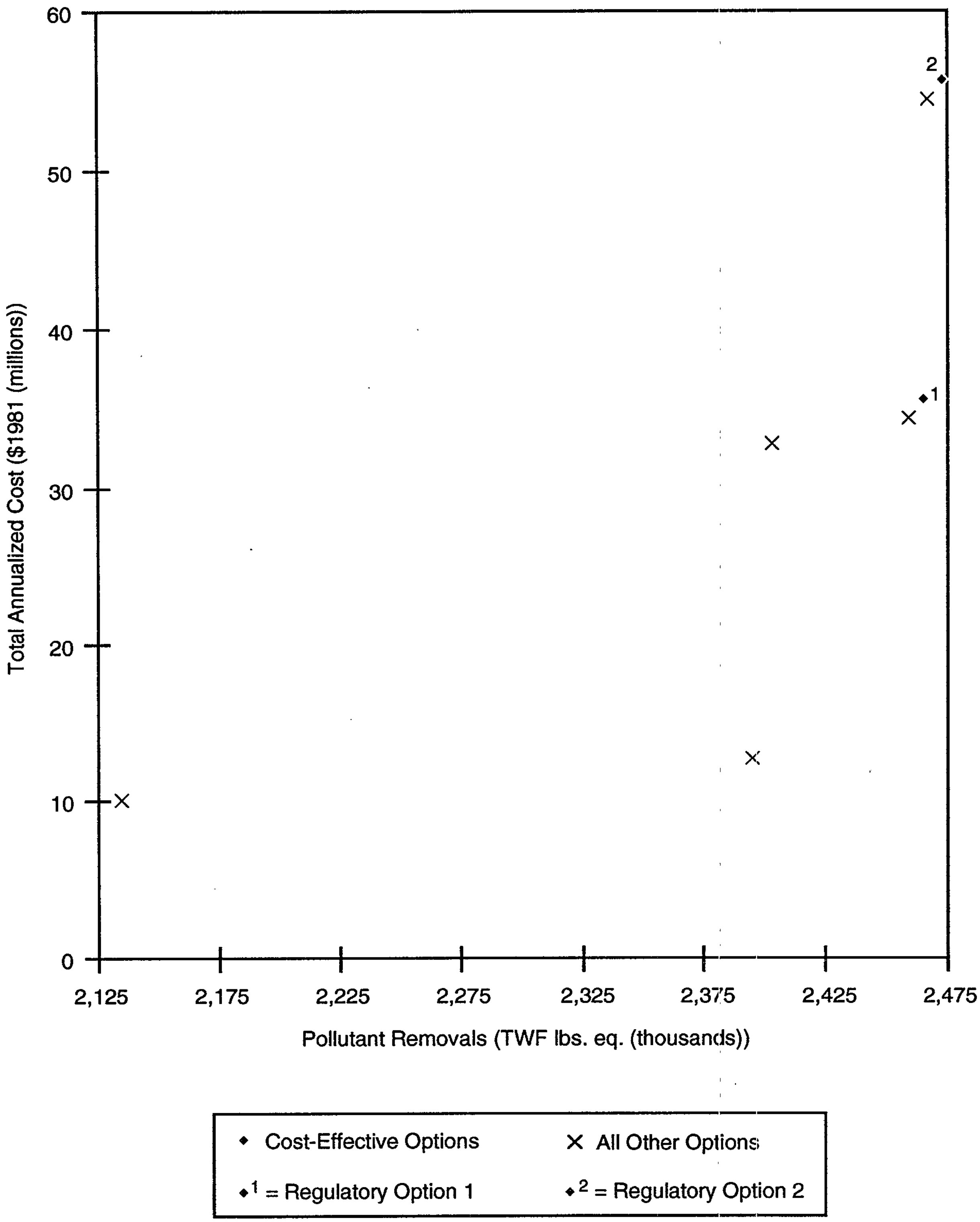


Figure 3-6. TWF Cost-Effectiveness Efficiency Frontier for All Dischargers



CHAPTER 4

COMPARISON OF THE COST-EFFECTIVENESS OF SELECTED CWT REGULATORY OPTIONS WITH THE COST-EFFECTIVENESS OF PREVIOUSLY APPROVED EFFLUENT GUIDELINES AND STANDARDS

Tables 4-1 and 4-2 respectively compare the estimated cost-effectiveness of each of the Agency's preferred regulatory alternatives for direct and indirect discharging CWT facilities to the cost-effectiveness of BAT regulations that have been approved for direct dischargers in other industries. This comparison is only possible using the cost-effectiveness values that are derived with pound-equivalent removals estimated using the TWF weighting approach. All costs are in 1981 dollars.

TABLE 4-1. INDUSTRY COMPARISON OF BAT COST-EFFECTIVENESS FOR DIRECT DISCHARGERS (TOXIC AND NONCONVENTIONAL POLLUTANTS ONLY; REMOVALS WEIGHTED USING TRADITIONAL TWFS[a]; $1981)

	Currently Discharged (lb. eq.)	Remaining at Selected Option(s) (lb. eq.)	Cost-Effectiveness of Selected Option(s) ($/lb. eq. rem.)
Aluminum Forming	1,340	90	121
Battery Manufacturing	4,126	5	2
Canmaking	12	0.2	10
Coal Mining	BAT=BPT	BAT=BPT	BAT=BPT
Coil Coating	2,289	9	49
Copper Forming	70	8	27
Centralized Waste Treatment - RO1	3,372	1,267	5
Centralized Waste Treatment - RO2	3,372	1,261	7
Electronics I	9	3	404
Electronics II	NA	NA	NA
Foundries	2,308	39	84
Inorganic Chemicals I	32,503	1,290	<1
Inorganic Chemicals II	605	27	6
Iron & Steel	40,746	1,040	2
Leather Tanning	259	112	BAT=BPT
Metal Finishing	3,305	3,268	12
Nonferrous Metals Forming	34	2	69
Nonferrous Metals Mfg I	6,653	313	4
Nonferrous Metals Mfg II	1,004	12	6
Offshore Oil and Gas[b]	3,808	2,328	33
Organic Chemicals	54,225	9,735	5
Pesticides	2,461	371	15
Pharmaceuticals	208	4	1
Plastics Molding & Forming	44	41	BAT=BPT
Porcelain Enameling	1,086	63	6
Petroleum Refining	BAT=BPT	BAT=BPT	BAT=BPT
Pulp & Paper	61,713	2,628	39
Textile Mills	BAT=BPT	BAT=BPT	BAT=BPT

[a]TWFs for some priority pollutants have changed across these rules; this table reflects the cost-effectiveness at the time of regulation.

