

# CONTENTS

Tables .....	xi
Figures .....	xv
Foreword .....	xvii
Preface .....	xxi
Chapter 1. Introduction .....	1
Chapter 2. Regulatory Approaches .....	7
Elements of a Regulatory Program .....	8
Developing Standards .....	8
Issuing Permits .....	8
Monitoring Compliance .....	9
Enforcing Regulations .....	9
The Clean Water Act .....	9
Technology-Based Standards .....	10
Technology-Based Toxics Standards .....	12
Technology-Based Standards for Indirect Dischargers .....	13
The Clean Air Act .....	14
Ambient-Based Standards .....	15
Benefits-Based Standards .....	16
Technology-Based Hazardous Air Standards .....	19
The Resource Conservation and Recovery Act .....	20
Hazardous Wastes .....	21
Chapter 3. Technology Approach .....	27
Pollution Control Costs And Effluents .....	29
Inventory - 1973, 1984, and 1994 .....	30
Effluent Data .....	30
Cost Modeling .....	30
Estimated Costs and Effluents .....	32

Cost Comparisons .....	35
Water Quality Impacts .....	35
Sample Sites .....	36
Scenarios .....	39
Water Quality Modeling .....	39
Estimated Water Quality Improvements .....	42
Validation of the RGDS Model .....	44
Monetary Benefits .....	45
Recreation Population .....	45
Valuation of Recreation Benefits .....	46
Estimated Benefits .....	48
Possible Biases in the Benefit Calculations .....	48
Findings .....	53
Appendix 3-A. Costs for Indirect-Discharging Mills .....	62
Appendix 3-B. Pulp and Paper Mills Evaluated in this Study ..	65
Appendix 3-C. Water Pollution Control Cost Estimation .....	69
Appendix 3-D. Water Pollution Control Cost Comparisons .....	71
Appendix 3-E. Loadings Data .....	74
Appendix 3-F. Water Quality Model .....	77
Appendix 3-G. Model Validation .....	83
Appendix 3-H. Visitation Estimates .....	86
Appendix 3-I. Recreation Benefit Studies .....	88
Appendix 3-J. Sensitivity Analysis for Benefit Calculations .....	92
Chapter 4. Ambient Approach .....	93
Pollution Control Costs and Emissions .....	95
Inventory - 1973, 1984, and 1994 .....	95
Emissions Data .....	96
Cost Modeling .....	96
Estimated Costs and Emissions .....	98
Cost Comparisons .....	101
Air Quality Impacts .....	101
Sample Sites .....	101
Scenarios .....	102
Air Quality Modeling .....	102
Estimated Air Quality Improvements .....	105
Validation of MCP Model .....	108
Monetary Benefits .....	108
Exposure .....	109
Health and Welfare Effects .....	110

Valuation of Benefits .....	113
Estimated Benefits .....	115
Possible Biases in the Benefit Calculations .....	115
Findings .....	115
Appendix 4-A. SO <sub>2</sub> Emissions and Costs .....	123
Appendix 4-B. Pulp-Producing Mills Evaluated in this Study ..	125
Appendix 4-C. Air Pollution Control Costs (TSP) .....	130
Appendix 4-D. Air Pollution Control Cost Comparisons .....	135
Appendix 4-E. Loadings Data .....	137
Appendix 4-F. Air Quality Model .....	138
Appendix 4-G. Emissions Versus Concentrations .....	142
Appendix 4-H. Model Validation .....	144
Appendix 4-I. Derivation of Concentration Response Functions for Health Effects .....	148
Chapter 5. Benefits Approach .....	153
Pollution Control Costs and Emissions .....	155
Inventory - 1973, 1984, and 1994 .....	155
Emissions Data .....	156
Cost Modeling .....	156
Estimated Costs and Emissions .....	158
Air Quality Impacts .....	160
Sample Sites .....	160
Scenarios .....	162
Air Quality Modeling .....	162
Estimated Air Quality Improvements .....	164
Monetary Benefits .....	165
Exposure .....	166
Health and Welfare Effects .....	166
Valuation of Effects .....	169
Estimated Benefits .....	171
Possible Biases in the Benefit Calculations .....	174
Findings .....	174
Appendix 5-A. Kraft Pulp Mills Evaluated in this Study .....	178
Appendix 5-B. Air Pollution Control Cost Estimation (TRS) ..	180
Appendix 5-C. TRS Emissions .....	182
Appendix 5-D. The MPTER Model .....	184

