THE COSTS OF WATER POLLUTION CONTROL IN THE CHESAPEAKE BAY DRAINAGE BASIN

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INTRODUCTION AND SUMMARY OF RESULTS CHAPTER 1

BACKGROUND

The U.S. Environmental Protection Agency's Office of Water (OW) is conducting a retrospective analysis of the costs and benefits related to water quality policies initiated over the last 25 years. The results of this national assessment will allow policy-makers to better understand the effectiveness of past programs and inform future policy-making decisions concerning water pollution control. As part of the national assessment, OW is conducting case studies of the costs and benefits of water pollution control for specific water bodies. In previous case studies, OW analyzed the upper Mississippi and lower Potomac Rivers, as well as the Willamette River basin in Oregon, all freshwater sites.[1] This report presents an assessment of water quality improvements in an estuarine setting, characterizing the costs of water quality improvements in the Chesapeake Bay drainage basin attributable to pollution control programs that went into effect between 1972 and 1997.[2]

The scope of this analysis includes the entire Chesapeake Bay drainage basin, which is illustrated in Exhibit 1-1. This watershed covers approximately 64,000 square miles and portions of six states, including Maryland, Virginia, Pennsylvania, New York, West Virginia, and Delaware, as well as the District of Columbia. Approximately 15 million people live within the watershed. Three major tributaries, the Susquehanna, Potomac, and James Rivers, drain approximately 49,000 square miles, or 76 percent, of the Chesapeake basin.

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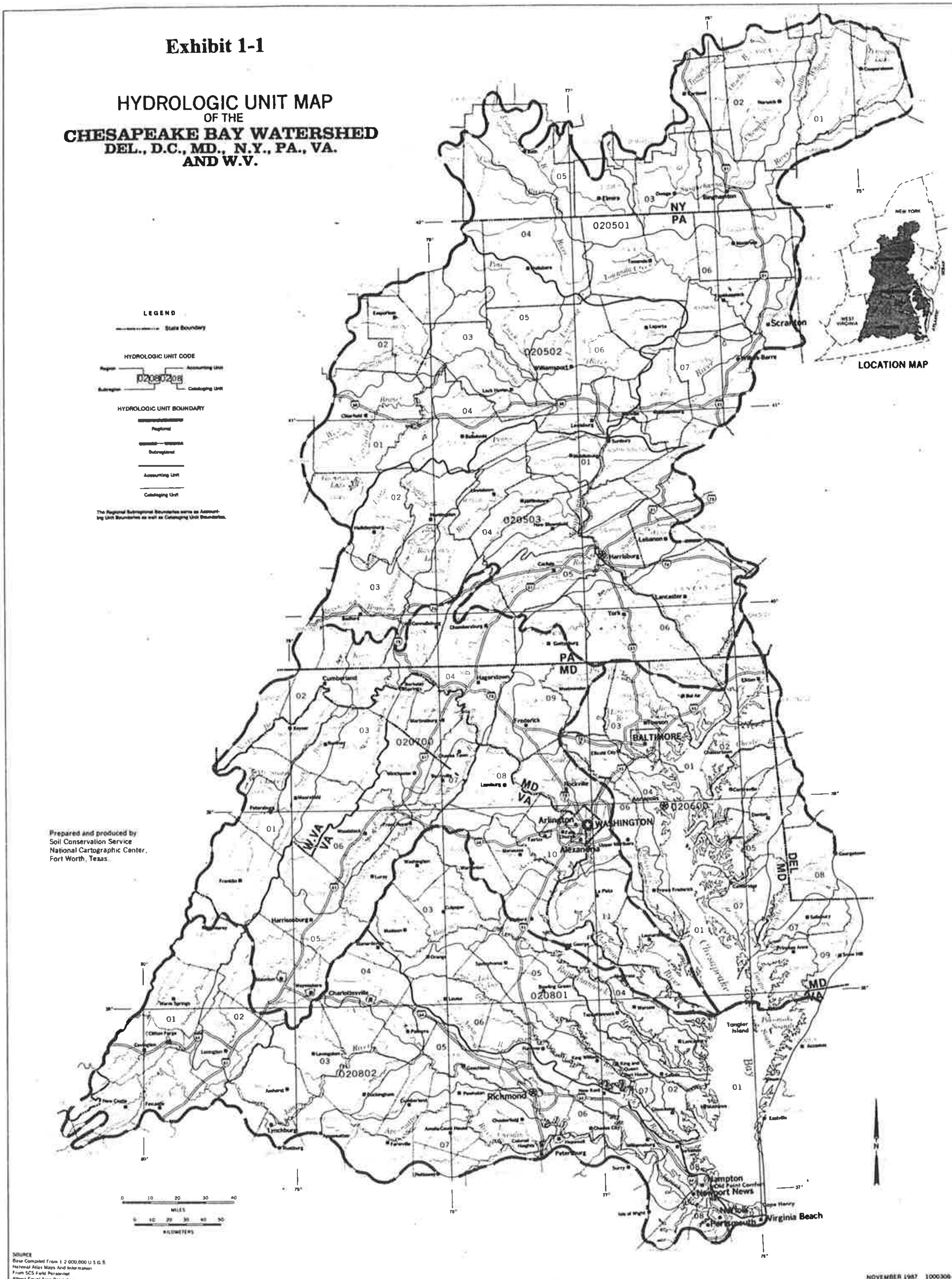
[1] Industrial Economics, Incorporated (IEc), *The Costs and Benefits of Municipal Wastewater Treatment: Upper Mississippi and Potomac River Case Studies*, Prepared for U.S. Environmental Protection Agency (EPA) Office of Water and Tetra Tech, Incorporated, August 1995; and IEc, *The Costs and Benefits of Water Quality Improvements In Oregon's Willamette Valley,* Prepared for Research Triangle Institute under a grant from EPA Office of Water, December 1997.