[b]Produced water only, for produced sand and drilling fluids and drill cuttings, BAT=NSPS.

TABLE 4-2. INDUSTRY COMPARISON OF PSES COST-EFFECTIVENESS FOR INDIRECT DISCHARGERS (TOXIC AND NONCONVENTIONAL POLLUTANTS ONLY; REMOVALS WEIGHTED USING TRADITIONAL TWFS[a]; $1981)

	Pollutants Currently Discharged (lb. eq.)	Pollutants Remaining at Selected Option (lb. eq.)	Cost-Effectiveness of Selected Option(s) ($/lb. eq. rem.)
Aluminum Forming	1,602	18	155
Battery Manufacturing	1,152	5	15
Canmaking	252	5.0	38
Coal Mining	NA	NA	NA
Coil Coating	2,503	10	10
Copper Forming	34	4	10
Centralized Waste Treatment - RO1	689	330	70
Centralized Waste Treatment - RO2	689	328	110
Electronics I	75	35	14
Electronics II	260	24	14
Foundries	2,136	18	116
Inorganic Chemicals I	3,971	3,004	9
Inorganic Chemicals II	4,760	6	<1
Iron & Steel	5,599	1,404	6
Leather Tanning	16,830	1,899	111
Metal Finishing	11,680	755	10
Nonferrous Metals Forming	189	5	90
Nonferrous Metals Mfg I	3,187	19	15
Nonferrous Metals Mfg II	38	0	12
Offshore Oil and Gas[b]	NA	NA	NA
Organic Chemicals	5,210	72	34
Pharmaceuticals	340	63	1
Plastics Molding & Forming	NA	NA	NA
Porcelain Enameling	1,565	96	14
Pulp & Paper	9,539	103	65

[a]TWFs for some priority pollutants have changed across these rules; this table reflects the cost effectiveness at the time of regulation.

[b]No known indirect dischargers at this time.

APPENDIX A

A.1 RESULTS OF COST-EFFECTIVENESS ANALYSIS USING THE PWF TOXIC WEIGHTING METHOD

This Appendix presents a second cost-effectiveness analysis of the nine control options and the 24 possible regulatory options that can be created by combining individual options from each of the treatment subcategories. The only difference between the analysis presented in this appendix and the analysis presented in Chapters 2 and 3 of this report is the toxic weighting approach used to estimate toxicity-weighted pounds of pollutant removals. The analysis presented here uses PWF pound-equivalent removals as the measure of the effectiveness of different control options and regulatory options, while the analysis presented in Chapters 2 and 3 uses the traditional TWF approach. Table A-1 presents the unweighted and PWF-weighted pound-equivalent removals achievable by each individual control option. Tables A-2 and A-3 present a PWF cost-effectiveness comparison of each of the individual control options.

The PWF cost-effectiveness analysis of all regulatory options that follows offers very similar results to the TWF comparison presented in Chapter 3. More regulatory options seem cost-effective both for direct dischargers and for indirect dischargers when removals are estimated using the PWF approach than is the case when the analysis relies on removals estimated with TWF approach. All of the regulatory options that were on the efficiency frontier for either discharge status using the TWF approach are also among the most cost-effective for the same discharge status using the PWF approach. There are several additional options that appear cost-effective for each discharge category when the PWF weighting method is employed. When the PWF cost-effectiveness is considered for all dischargers together the same seven regulatory options are the most cost-effective.

Tables A-4 and A-5 present the PWF cost-effectiveness analysis of all 24 regulatory options with options sorted in ascending order of weighted removals based on the PWF toxic weighting approach. The regulatory options are ordered differently in Tables A-4 and A-5 than they were in Tables 3-1 and 3-2, where options were sorted in ascending order of TWF removals.

The organization of Tables A-4 and A-5 is identical to that of Tables 3-1 and 3-2, except that removals are weighted using the PWF weighting method. Note that there are 9 superior regulatory options for direct dischargers and 13 superior options for indirect dischargers in this analysis, while there were only 6 and 7 superior options in the corresponding cost-effectiveness comparisons with removals weighted using the traditional TWF approach.

TABLE A-1. SUMMARY OF WEIGHTED AND UNWEIGHTED POLLUTANT REMOVALS FOR DIRECT AND INDIRECT DISCHARGERS

Weighting Method	Control Option Name	Total Removals by Direct Dischargers	Total Removals by Indirect Dischargers	Total Removals by All Dischargers
Unweighted		(lbs./yr)	(lbs./yr)	(lbs./yr)
	MET1	9,329,643	3,528,937	12,858,580
	MET2	27,609,319	6,080,565	33,689,883
	MET3	28,739,622	6,322,709	35,062,331
	OIL1	0	0	0
	OIL2	21,004,158	11,263,808	32,267,966
	OIL3	23,108,164	11,586,370	34,694,534
	OIL4	23,300,182	11,619,866	34,920,048
	ORG1	5,372,689	1,458,139	6,830,828
	ORG2	831,011	1,391,288	2,222,299
PWF		(PWF lb. eq./yr)	(PWF lb. eq./yr)	(PWF lb. eq./yr)
	MET1	520,605	43,239	563,844
	MET2	563,472	47,063	610,535
	MET3	567,776	47,313	615,089
	OIL1	0	0	0
	OIL2	26,398	27,698	54,096
	OIL3	32,653	29,138	61,791
	OIL4	32,394	29,039	61,433
	ORG1	158,530	1,455,531	1,614,061
	ORG2	106,970	1455847	1,562,817

Note: lb. eq. = pound equivalent

TABLE A-2. COST-EFFECTIVENESS COMPARISON OF CONTROL OPTIONS FOR DIRECT DISCHARGING CWT FACILITIES

Treatment Category	Control Option	Total Costs ($1981)	Total Cost ($1990)	PWF Total Removals	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)
Metals	1	2,278,827	3,050,380	520,605	4.38	
	2	8,541,863	11,433,921	563,472	15.16	146.10
	3	8,840,764	11,834,022	567,776	15.57	69.46
Oils	1	0	0	0		
	2	628,228	840,930	26,398	23.80	23.80
	3	6,143,622	8,223,696	32,653	188.15	881.74
	4	7,262,456	9,721,340	32,394	224.19	(4,318.78)
Organics	1	293,191	392,459	158,530	1.85	
	2	2,280,094	3,052,076	106,970	21.32	(38.54)

Note: The shaded area indicates that the option in question has fewer weighted removals than the preceding option. That is, incremental values are not meaningful. These costs do not include RCRA and monitoring costs.