Chapter 6. Compliance . . . . .	185
Measuring Compliance . . . . .	185
Water . . . . .	185
Air . . . . .	186
Water Compliance . . . . .	187
Technology-Based Compliance . . . . .	188
Ambient-Based Compliance . . . . .	193
Benefits-Based Compliance . . . . .	196
Findings - Water . . . . .	198
Air Compliance . . . . .	199
Technology-Based Compliance . . . . .	200
Ambient-Based Compliance . . . . .	202
Benefits-Based Compliance . . . . .	206
Findings - Air . . . . .	207
Findings . . . . .	208
Chapter 7. Growth . . . . .	213
Conventional Water Pollutants . . . . .	215
Technology-Forcing Approach . . . . .	216
Antidegradation Approach . . . . .	220
Benefits Approach . . . . .	224
Findings - Water . . . . .	227
Criteria Air Pollutants -- TSP . . . . .	228
Technology-Forcing Approach . . . . .	229
Nondegradation Approach . . . . .	232
Benefits Approach. . . . .	237
Findings - TSP . . . . .	238
Designated Air Pollutants -- TRS . . . . .	239
Technology-Forcing Approach . . . . .	241
Ambient Approach . . . . .	241
Benefits Approach . . . . .	243
Findings - TRS . . . . .	243
Findings . . . . .	243
Appendix 7-A. 1984-1994 TRS Emission Reduction Policies . . . . .	248

Chapter 8. Toxic Pollutants . . . . .	249
Water Pollutants -- Dioxin . . . . .	250
Effluents . . . . .	250
Health and Ecological Effects . . . . .	252
Ambient Concentrations . . . . .	253
Risks to Public Health . . . . .	253
Risks to Ecosystem . . . . .	256
Effluent Reduction Technology and Costs . . . . .	257
Dioxins . . . . .	259
Regulatory Approaches . . . . .	259
Findings -- Dioxin . . . . .	262
Chloroform -- Air Pollutant . . . . .	263
Emissions . . . . .	263
Health and Ecological Effects . . . . .	263
Risks to Public Health . . . . .	264
Emission Reduction Technology and Costs . . . . .	266
Regulatory Approaches . . . . .	267
Findings -- Chloroform As A Hazardous Air Pollutant . . .	269
Chloroform -- Hazardous Waste . . . . .	269
Pulp and Paper Wastes . . . . .	270
Risks To Public Health . . . . .	271
Effluent Reduction Technology and Costs . . . . .	273
Regulatory Approaches . . . . .	274
Findings -- Chloroform as a Hazardous Waste . . . . .	276
Findings . . . . .	276
Appendix 8-A. Mills in the TOX Analysis . . . . .	283
Appendix 8-B. Critique of the Chloroform Risk Assessment . .	287
Appendix 8-C. Process Modification Costs . . . . .	291
Appendix 8-D. Mill-Specific Costs for Hypochlorite Elimination	293
Appendix 8-E. Mill-Specific Costs for Chloroform Reduction . .	295
Chapter 9. Conclusions . . . . .	297
Regulatory Approaches . . . . .	297
Historical Analysis (1973-1984) . . . . .	298
Projections of the Future (1984-1994) . . . . .	300
Historical Perspective . . . . .	303
Future Direction . . . . .	304

Appendix A. The Pulp and Paper Industry . . . . .	311
Industry Profile . . . . .	311
Capacity . . . . .	312
Geographic Distribution . . . . .	312
Standard Manufacturing Processes . . . . .	316
Preparing Raw Material . . . . .	316
Pulping . . . . .	316
Bleaching of Wood Pulps . . . . .	320
Papermaking . . . . .	322
Converting . . . . .	322
Sources of Wastes . . . . .	323
Water Effluents . . . . .	323
Air Emissions . . . . .	326
Solid Wastes . . . . .	327
Estimated Generation of Wastes . . . . .	328
Appendix B. Mills Evaluated in the Study . . . . .	331
Appendix C. Inflation Indexes . . . . .	343
Appendix D. Glossary of Environmental Terms . . . . .	345
Subject Index . . . . .	357
Author Index . . . . .	361