[2] The benefits component of this assessment will be completed by OW at a later date.

Exhibit 1-1



USDA, NRCS, NATIONAL CARTOGRAPHY & GEOSPATIAL CENTER, FORT WORTH, TX,1997

OVERVIEW OF ANALYTIC APPROACH

The analysis focuses on both point and nonpoint sources of discharge to the Chesapeake Bay and its tributaries. Point sources examined include municipal wastewater treatment plants and industrial facilities. Our examination of nonpoint sources considers agricultural and forest runoff, as well as urban stormwater and other runoff.

- **Municipal Wastewater Treatment Facilities.** According to EPA's Chesapeake Bay Program Office (CBPO), there were 476 active facilities operating in 1997 within the basin, generating total wastewater flows of nearly 1,700 million gallons per day (mgd). In response to the Clean Water Act and other federal and state initiatives, including the Chesapeake Bay Agreement, these facilities have undergone significant capital improvements over the last 25 years. This analysis estimates the incremental increase in annual capital and operations and maintenance (O&M) expenditures attributable to these improvements.

- **Industrial Facilities.** The CBPO data also indicate that in 1997 approximately 51 large industrial facilities discharged treated wastewater directly into Chesapeake Bay tributaries, with total daily flow from these facilities equaling approximately 480 mgd. In addition, numerous facilities pretreat their wastewater prior to discharge to municipal treatment facilities. As with municipal treatment facilities, this analysis considers the incremental increase in total annual capital and O&M costs incurred by both direct discharge and pretreatment facilities as a result of pollution control initiatives promulgated during the study period.

- **Nonpoint Sources.** The nonpoint sources addressed in this analysis include runoff from agricultural lands, urban stormwater flows, and erosion associated with forestry. As a result of the Clean Water Act and, in particular, the Chesapeake Bay Agreement, jurisdictions within the basin encouraged or required landowners to implement a range of best management practices (BMPs) to mitigate nonpoint source runoff. These include BMPs focusing on changing certain land use practices, such as replacing conventional tillage with conservation tillage, as well as specific structural improvements, such as cultivating grassed filter strips to trap and absorb runoff. We estimate total annual capital and O&M costs related to these initiatives.

To calculate the incremental costs attributable to the Clean Water Act and other pollution control initiatives for each discharge source, we develop estimates of both total costs and "baseline" costs, or costs that likely would have been incurred in the absence of these initiatives. The difference between these two estimates represents the "net" or incremental annual cost. It is important to note that to calculate net costs we compare 1997 actual costs with 1997 baseline costs; that is, we assume the same level and spatial distribution of human activities, as well as municipal and industrial wastewater flow volume, under both scenarios. This approach ignores how population patterns and the distribution of facilities may have been affected by the Clean Water Act and other policies over the study period. We employ this approach because it allows EPA to link the cost assessment with the Agency's Chesapeake Bay water quality models and, ultimately, the benefits assessment.[3] It is important to note, however, that, due to limitations in both methodology and data, the correlation of the cost analysis, water quality models, and benefits assessment will be less than exact. For example, this cost analysis considers total compliance costs for all facilities in the basin and for all pollutants (i.e., nutrients and toxics). In contrast, EPA's Chesapeake Bay models focus on water quality impacts from nutrient loadings to the bay and tidal portions of rivers and streams, ignoring loading impacts from certain small municipal and industrial facilities, particularly in upstream areas. In addition, the models would not directly capture the water quality effects of toxics loadings from small industrial direct dischargers in the basin, while this analysis does capture related treatment costs for these facilities. The benefits assessment will primarily rely on water quality outputs from these models to generate estimates of benefits from improved water quality. As a result, the benefits assessment will likely yield benefits estimates that are understated relative to the cost estimates presented in this report.

It is also important to recognize that this analysis focuses on direct compliance costs related to water pollution control initiatives promulgated over the study period. We are therefore implicitly assuming that these estimates represent a reasonable proxy for true social costs. This distinction is relevant because the related benefits assessment will focus on the estimation of "social" benefits from improved water quality. A full social cost analysis would involve estimating changes in producer and consumer surplus in directly-affected markets (i.e., a partial equilibrium analysis) or changes in the total output of the national economy (i.e., a general equilibrium analysis) resulting from these initiatives. The complexity of these approaches is beyond the scope of this analysis. In addition, it is unclear whether a general or partial equilibrium approach would yield sufficiently superior results to justify the increased commitment of resources.[4]

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[3] Also note that this analysis focuses exclusively on wastewater treatment and BMP costs. It does not include costs incurred to reduce atmospheric deposition of nutrients and other pollutants. The related benefits assessment will also exclude any water quality benefits resulting from reduced levels of atmospheric deposition. This approach allows EPA to estimate the costs and benefits of water pollution control only, and avoids double counting the impacts related to air pollution control initiatives.

[4] In general, a direct compliance cost approach is likely to overstate true social costs because it does not account for market adjustments. On the other hand, we exclude certain implementation costs in this analysis (the costs to administer and enforce these programs, for example) that may serve to temper any upward bias.

The methods we employ to estimate these costs and the results of the analysis are discussed in detail in the following chapters. We summarize the results below.