TABLE A-3. COST-EFFECTIVENESS COMPARISON OF CONTROL OPTIONS FOR INDIRECT DISCHARGING CWT FACILITIES

Treatment Category	Control Option	Total Costs ($1981)	Total Cost ($1990)	PWF Total Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)
Metals	1	2,410,819	3,227,061	43,239	55.76	
	2	17,790,208	23,813,521	47,063	378.01	4,021.97
	3	18,676,537	24,999,938	47,313	394.74	3,540.86
Oils	1	0	0	0		
	2	2,021,483	2,705,906	27,698	72.98	72.98
	3	16,570,113	22,180,332	29,138	568.69	10,106.08
	4	19,864,864	26,590,602	29,039	684.08	(33,412.99)
Organics	1	1,837,897	2,460,162	1,455,531	1.26	
	2	3,722,098	4,982,305	1,455,847	2.56	5,961.27

Note: The shaded area indicates that the option in question has fewer weighted removals than the preceding option. That is, incremental values are not meaningful. These costs do not include RCRA and monitoring costs.

TABLE A-4. PWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR DIRECT DISCHARGING CWT FACILITIES

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG2MET1OIL1	5,092,902	627,575	8.12	8.12	Drop
	ORG2MET1OIL2	5,721,129	653,973	8.75	23.80	Drop
	ORG2MET1OIL4	12,355,358	659,969	18.72	1,106.43	Drop
	ORG2MET1OIL3	11,236,524	660,228	17.02	(4,318.78)	Drop
	ORG2MET2OIL1	11,355,938	670,442	16.94	11.69	Drop
	ORG2MET3OIL1	11,654,838	674,746	17.27	69.46	Drop
	ORG1MET1OIL1	**3,105,999**	**679,135**	**4.57**	**(1,947.72)**	**Keep**
	ORG2MET2OIL2	11,984,166	696,841	17.20	501.43	Drop
	ORG2MET3OIL2	12,283,066	701,144	17.52	69.46	Drop
	ORG2MET2OIL4	18,618,394	702,837	26.49	3,742.95	Drop
	ORG2MET2OIL3	17,499,560	703,096	24.89	(4,318.78)	Drop
	ORG1MET1OIL2	**3,734,226**	**705,533**	**5.29**	**(5,647.36)**	**Keep**
	ORG2MET3OIL4	18,917,295	707,140	26.75	9,448.58	Drop
	ORG2MET3OIL3	17,798,460	707,399	25.16	(4,318.78)	Drop
	ORG1MET1OIL4	10,368,455	711,529	14.57	(1,799.00)	Drop
	ORG1MET1OIL3	**9,249,621**	**711,788**	**12.99**	**(4,318.78)**	**Keep**
	ORG1MET2OIL1	**9,369,035**	**722,002**	**12.98**	**11.69**	**Keep**
	ORG1MET3OIL1	**9,667,936**	**726,306**	**13.31**	**69.46**	**Keep**
	ORG1MET2OIL2	**9,997,263**	**748,400**	13.36	14.91	**Keep**
Reg Opt 1	**ORG1MET3OIL2**	**10,296,163**	**752,704**	13.68	69.46	**Keep**
	ORG1MET2OIL4	16,631,491	754,397	22.05	3,742.95	Drop
	ORG1MET2OIL3	**15,512,657**	**754,656**	20.56	(4,318.78)	**Keep**
	ORG1MET3OIL4	16,930,392	758,700	22.32	350.54	Drop
Reg Opt 2	**ORG1MET3OIL3**	**15,811,557**	**758,959**	20.83	(4,318.78)	**Keep**

Note: Costs for each option include annualized $1981 RCRA and monitoring costs of $533,980.

TABLE A-5. PWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR INDIRECT DISCHARGING CWT FACILITIES

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	**7,002,917**	**1,498,770**	**4.67**	**4.67**	**Keep**
	ORG2MET1OIL1	**8,887,118**	**1,499,086**	**5.93**	**5,961.27**	**Keep**
	ORG1MET2OIL1	22,382,306	1,502,594	14.90	3,847.23	Drop
	ORG1MET3OIL1	23,268,634	1,502,844	15.48	3,540.86	Drop
	ORG2MET2OIL1	24,266,507	1,502,910	16.15	15,174.60	Drop
	ORG2MET3OIL1	25,152,835	1,503,161	16.73	3,540.86	Drop
	ORG1MET1OIL2	**9,024,400**	**1,526,468**	**5.91**	**(691.98)**	**Keep**
	ORG2MET1OIL2	**10,908,601**	**1,526,784**	**7.14**	**5,961.27**	**Keep**
	ORG1MET1OIL4	26,867,781	1,527,809	17.59	15,571.28	Drop
	ORG1MET1OIL3	**23,573,029**	**1,527,908**	**15.43**	**(33,412.99)**	**Keep**
	ORG2MET1OIL4	28,751,981	1,528,125	18.82	23,814.90	Drop
	ORG2MET1OIL3	25,457,230	1,528,224	16.66	(33,412.99)	Drop
	ORG1MET2OIL2	**24,403,789**	**1,530,292**	**15.95**	**(509.36)**	**Keep**
Reg Opt 1	**ORG1MET3OIL2**	**25,290,118**	**1,530,542**	**16.52**	**3,540.86**	**Keep**
	ORG2MET2OIL2	**26,287,990**	**1,530,608**	**17.17**	**15,174.60**	**Keep**
	ORG2MET3OIL2	**27,174,318**	**1,530,859**	**17.75**	**3,540.86**	**Keep**
	ORG1MET2OIL4	42,247,170	1,531,633	27.58	19,458.96	Drop
	ORG1MET2OIL3	**38,952,419**	**1,531,732**	**25.43**	**(33,412.99)**	**Keep**
	ORG1MET3OIL4	43,133,498	1,531,883	28.16	27,560.13	Drop
	ORG2MET2OIL4	44,131,371	1,531,949	28.81	15,174.60	Drop
Reg Opt 2	**ORG1MET3OIL3**	**39,838,747**	**1,531,982**	**26.00**	**(130,683.37)**	**Keep**
	ORG2MET2OIL3	**40,836,619**	**1,532,048**	**26.65**	**15,174.60**	**Keep**
	ORG2MET3OIL4	45,017,699	1,532,199	29.38	27,560.13	Drop
	ORG2MET3OIL3	**41,722,948**	**1,532,298**	**27.23**	**(33,412.99)**	**Keep**

Note: Costs for each option include RCRA and monitoring costs of 2,754,201.