## TABLES

Table 2-1.	EPA's Major Statutes . . . . .	7
Table 3-1.	National Summary of Water Pollution Control Costs and Effluents for Direct-Discharging Mills in this Study	34
Table 3-2.	Impacts of Three Scenarios for Four Mills on Water Quality and Activity Levels . . . . .	42
Table 3-3.	Assumed Transfer Values for Water Quality Benefits . . . . .	47
Table 3-4.	Estimated Benefits and Costs of the Clean Water Act for 68 Pulp and Paper Mills . . . . .	49
Table 3-5.	Benefits and Costs Attributable to the Clean Water Act Technology-Based Standard . . . . .	54
Table 3-A-1.	National Summary of Water Pollution Control Costs for Indirect Discharging Mills in This Study . .	63
Table 3-B-1.	EPA Subcategories: Pulp, Paper, and Paperboard Industry . . . . .	66
Table 3-C-1.	Treatment Components . . . . .	70
Table 3-D-1.	Aggregate Cost Comparisons . . . . .	72
Table 3-E-1.	Effluent Loadings Data for Pulp and Paper Mills Analyzed in Water Quality Simulations . . . . .	75
Table 3-E-2.	Effluent Loadings Data for Municipal Treatment Plants Analyzed in Water Quality Simulations . . . . .	76
Table 3-F-1.	Reaeration Coefficients . . . . .	78
Table 3-H-1.	Data for Calculating Recreation Participation Rates .	86
Table 3-I-1.	Estimated Water Quality Benefits per Household in Three Studies . . . . .	89
Table 3-J-1.	Alternative Benefit Calculations . . . . .	92
Table 4-1.	National Summary of TSP Pollution Control Costs and Emissions for Pulp Mills in This Study . . . . .	100
Table 4-2.	Annual Average Concentration Values for Four Pulp-Producing Mills . . . . .	106
Table 4-3.	Total Exposures for Four Pulp Mills . . . . .	110
Table 4-4.	Estimated Benefits and Costs of the Clean Air Act for 60 Pulp Mills . . . . .	116

Table 4-5.	Benefits and Costs Attributable to the Clean Air Act Ambient-Based Standard for TSP . . . . .	118
Table 4-A-1.	National Summary of SO <sub>2</sub> Pollution Control Costs and Emissions for Pulp Mills in this Study . . . . .	124
Table 4-B-1.	Required Plant Components and Control Equipment and Air Pollutant Default Values . . . . .	128
Table 4-C-1.	1984 Kraft Process Particulate Control Cost Factors	133
Table 4-C-2.	1984 Sulfite Pulping Particulate Control Cost Factors	134
Table 4-C-3.	1984 Power Boiler Particulate Control Cost Factors .	134
Table 4-D-1.	Aggregate Cost Comparisons . . . . .	136
Table 4-E-1.	Total TSP Emissions for 60 Pulp-Producing Mills . . .	137
Table 4-G-1.	Mills With Large Reductions in TSP Emissions and Mills With Large Reductions in TSP Concentrations .	143
Table 4-H-1.	Maximum Annual Average TSP Concentration . . . . .	146
Table 5-1.	National Summary of Estimated TRS Pollution Control Costs and Emissions for Kraft Mills in This Study . .	159
Table 5-2.	Average Number of Days with at Least One 1-hr Average TRS Concentration greater than 0.005 mg/m <sup>3</sup>	164
Table 5-3.	Health Effects - Hydrogen Sulfide . . . . .	168
Table 5-4.	Valuation Schemes for TRS Reductions . . . . .	171
Table 5-5.	Estimated Benefits and Costs of the Clean Air Act (TRS) for 60 Kraft Pulp Mills . . . . .	172
Table 5-6.	Benefits and Costs Attributable to the Clean Air Act Benefit-Based Standard for TRS . . . . .	174
Table 5-B-1.	Total Reduced Sulfur Control Costs . . . . .	181
Table 5-C-1.	Total TRS Emissions for the Kraft Pulp Mills Covered in This Study . . . . .	182
Table 6-1.	Comparison of Non-Complying Mills Based on the Permit Compliance System (PCS) and the Cost of Clean (COC) Model . . . . .	188
Table 6-2.	Benefit-Cost Analysis of a Technology-Based Water Compliance Strategy . . . . .	192
Table 6-3.	Benefit-Cost Analysis of an Ambient-Based Water Compliance Strategy . . . . .	195
Table 6-4.	Benefit-Cost Analysis of a Benefits-Based Water Compliance Strategy . . . . .	197
Table 6-5.	Summary of the Benefit-Cost Assessments of Water Compliance Strategies . . . . .	198