SUMMARY OF WATER POLLUTION CONTROL COSTS

Exhibit 1-2 summarizes our estimates of costs associated with water pollution control in the Chesapeake basin. Since 1972, investments to improve water quality have been substantial, with net annual costs equaling approximately $1.0 to $1.3 billion. This range represents the incremental increase in annual O&M and capital costs incurred by both the private and public sector to comply with the Clean Water Act and other pollution control initiatives. The analysis suggests municipal wastewater treatment facilities made the largest investments, expending between $706 and $884 million on an annualized basis over the study period. Industrial facilities experienced annual cost increases of $272 to $320 million. The analysis also suggests that BMP initiatives within the basin cost between $99 and $124 million per year.

Exhibit 1-2

SUMMARY OF ANNUAL POLLUTION CONTROL EXPENDITURES IN THE CHESAPEAKE BASIN (millions $1997)

Discharge Source	Net Annual Costs	
	Lower	Higher
Municipal Treatment Facilities	$706	$884
Industrial Treatment Facilities	$272	$320
Nonpoint Source BMPs	$99	$124
TOTAL	**$1,077**	**$1,328**

Notes:
1. Lower and higher bound values represent total costs annualized using a discount rate of two and seven percent, respectively.
2. Columns may not sum to exact totals reported due to rounding error.

Exhibit 1-3 presents the total and baseline annual costs incurred by each of the three discharge sources under analysis. For all three sources, total annual costs equal approximately $1.6 to 2.0 billion, with baseline costs representing 33 percent of the total. Municipal sources incur the largest total annual costs, expending between $1.0 and 1.3 billion, $308 to $370 million of which represent baseline annual costs. Industrial facilities incur total annual costs that are approximately half those of municipal facilities, with baseline costs representing a greater share of the total, (46 to 30 percent). Note also that we report baseline costs of zero for nonpoint source BMPS; we assume that all costs associated with nonpoint source control are a result of post-1972 water pollution control initiatives.

Exhibit 1-3 TOTAL AND BASELINE COSTS BY DISCHARGE SOURCE (millions $1997)					
Discharge Source		**Total Annual Costs**	**Baseline as % of Total**	**Baseline Annual Cost**	**Net Annual Cost**
Municipal	Lower	$1,013	30%	$308	$706
	Higher	$1,254	30%	$370	$884
Industrial	Lower	$507	46%	$235	$272
	Higher	$600	46%	$280	$320
Nonpoint	Lower	$99	0%	$0	$99
	Higher	$124	0%	$0	$124
TOTAL	Lower	$1,619	33%	$543	$1,077
	Higher	$1,978	33%	$650	$1,328

Notes:
1. Lower and higher bound values represent total costs annualized using a discount rate of two and seven percent, respectively.
2. Columns may not sum to exact totals reported due to rounding error.

Exhibit 1-4 summarizes net annual costs incurred by each discharge source for each state in the Chesapeake basin. As the exhibit shows, Virginia, Maryland, Pennsylvania, and the District of Columbia account for 96 percent of the basin's net municipal wastewater treatment costs. These jurisdictions also account for 93 percent of net annual nonpoint costs. Finally expenditures by facilities in Maryland, Virginia, and Pennsylvania represent approximately 93 percent of net industrial water pollution control costs within the basin.

Exhibit 1-4

NET ANNUAL COSTS FOR ALL COST CATEGORIES, BY STATE
(millions $1997)

Basin State	Municipal		Industrial		Nonpoint		Total	
	Lower	**Higher**	**Lower**	**Higher**	**Lower**	**Higher**	**Lower**	**Higher**
Delaware	$1	$1	$7	$8	$1	$2	$9	$11
District of Columbia	$145	$176	N/A	N/A	$2	$2	$147	$177
Maryland	$168	$221	$111	$128	$45	$57	$324	$406
New York	$23	$31	$7	$8	$11	$12	$41	$51
Pennsylvania	$168	$213	$54	$65	$6	$9	$228	$287
Virginia	$197	$239	$88	$106	$33	$41	$318	$386
West Virginia	$2	$3	$5	$6	$1	$1	$8	$10
TOTAL	**$706**	**$884**	**$272**	**$320**	**$99**	**$124**	**$1,077**	**$1,328**

Notes:
1. Industrial cost data for the District of Columbia are unavailable because of the small number of relevant facilities. Available O&M data suggest that industrial expenditures (capital and O&M) within DC are minor.
2. Lower and higher bound values represent total costs annualized using a discount rate of two and seven percent, respectively.
3. Columns may not sum to exact totals reported due to rounding error.

REPORT STRUCTURE

The following chapters discuss our assessment of point and nonpoint source water pollution control costs in greater detail.

- **Chapter 2** presents our analysis of the costs of water pollution control at municipal treatment plants located within the Chesapeake Bay drainage basin.

- **Chapter 3** presents our analysis of water pollution control costs at industrial facilities within the basin, including both direct dischargers and industrial pre-treatment facilities.

- **Chapter 4** examines the costs of BMPs implemented within the basin.

CHAPTER 1 REFERENCES

Industrial Economics, Incorporated (IEc), *The Costs and Benefits of Municipal Wastewater Treatment: Upper Mississippi and Potomac River Case Studies*, Prepared for U.S. Environmental Protection Agency (EPA) Office of Water and Tetra Tech, Incorporated, August 1995.