Figures A-1 and A-2 are scatter graphs of the costs and removals for each option listed in Tables A-4 and A-5, respectively. Total costs are measured along the y axis, and total removals are measured along the x axis. Here again, the cost-effectiveness efficiency frontier is in each case formed by the options plotted in the lower right-hand section of the graph. Superior regulatory options and the Agency's preferred regulatory options are identified as they were for the cost-effectiveness comparison with removals weighted using TWFs. Nine regulatory options are on the efficiency frontier for direct dischargers, and 13 options are on the efficiency frontier for indirect dischargers when removals are estimated using the PWFs. The Agency's preferred regulatory option is again on each of these frontiers.

Tables A-6 and A-7 are organized in the same way as Tables A-4 and A-5, but they include only the superior regulatory options for the corresponding discharge status from Tables A-4 and A-5.

Figures A-3 and A-4 are close-up images of Figures A-1 and A-2; in each case, all regulatory options that do not lie on the efficiency frontier for the corresponding discharge status are omitted. Looking at the efficiency frontier for both types of dischargers, the scale of the y axis, along which costs are measured, and the scale of the x axis, along which removals are measured, have been changed to permit a closer look at differences in costs and removals across options.

Only 6 of the 24 regulatory options evaluated are on the efficiency frontiers for both direct and indirect discharging facilities regardless of the toxic weighting method used to estimate pollutant removals. A total of 15 regulatory options are on at least one efficiency frontier for direct or indirect dischargers using one of the two weighting approaches.

Table A-8 compares the relative cost-effectiveness of all options with removals estimated using the PWF approach, and all dischargers included. Table A-9 presents the relative cost-effectiveness of seven regulatory options that form the PWF cost-effectiveness efficiency frontier. Figure A-5 is a scatter graph of the relative cost-effectiveness of all 24 regulatory options with pollutant removals estimated using the alternative PWF method. Figure A-6 is a larger scale image of the relative cost-effectiveness of the seven regulatory options forming the efficiency frontier in Figure A-5.

Figure A-1. PWF Cost-Effectiveness of Regulatory Options for Direct Dischargers

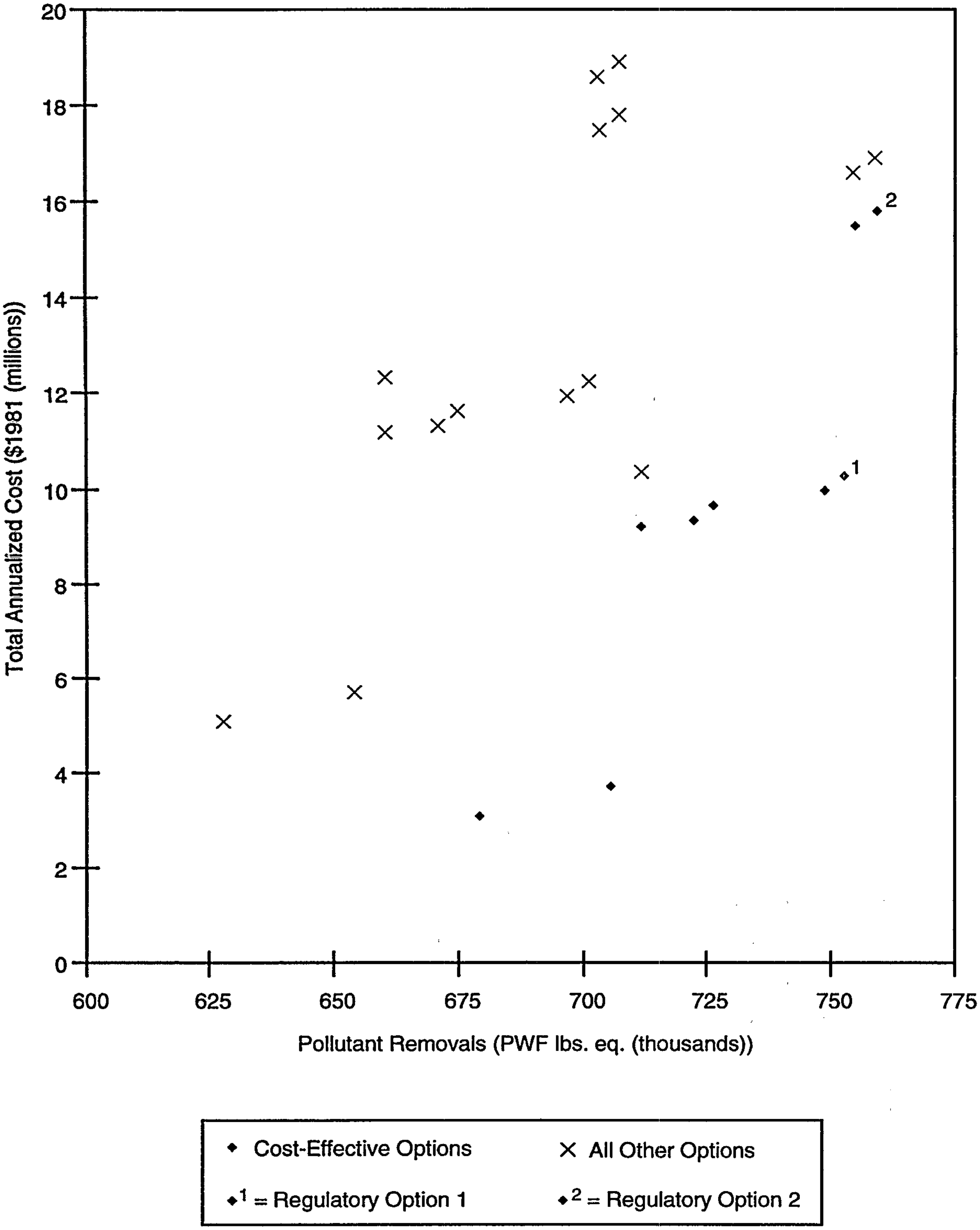


Figure A-2. PWF Cost-Effectiveness of Regulatory Options for Indirect Dischargers