Table 6-6.	Benefit-Cost Analysis of a Technology-Based Air Compliance Strategy . . . . .	203
Table 6-7.	Benefit-Cost Analysis of an Ambient-Based Air Compliance Strategy . . . . .	205
Table 6-8.	Benefit-Cost Analysis of a Benefits-Based Air Compliance Strategy . . . . .	207
Table 6-9.	Summary of the Benefit-Cost Assessments of Air Pollution Compliance Strategies . . . . .	208
Table 7-1.	Pulp, Paper and Paperboard Capacity and Water and Air Pollutant Loadings Included in This Study -- 1973, 1984, and 1994 . . . . .	215
Table 7-2.	Benefit-Cost Analysis for the 44 Mills Affected by a Technology-Forcing Water Approach . . . . .	219
Table 7-3.	Benefit-Cost Analysis for the 12 Mills Affected by a 1994 Antidegradation Water Approach . . . . .	224
Table 7-4.	Benefit-Cost Analysis for the 34 Mills Potentially Affected by a 1994 Benefits Approach . . . . .	226
Table 7-5.	Summary Comparison of 1984 - 1994 Regulatory Approaches for Conventional Water Pollutants . . . . .	227
Table 7-6.	Benefit-Cost Analysis for the 11 Mills Affected by a 1994 Technology-Forcing Approach . . . . .	233
Table 7-7.	Benefit-Cost Analysis for the Seven Mills Affected by a 1994 Nondegradation Approach -- TSP . . . . .	237
Table 7-8.	Benefit-Cost Analysis for the 15 Mills Potentially Affected by a 1994 Benefits Approach -- TSP . . . . .	239
Table 7-9.	Summary Comparison of 1984 - 1994 Regulatory Approaches for TSP . . . . .	240
Table 7-10.	Benefit-Cost Analysis for Selected Mills with Increased TRS Emissions between 1984 and 1994 . . . . .	242
Table 7-A-1.	Mill Specific TRS Benefit and Cost Estimates for 1984-1994 . . . . .	248
Table 8-1.	Risk Assessment for Ingestion of Fish Contaminated with 2,3,7,8-TCDD . . . . .	256
Table 8-2.	Evaluation of Alternative Approaches to Regulating Dioxin as a Toxic Water Pollutant . . . . .	260
Table 8-3.	Summary of Pulp Mills with Chloroform as a Toxic Air Pollutant . . . . .	265
Table 8-4.	Evaluation of Alternative Approaches to Regulating Chloroform as a Toxic Air Pollutant . . . . .	268

Table 8-5.	Summary Data on Pulp Mills with Potentially Hazardous Waste Pollutants . . . . .	273
Table 8-6.	Evaluation of Alternative Approaches to Regulating Chloroform as a Hazardous Waste . . . . .	274
Table 8-A-1.	Pulp Mills in the TOX Analysis. . . . .	283
Table 8-C-1.	Process Modification Costs to Model Mills with Existing Bleach Plant Sequences . . . . .	291
Table 8-D-1.	Costs of Hypochlorite Elimination . . . . .	293
Table 8-E-1.	Annual Costs Used in Evaluating Alternative Regulatory Approaches for Chloroform as a Hazardous Waste. . . . .	295
Table 9-1.	Benefits and Costs Attributable to the Three Approaches --1973-1984 . . . . .	298
Table 9-2.	Benefits and Costs Attributable to the Three Compliance Strategies . . . . .	300
Table 9-3.	Benefits and Costs Attributable to the Three Approaches to Industrial Growth . . . . .	301
Table A-1.	Pulp, Paper and Paperboard Capacity -- 1973, 1984, and 1994 . . . . .	313
Table A-2.	Unit Pollutant Factors by Illustrative Subcategory and Pollution Control . . . . .	325
Table A-3.	Estimated Discharges to the Environment by the Pulp and Paper Industry -- 1973 and 1984 . . . . .	329
Table B-1.	Mills Evaluated in the Study . . . . .	331
Table C-1.	Inflation Indexes . . . . .	343