Industrial Economics, Incorporated (IEc), *The Costs and Benefits of Water Quality Improvements In Oregon's Willamette Valley*, Prepared for Research Triangle Institute under a grant from U.S. Environmental Protection Agency (EPA) Office of Water, December 1997.

COSTS OF WATER POLLUTION CONTROL AT MUNICIPAL TREATMENT PLANTS **CHAPTER 2**

INTRODUCTION

This chapter discusses the costs of improved and expanded wastewater treatment at publicly-owned treatment works (POTWs) operating within the Chesapeake Bay drainage basin. After the passage of the Clean Water Act in 1972 and the subsequent initiation of the Federal Construction Grants Program, state and local entities spent billions of dollars to upgrade technology and expand capacity at these facilities. Investments in improved treatment are continuing through the State Revolving Fund (SRF) loan program and other initiatives. This case study focuses on the capital and operations and maintenance (O&M) expenditures made as a result of these initiatives from 1972 through 1997.

The chapter contains three sections. First, we summarize the regulatory history behind increased investment in water pollution control over the study period and describe the location and size of POTWs located within the Chesapeake Bay basin. The second section outlines the analytic approach we employ to derive cost estimates for these investments and discusses related uncertainties. The third section provides the results of the analysis.

BACKGROUND

The U. S. Congress established the Construction Grants Program in 1972 to provide local governments with funding for the construction of public wastewater treatment facilities as required under the newly enacted Clean Water Act. During the 1970s and 1980s, the federal government provided more than $60 billion of non-repayable grants nationwide under this program.[1] In addition, the Construction Grants Program required states and municipalities to match a proportion of the federal grants with their own funds. This cost share proportion equaled

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[1] U.S. Environmental Protection Agency, "Construction Grants Overview," obtained from: http://www.epa.gov/enviro/html/gics/gics_cg1.html, July 8, 1998.

25 percent of total grant awards from 1972 through 1983, and 45 percent of total awards after 1983.[2]

The 1987 amendments to the Clean Water Act established 1990 as the last year for the appropriation of Construction Grant funding and authorized the creation of the State Revolving Fund (SRF) loan program. With the phase-out of the Construction Grants Program, the SRF has become the principal funding source for construction of wastewater treatment projects nationwide. All 50 states and Puerto Rico have established SRFs, which provide communities with low-interest loans to finance pollution control investments. To date, total capitalization of the SRF program is more than $20 billion.[3]

EPA's Chesapeake Bay Program Office maintains an inventory of 476 active POTWs in the Chesapeake Bay basin, each of which has been affected by these pollution control programs. Exhibit 2-1 shows the location and size of these facilities by estimated daily flow. Estimated actual wastewater flow from these facilities in 1997 was 1,690 million gallons per day (mgd). Virginia POTWs generate the largest flow volume in the watershed (551 mgd), followed by Pennsylvania (387 mgd), Maryland (347 mgd), the District of Columbia (341 mgd), New York (58 mgd), West Virginia (5 mgd), and Delaware (2 mgd). Most of the facilities are relatively small, with 96 percent generating average flows of between zero and 20 mgd. These facilities generate approximately 48 percent of total daily flow in the basin, followed by facilities generating average flows of greater than 80 mgd (26 percent), 20 to 40 mgd (17 percent), and 40 to 80 mgd (9 percent).

In response to the Clean Water Act and other federal and state pollution control initiatives, POTWs within the Chesapeake Bay basin have undergone substantial capital improvements and expansions over the last 25 years. As a result of these investments, the cost to operate and maintain these facilities has also increased. The remainder of this chapter discusses our methods for estimating these capital and O&M costs and presents the results of the analysis.