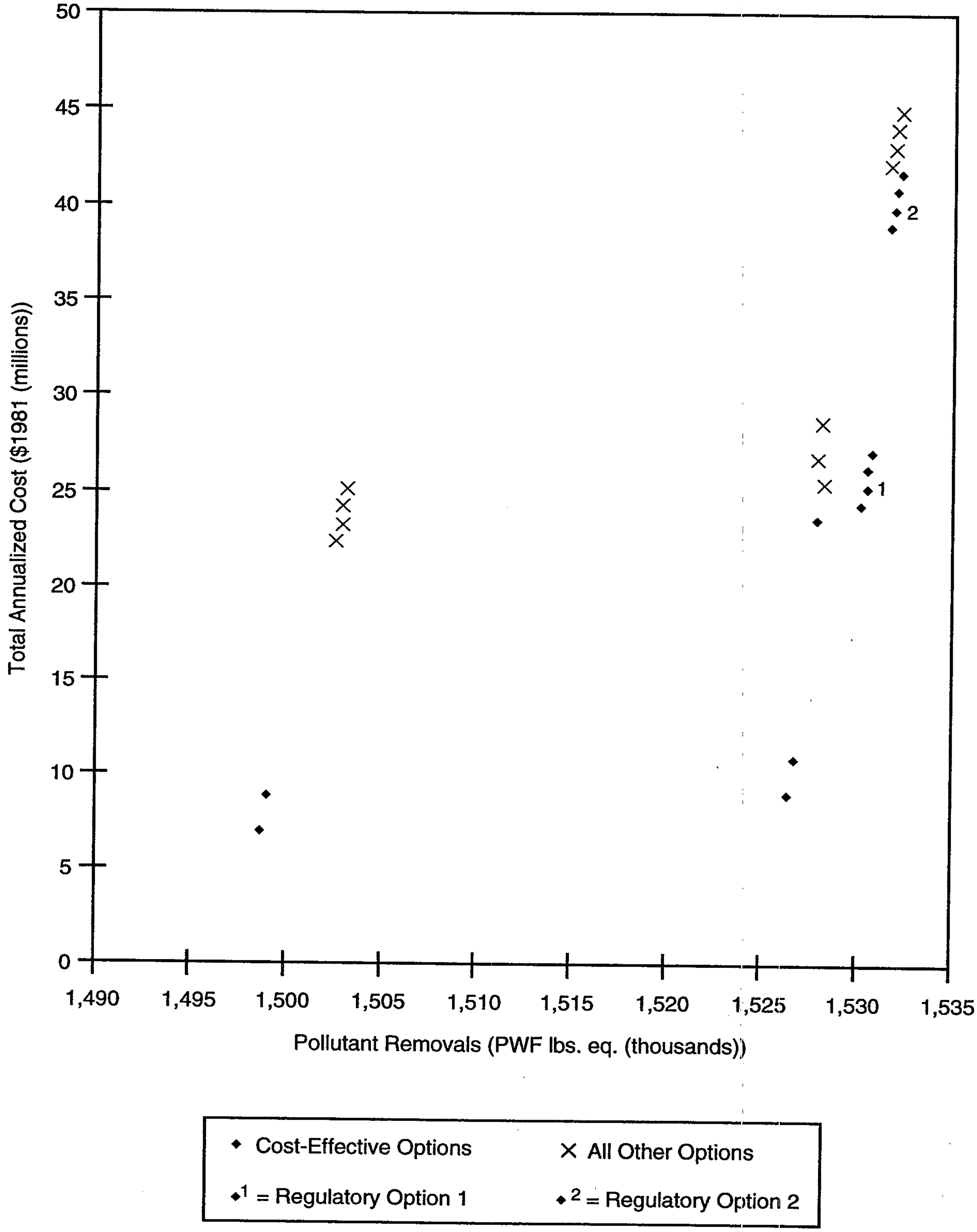


TABLE A-6. PWF COST-EFFECTIVENESS EFFICIENCY FRONTIER FOR DIRECT DISCHARGING CWT FACILITIES

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	3,105,999	679,135	4.57	4.57	Keep
	ORG1MET1OIL2	3,734,226	705,533	5.29	23.80	Keep
	ORG1MET1OIL3	9,249,621	711,788	12.99	881.74	Keep
	ORG1MET2OIL1	9,369,035	722,002	12.98	11.69	Keep
	ORG1MET3OIL1	9,667,936	726,306	13.31	69.46	Keep
	ORG1MET2OIL2	9,997,263	748,400	13.36	14.91	Keep
Reg Opt 1	ORG1MET3OIL2	10,296,163	752,704	13.68	69.46	Keep
	ORG1MET2OIL3	15,512,657	754,656	20.56	2,672.84	Keep
Reg Opt 2	ORG1MET3OIL3	15,811,557	758,959	20.83	69.46	Keep

Note: Costs for each option include $1981 RCRA and monitoring costs of $533,980.

TABLE A-7. PWF COST-EFFECTIVENESS EFFICIENCY FRONTIER FOR INDIRECT DISCHARGING CWT FACILITIES

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	7,002,917	1,498,770	4.67	4.67	Keep
	ORG2MET1OIL1	8,887,118	1,499,086	5.93	5,961.27	Keep
	ORG1MET1OIL2	9,024,400	1,526,468	5.91	5.01	Keep
	ORG2MET1OIL2	10,908,601	1,526,784	7.14	5,961.27	Keep
	ORG1MET1OIL3	23,573,029	1,527,908	15.43	11,272.12	Keep
	ORG1MET2OIL2	24,403,789	1,530,292	15.95	348.44	Keep
Reg Opt 1	ORG1MET3OIL2	25,290,118	1,530,542	16.52	3,540.86	Keep
	ORG2MET2OIL2	26,287,990	1,530,608	17.17	15,174.60	Keep
	ORG2MET3OIL2	27,174,318	1,530,859	17.75	3,540.86	Keep
	ORG1MET2OIL3	38,952,419	1,531,732	25.43	13,488.37	Keep
Reg Opt 2	ORG1MET3OIL3	39,838,747	1,531,982	26.00	3,540.86	Keep
	ORG2MET2OIL3	40,836,619	1,532,048	26.65	15,174.60	Keep
	ORG2MET3OIL3	41,722,948	1,532,298	27.23	3,540.86	Keep

Note: Costs for each option include annualized RCRA and monitoring costs of 2,754,201.