## FIGURES

Figure 3-1.	Framework for Benefit-Cost Analysis of the Clean Water Act Technology-Based Standards . . . . .	28
Figure 3-2.	Simplified Flowchart of the Cost of Clean Model -- Water . . . . .	31
Figure 3-3.	Map of Pulp & Paper Mills Included in the Water Analysis . . . . .	37
Figure 3-4.	Comparison of Dilution Ratios between Sample Mills and All Mills . . . . .	38
Figure 3-5.	Water Quality Impacts on Stream Usage . . . . .	40
Figure 3-6.	Potential Recreation Activities With and Without the Clean Water Act . . . . .	43
Figure 3-7.	Distribution of Households Around Mills . . . . .	51
Figure 3-F-1.	Streamflow Representation Used in This Study . . . . .	80
Figure 3-G-1.	Dissolved Oxygen Change 1973 - 1984 . . . . .	84
Figure 4-1.	Framework for Benefit-Cost Analysis of the Clean Air Act Ambient-Based Standards . . . . .	94
Figure 4-2.	Simplified Flowchart of the Cost of Clean Model -- TSP . . . . .	97
Figure 4-3.	Map of Kraft Pulp Mills Included in the Air (TSP) Analysis . . . . .	103
Figure 4-4.	Pollution Dispersion around the Union Camp Mill . . . . .	104
Figure 4-5.	Air Quality around 60 Mills With and Without the Clean Air Act . . . . .	107
Figure 4-6.	Comparison of Exposure Change Profiles . . . . .	112
Figure 4-7.	Comparison of Population Profiles . . . . .	117
Figure 5-1.	Framework for Benefit-Cost Analysis of Clean Air Act Benefits-Based Standards . . . . .	154
Figure 5-2.	Simplified Flowchart of the Cost of Clean Model -- TRS . . . . .	157
Figure 5-3.	Map of Kraft Pulp Mills Included in the Air (TRS) Analysis . . . . .	161
Figure 5-4.	Number of Days Around 60 Mills with Estimated Concentrations Greater than 0.005 mg/m <sup>3</sup> . . . . .	165

Figure 6-1.	Water Quality Impacts and Compliance Costs for the 49 Non-Complying Mills Identified by the Cost of Clean Model . . . . .	190
Figure 6-2.	Air Quality Impacts and Compliance Costs for the 17 Non-Complying Mills Identified by the Compliance Data System . . . . .	201
Figure 7-1.	Water Quality Impacts and Pollution Reduction Costs for the 176 Mills Affected by a 1994 Technology-Forcing Water Policy . . . . .	217
Figure 7-2.	Water Quality Impacts and Pollution Reduction Costs for the 60 Mills Potentially Affected by a 1994 Antidegradation Policy . . . . .	222
Figure 7-3.	Air Quality Impacts and Pollution Reduction Costs for the 59 Mills Affected by a 1994 Technology-Forcing Policy for TSP . . . . .	231
Figure 7-4.	Air Quality Impacts and Pollution Reduction Costs for the 54 Mills Potentially Affected by a 1994 Non-Degradation Approach for TSP . . . . .	235
Figure 8-1.	TOX Discharges for 103 Bleached Kraft Mills . . . . .	251
Figure 8-2.	Percentages of Mills Violating In-Stream Dioxin Standards . . . . .	254
Figure A-1.	Location of Pulp and Paper Mills Operating in 1984	314
Figure A-2.	Pulping and Papermaking Processes and Sources of Wastes . . . . .	317