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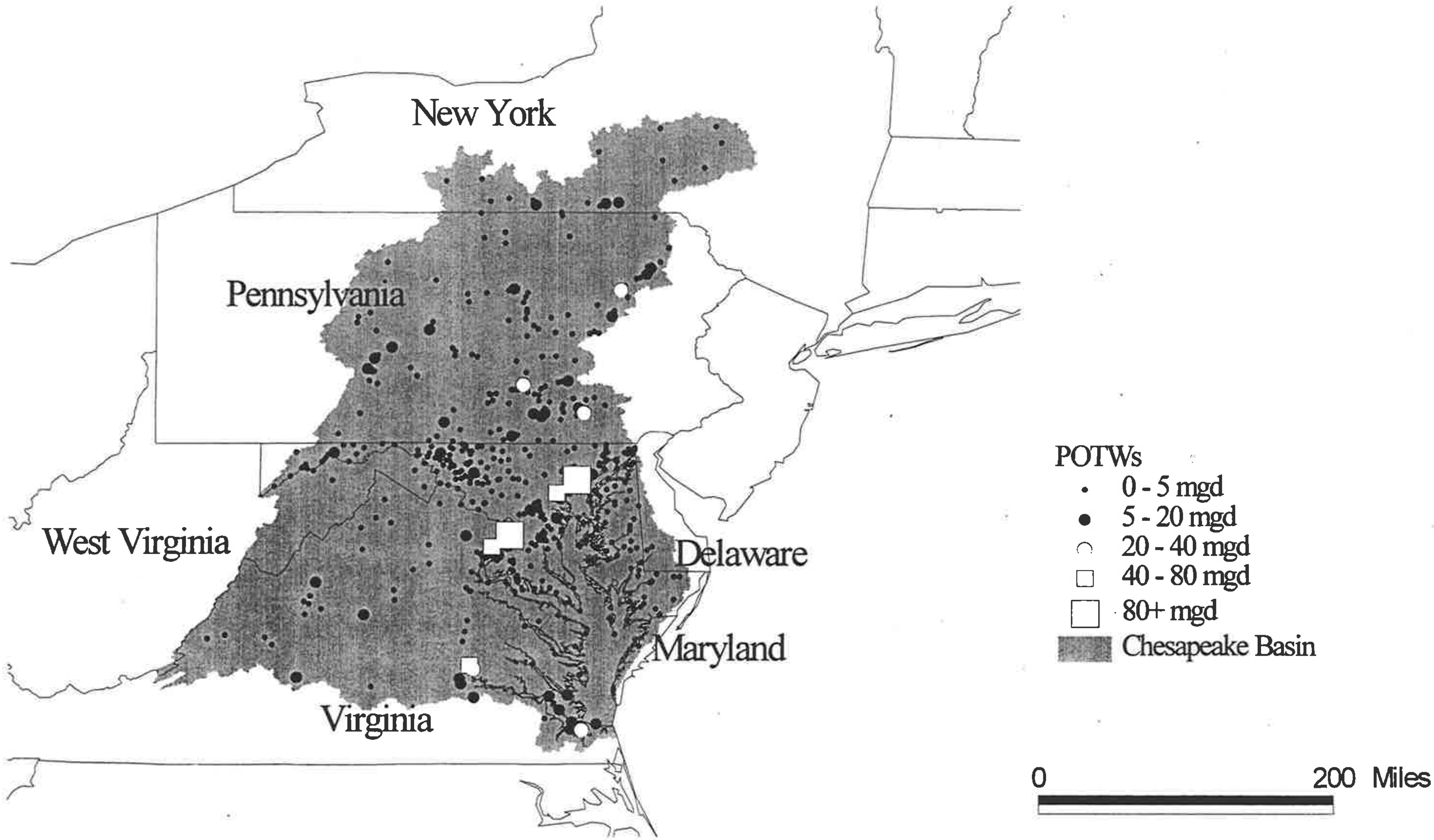
[2] Beginning in 1984, the U.S. Congress increased the cost share requirement for states and municipalities from 25 to 45 percent.

[3] U.S. Environmental Protection Agency, "State Revolving Fund System Overview," obtained from: http://mountain.epa.gov/enviro/html/gics/gics_sr1.html, July 8, 1998.

Exhibit 2-1

POTWs IN THE CHESAPEAKE BASIN



ANALYTIC APPROACH

Estimating the expenditures incurred by municipal wastewater treatment facilities related to pollution control regulations initiated over the last 25 years requires collecting data on both capital and operations and maintenance (O&M) costs. Exhibit 2-2 illustrates the methodology we employ to estimate total annual capital and O&M costs for each facility; we discuss the approach in detail below.

Estimating Capital Costs

As illustrated in the exhibit, the calculation of annual capital expenditures requires four steps: (1) developing estimates of capital expenditures occurring within the Chesapeake basin during the years 1972 through 1997; (2) deriving "baseline" capital expenditures; (3) estimating "net" capital costs; and (4) converting these net capital expenditures into an equivalent annualized cost.

Estimating Total Expenditures

Two potential approaches exist for developing estimates of capital expenditures. The first approach involves collecting Construction Grants data, SRF loan data, and other expenditure data for each facility in the basin over the study period. The second approach involves using engineering cost equations that employ facility size and treatment level information to derive an estimate of total construction costs for a particular facility. Due to the large number of facilities located within the study area and the incompleteness of the available data, the first approach is problematic. We therefore rely primarily on engineering cost equations to derive estimates of capital expenditures. To check the accuracy of this approach, we also analyze aggregated Construction Grants data for basin facilities and compare these figures to the results generated by the cost equations.

The wastewater treatment facility cost equations we employ in this analysis were developed by EPA as part of the Agency's "Needs Survey." These equations are provided in Exhibit 2-3. We then apply the appropriate equation to each POTW using the design flow and treatment level data contained in the Chesapeake Bay Program Office's inventory of POTWs located within the basin. Each facility in the inventory is placed in one of three treatment categories: secondary treatment, advanced treatment, or lagoon treatment. In addition, we employ the salvage cost deduction equation for existing primary treatment in our calculation of baseline capital expenditures (see later discussion). This approach allows us to develop facility-specific capital cost estimates based on facility size and treatment level. In particular, the cost equations should capture the higher costs incurred by certain facilities (e.g., Baltimore's Back River wastewater treatment facility) that have implemented advanced wastewater treatment, as well as total costs for all levels of government -- federal, state, and local.