Figure A-3. PWF Cost-Effectiveness Efficiency Frontier for Direct Dischargers

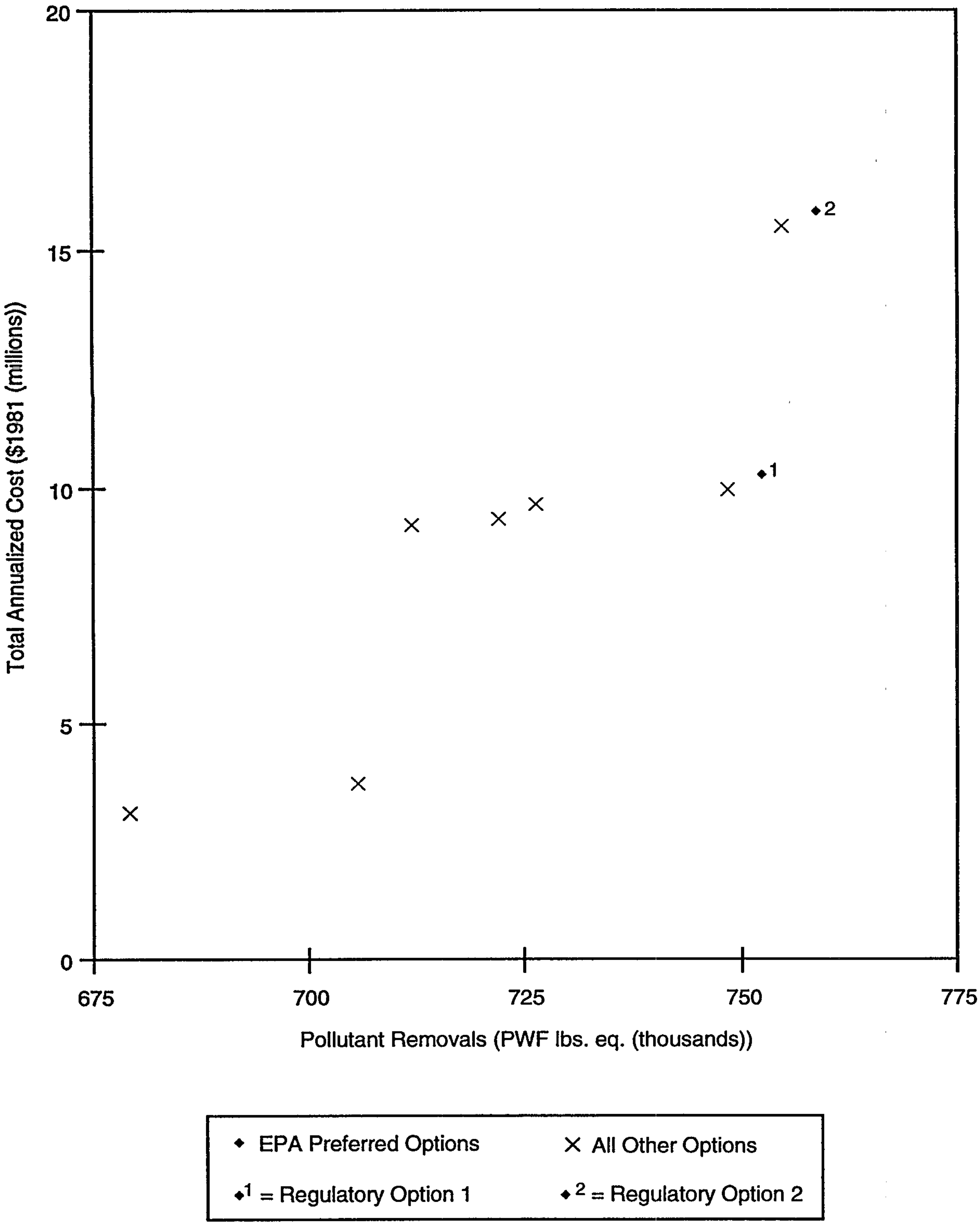


Figure A-4. PWF Cost-Effectiveness Efficiency Frontier for Indirect Dischargers

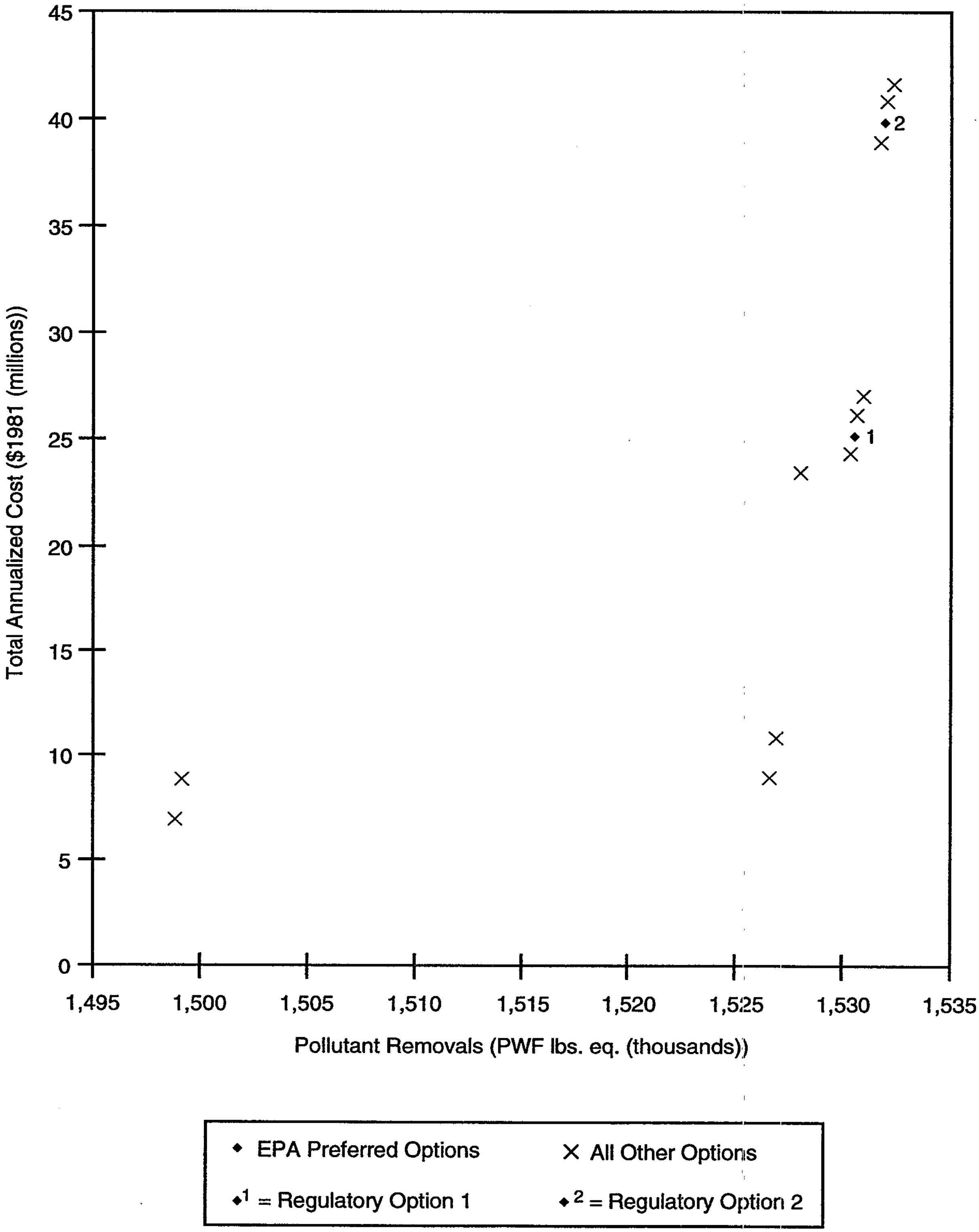


TABLE A-8. PWF COST-EFFECTIVENESS COMPARISON OF ALL REGULATORY OPTIONS FOR ALL DISCHARGERS

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG2MET1OIL1	13,980,019	2,126,661	6.57	6.57	Drop
	ORG2MET2OIL1	35,622,445	2,173,353	16.39	463.52	Drop
	ORG1MET1OIL1	**10,108,915**	**2,177,905**	**4.64**	**(5,604.06)**	**Keep**
	ORG2MET3OIL1	36,807,674	2,177,906	16.90	24,547,155.55	Drop
	ORG2MET1OIL2	16,629,730	2,180,757	7.63	(7,077.25)	Drop
	ORG2MET1OIL4	41,107,339	2,188,095	18.79	3,336.17	Drop
	ORG2MET1OIL3	36,693,754	2,188,452	16.77	(12,339.85)	Drop
	ORG1MET2OIL1	31,751,341	2,224,597	14.27	(136.74)	Drop
	ORG2MET2OIL2	38,272,156	2,227,449	17.18	2,286.25	Drop
	ORG1MET3OIL1	32,936,570	2,229,150	14.78	(3,135.65)	Drop
	ORG1MET1OIL2	**12,758,627**	**2,232,001**	**5.72**	**(7,077.25)**	**Keep**
	ORG2MET3OIL2	39,457,385	2,232,002	17.68	24,547,155.55	Drop
	ORG2MET2OIL4	62,749,765	2,234,786	28.08	8,368.71	Drop
	ORG2MET2OIL3	58,336,179	2,235,143	26.10	(12,339.85)	Drop
	ORG1MET1OIL4	37,236,236	2,239,338	16.63	(5,029.76)	Drop
	ORG2MET3OIL4	63,934,994	2,239,340	28.55	24,547,155.55	Drop
	ORG1MET1OIL3	**32,822,650**	**2,239,696**	**14.65**	**(87,251.64)**	**Keep**
	ORG2MET3OIL3	59,521,408	2,239,697	26.58	24,547,155.55	Drop
	ORG1MET2OIL2	**34,401,052**	**2,278,693**	**15.10**	**(644.19)**	**Keep**
Reg Opt 1	**ORG1MET3OIL2**	**35,586,281**	**2,283,246**	**15.59**	**260.27**	**Keep**
	ORG1MET2OIL4	58,878,661	2,286,030	25.76	8,368.71	Drop
	ORG1MET2OIL3	**54,465,076**	**2,286,387**	**23.82**	**(12,339.85)**	**Keep**
	ORG1MET3OIL4	60,063,890	2,290,583	26.22	1,334.29	Drop
Reg Opt 2	**ORG1MET3OIL3**	**55,650,304**	**2,290,941**	**24.29**	**(12,339.85)**	**Keep**

Note: Costs shown include RCRA and monitoring costs of $3,288,181.

TABLE A-9. PWF COST-EFFECTIVENESS EFFICIENCY-FRONTIER FOR ALL DISCHARGERS

PWF	Regulatory Option	Total Costs ($1981)	Total PWF Removals (lb. eq.)	PWF Cost-Effectiveness ($/lb. eq.)	Incremental PWF Cost-Effectiveness ($/lb. eq.)	Status
	ORG1MET1OIL1	10,108,915	2,177,905	4.64	4.64	Keep
	ORG1MET1OIL2	12,758,627	2,232,001	5.72	48.98	Keep
	ORG1MET1OIL3	32,822,650	2,239,696	14.65	2,607.51	Keep
	ORG1MET2OIL2	34,401,052	2,278,693	15.10	40.48	Keep
Reg Opt 1	ORG1MET3OIL2	35,586,281	2,283,246	15.59	260.27	Keep
	ORG1MET2OIL3	54,465,076	2,286,387	23.82	6,010.55	Keep
Reg Opt 2	ORG1MET3OIL3	55,650,304	2,290,941	24.29	260.27	Keep

Note: Costs shown include $1981 RCRA and monitoring costs of $3,288,181.