Exhibit 2-2

METHODOLOGY FOR DEVELOPING POTW ANNUAL CAPITAL AND O&M COST ESTIMATES

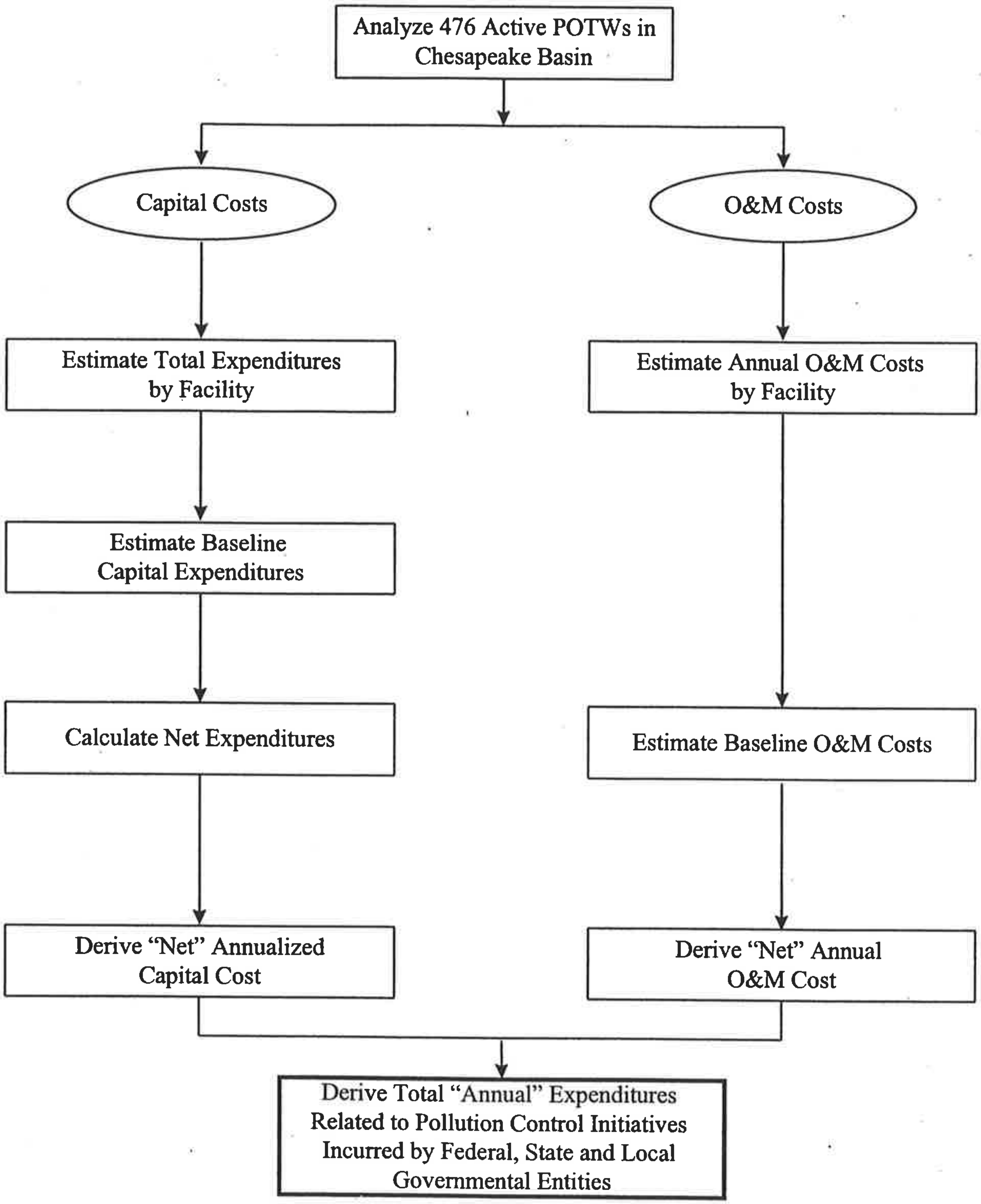


Exhibit 2-3

CAPITAL CONSTRUCTION COST EQUATIONS

Treatment Category	Cost Equations	Description
Secondary	$C_1 = 5.94*10^6Q^{0.754}$ $C_2 = 5.94*10^6Q^{1.923}$	Secondary treatment with nutrient removal
Advanced	$C_1 = 7.391*10^6Q^{0.830}$ $C_2 = 7.391*10^6Q^{2.131}$	Advanced treatment II with nutrient removal
Lagoon	$C_1 = 4.069*10^6Q^{0.660}$ $C_2 = 4.069*10^6Q^{1.563}$	Lagoon secondary treatment
Baseline -- Primary	$C = 1.766*10^6Q^{0.770}$	Deduction for existing primary treatment

Notes:
C is the cost in 1996 dollars for facilities with design flow greater than or equal to 0.35 mgd.
C_1 is the cost in 1996 dollars for facilities with design flow greater than or equal to 1.0 mgd.
C_2 is the cost in 1996 dollars for facilities with design flow greater than or equal to 0.35 mgd but less than 1.0 mgd.
Q equals facility design flow in mgd.

Source: EPA, *1996 Clean Water Needs Survey Manual*, October 1995, p. 12-41.

To confirm that the cost estimates generated by the cost equations are reasonable, we also collected information on Federal Construction Grants that were earmarked for wastewater treatment projects in the Chesapeake Bay basin. Specifically, we rely on data from EPA's Grants Information Control System (GICS). This database tracks all wastewater treatment grant projects awarded under the Construction Grants Program. Using the inventory of municipal facilities developed by EPA's Chesapeake Bay Office, we compiled GICS data for facilities in the basin, including total grant awards received and state matching amounts each year from 1972 through the end of the grants program.[4] Although these grant awards will not capture all expenditures made by facilities within the basin over the study period (the figures exclude SRF loan capitalizations, for example), they provide a useful means to corroborate the cost equation results.

Deriving Baseline Expenditures

Calculating the capital costs associated with the Clean Water Act and other pollution control initiatives also requires that we make certain assumptions concerning "baseline" costs, or costs that likely would have been incurred in the absence of these initiatives. Predicting the behavior of governmental entities, the regulated community, and the general public in the absence of these initiatives is difficult and, to a certain degree, subjective. The exercise is necessary, however, because it is likely that treatment facilities would have maintained the

[4] The GICS data were provided by Sandra Duncan of EPA's Office of Water, Office of Wastewater Management, Municipal Technology Branch.

capital stock in place prior to 1972 and engaged in some capital improvements and expansions (to address population growth, for example) without the subsequent promulgation of the Clean Water Act and other pollution control initiatives.

For the purposes of developing a baseline scenario in this analysis, we estimate the proportion of total capital expenditures incurred over the study period that are related to the construction or expansion of the primary treatment component of a secondary or advanced treatment facility. This proportion serves as a proxy for the capital costs necessary to maintain a removal efficiency equivalent to the treatment capabilities in place in 1972. We refer to this as the "constant removal efficiency" baseline.[5]

We calculated this proportion using the primary treatment salvage value equation developed for the Needs Survey (see Exhibit 2-3). This equation provides an estimate of the salvage value of existing primary treatment facilities when a facility is upgraded to secondary or advanced treatment. It also serves as a useful estimate of the capital costs related to the primary treatment component of more advanced treatment facilities. Applying this equation, baseline costs represent 17 to 33 percent of total capital costs yielded by the secondary, advanced, and lagoon treatment cost equations.[6] To calculate "net" capital costs incurred over the study period, we reduce total costs by these percentages.[7]

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[5] We recognize that certain facilities in the case study area did install secondary treatment capability prior to 1972; however, in many instances the capacity of these facilities was insufficient to handle increasing treatment demands and population growth, yielding an actual removal efficiency that was roughly equivalent to the primary treatment level.

[6] The range of percentages is dependent upon the treatment level of the facility. For example, costs to construct an advanced treatment facility are higher than costs for a secondary treatment facility, while baseline costs remain the same. As a result, baseline costs represent a higher proportion of total costs for a secondary treatment facility compared to an advanced treatment facility. The average baseline cost percentage across all facilities is 26 percent.

[7] To check the accuracy of this approach, we also estimated a baseline cost proportion using engineering cost data developed by EPA for the construction of municipal wastewater treatment plants (see U.S. Environmental Protection Agency, *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*, Office of Water, April 1980, page 31, EPA/430/9-80-003). We first considered the unit process costs related to the construction of primary treatment capabilities, which include the following process units: influent pumping, primary treatment, and primary sedimentation. We then compared these costs to total unit process construction costs of an activated sludge secondary treatment facility. Based on the EPA data, primary treatment construction costs represent approximately 20 percent of total construction costs, consistent with the range yielded by the application of the baseline cost curve.

Calculating Annualized Expenditures

The analysis of expenditures related to wastewater treatment improvements in the Chesapeake Bay basin is part of a broader analysis of the costs and benefits of water quality improvements in the region. Benefits will be estimated on an annual basis (i.e., dollars per year). To compare these benefits with pollution control costs, we must convert net investments in new plant and equipment over the study period into an equivalent annual cost. The calculation of annualized costs involves three steps: (1) estimating the useful life of the capital expenditures and selecting appropriate discount rates; (2) converting yearly capital expenditures into nominal "annuity equivalents;" and (3) adjusting nominal figures for all costs to 1997 dollars.

We annualize POTW capital costs over a useful life of 30 years. Although differences in plant-specific improvements, maintenance policies, and equipment and infrastructure lives make it difficult to estimate a single replacement cycle for these expenditures, EPA and plant officials indicate that 30 years represents a reasonable weighted average of the useful life of all facility components. Plant infrastructure, for example, may last 40 or 50 years before it needs replacement, while the machinery and systems required to treat wastewater may have shorter lifespans of 15 to 30 years.[8]

According to Circular A-94, issued by the U.S. Office of Management and Budget (OMB), "benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real interest rate of seven percent."[9] The Circular also notes that analyses should show the sensitivity of discounted net present values to variations in the discount rate. In this analysis, we annualize capital investments using real discount rates of two and seven percent. The seven percent rate represents the real rate of return of private investments. The two percent estimate is based on the Congressional Budget Office's (CBO)

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[8] See, for example, Massachusetts Water Resources Authority (MWRA), "Proposed Capital Improvement Program, Fiscal Years 1998 - 2000." December 30, 1996, p. C-1. Note that the appropriate period for annualizing capital costs is a facility's "useful" life, or the period during which a facility actually operates, as opposed to "design" life, which refers to a planning period for sizing POTWs that is specified in the Clean Water Act. Specifically, the Act requires facility construction and expansion grants to be funded based on a 20 year design life, allowing for sufficient reserve capacity to accommodate population and flow increases for 20 years (see U.S.C. § 1284 (b)(4)(c); Federal Water Pollution Control Act). As a result, studies related to construction grant awards commonly annualize capital costs over a 20-year period. Based on our review of the available literature and interviews with facility managers, the actual useful life of a POTW is likely to be longer than 20 years, and potentially as high as 40 years. For example, MWRA assumes a useful life of 40 years for wastewater treatment facilities, and the following distribution of useful lives by type of capital component: equipment (15 years); cathodic protection (15 years); control valves, pipeline, relief sewer, pump station (40 years); wastewater treatment facility structure (40 years); tunnels (100 years).

[9] Office of Management and Budget, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Circular No. A-94, October 29, 1992.

recommendation that for analyses involving government investment projects, the discount rate should reflect the long-run real rate of return on government securities, which the CBO estimates to be two percent.[10] For purposes of consistency, and to illustrate a range of results generated by different discount rates, we use these two rates for municipal, industrial, and nonpoint investments.