Figure A-5. PWF Cost-Effectiveness of Regulatory Options for All Dischargers

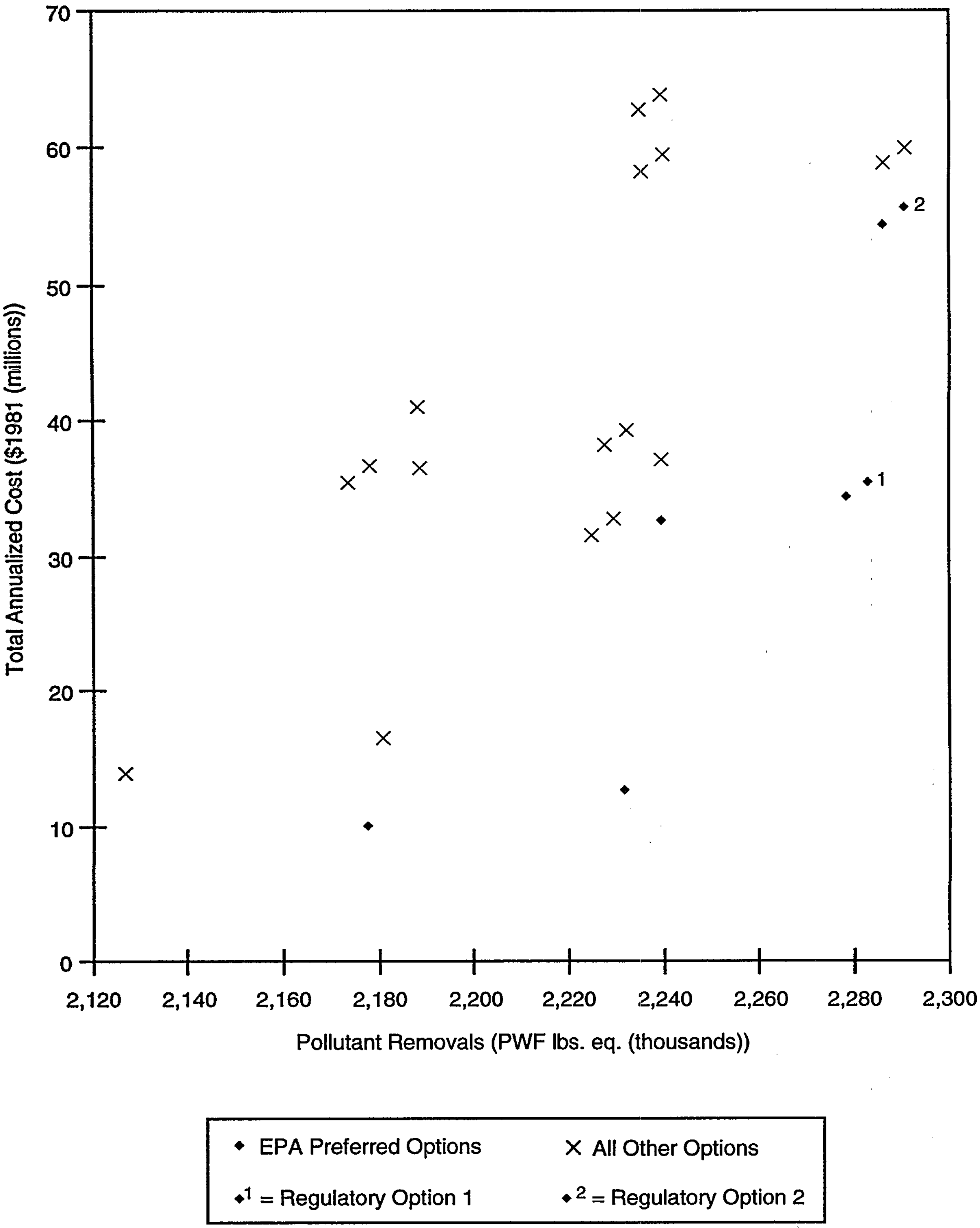
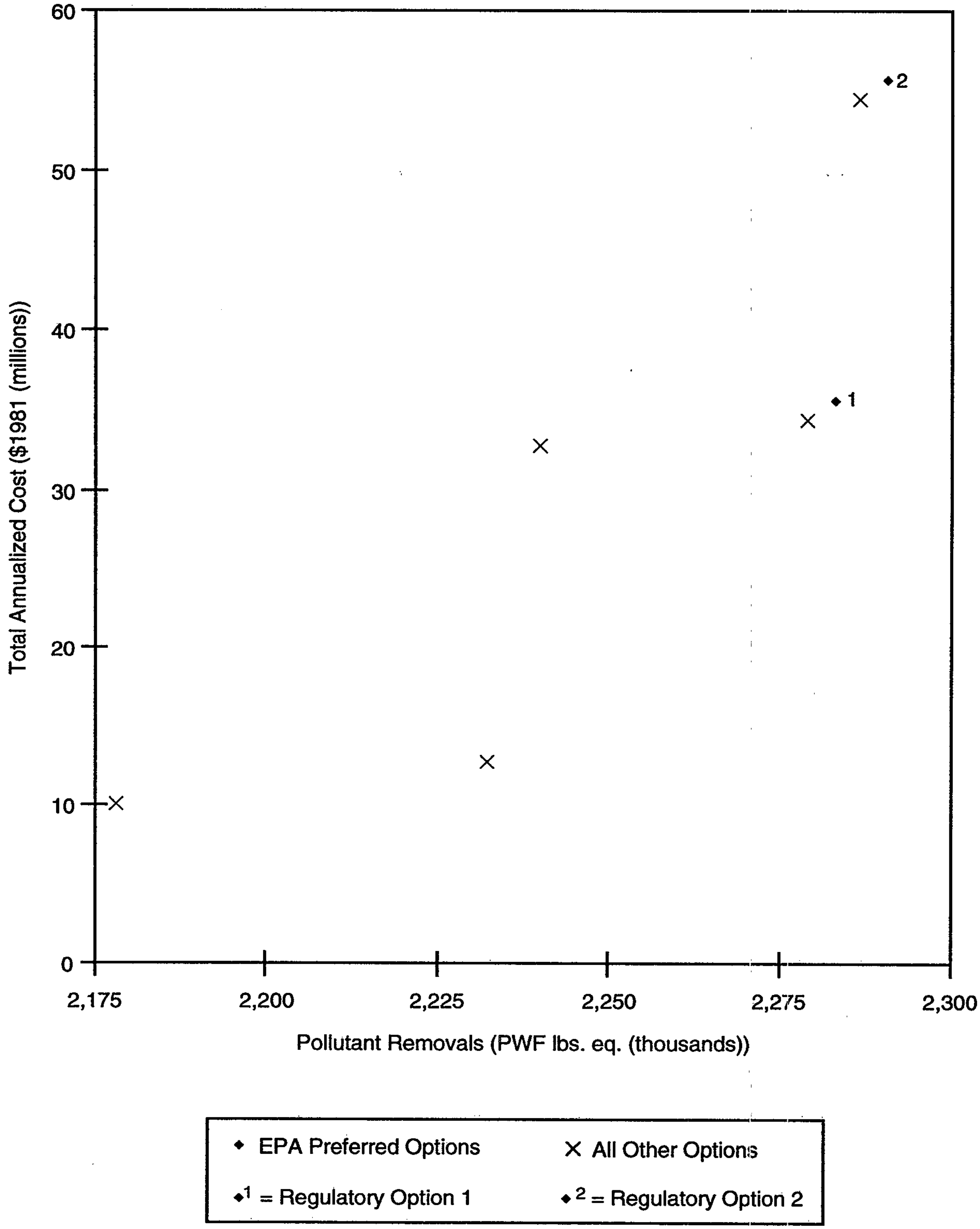


Figure A-6. PWF Cost-Effectiveness Efficiency Frontier for All Dischargers



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