To convert net capital expenditures into annualized values, we calculate "annuity equivalents." An annuity is a stream of constant payments over a finite period of time. By converting capital costs into an equivalent annuity, we effectively annualize these costs. This calculation employs the capital expenditure figure for a given facility, its assumed lifespan, and appropriate discount rate.[11]

To inflate nominal capital costs to 1997 dollars, we use the *Chemical Engineering* Plant Cost Index, an index that reflects changes in the prices of items used in construction, including building materials, equipment, and construction labor. The yearly index values are detailed in Appendix 2-A.

Estimating Operations and Maintenance Costs

The other major category of POTW expenditures is operations and maintenance (O&M) costs. Major components of O&M costs include salaries for treatment facility staff, routine maintenance and replacement of equipment, and materials for treatment and disinfection processes. In this analysis, we employ actual facility flow data from the Chesapeake Bay POTW inventory and apply unit O&M cost figures (i.e., dollars per mgd of flow) to derive total annual O&M cost estimates for each facility. From these amounts, we then subtract annual O&M costs related to primary treatment at these facilities to derive net annual O&M costs attributable to pollution control initiatives promulgated over the study period. The steps in this process are described below.

Estimating Annual O&M Costs

The estimation of annual O&M costs for the facilities in the Chesapeake basin relies on two primary inputs: (1) actual annual flow and treatment level data for each facility; and (2) unit

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[10] Robert W. Hartman, "One Thousand Points of Light Seeking a Number: A Case Study of CBO's Search for a Discount Rate Policy," *Journal of Environmental Economics and Management*, vol. 18, pp. 53-57, 1990.

[11] The annualized cost is calculated as follows:

$$\text{Annualized Capital Expenditure} = \text{Total Capital Expenditures} * \frac{r}{1-1/(1+r)^t},$$

where r = discount rate and t = useful life.

O&M costs, in dollars per mgd treated, collected through a survey conducted by the Association of Metropolitan Sewerage Agencies (AMSA).[12] We present our unit O&M cost estimate for each facility size category in Exhibit 2-4. To develop the unit cost estimates, we calculated median O&M unit costs, by facility size category, for 100 facilities nationwide responding to the 1996 AMSA survey.[13] As the exhibit shows, unit O&M costs are lower for larger treatment facilities, suggesting larger facilities realize some economies of scale in the treatment process.

The AMSA data also suggest that O&M costs vary by treatment level. For example, an advanced wastewater treatment facility incurs higher O&M costs relative to a secondary treatment facility. To capture treatment level effects on costs, we first calculated median treatment costs for all facilities (secondary and advanced) across all size categories. We then calculated median costs for advanced wastewater treatment and median costs for secondary treatment across all facility size categories. Based on these comparisons, we then developed scalar values to derive costs for advanced and secondary treatment. The survey data suggest that, compared to median costs for all types of secondary and advanced treatment facilities, median O&M costs related to advanced treatment are 18 percent higher, while O&M costs for secondary treatment are 5 percent lower. We apply these scalars as appropriate using treatment level data in the Chesapeake Basin facility inventory.

To inflate O&M costs to 1997 dollars, we apply the Gross Domestic Product (GDP) deflator. This inflation index best captures changes in the types of costs included in O&M activities. The yearly index values are detailed in Appendix 2-A.

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[12] The flow and treatment level data are contained in a database of facilities located within the Chesapeake basin developed and maintained by EPA's Chesapeake Bay Program Office. Unit O&M cost data were derived from information contained in: Association of Metropolitan Sewerage Agencies, *The AMSA Financial Survey, 1996*, Washington, DC. We employ the figures presented in the 1996 survey, which is AMSA's most recent, because they likely represent the closest approximation to unit O&M costs required to operate and maintain the total capital stock constructed during the study period.

[13] The number of facilities within the Chesapeake basin that responded to the survey was too small to generate a sufficient sample for estimating costs specific to the basin. In addition, we employ median values, as opposed to mean values, because the number of facilities responding to the AMSA survey within each facility size category was relatively small. As a result, mean O&M costs were significantly affected by O&M figures for specific facilities that were much higher or lower relative to the majority of facilities. Given these factors, median O&M costs from the AMSA survey likely represent a better measure of the central tendency of O&M costs for facilities within the basin.

Exhibit 2-4 UNIT O&M COST ESTIMATES (per mgd, $1997)			
Facility Size (mgd)	**Median O&M Cost For All Facilities**	**O&M Cost for Secondary Treatment Facilities (scalar = 0.95)**	**O&M Cost for Advanced Treatment Facilities (scalar = 1.18)**
0.0 - 20.0	$1,219	$1,157	$1,441
20.1 - 40.0	$1,166	$1,107	$1,378
40.1 - 80.0	$1,012	$961	$1,196
> 80.0	$931	$884	$1,100
Note: Scaled values may not be exact due to rounding. Sources: AMSA, *The AMSA Financial Survery, 1996.* IEc analysis.			

Deriving Baseline O&M Expenditures

To estimate net O&M costs related to pollution control initiatives occurring during the study period, we develop a baseline expenditure scenario consistent with the approach used for capital costs. The unit O&M cost figures cited above represent costs related primarily to the operation and maintenance of secondary or advanced treatment facilities. To derive baseline O&M costs attributable to the primary treatment component, we employ data developed by EPA concerning O&M costs for municipal wastewater treatment systems.[14] Based on these data, O&M costs for a primary treatment facility equal approximately 40 percent of total O&M costs at an activated sludge secondary treatment plant, and approximately 22 percent of total O&M costs at an advanced wastewater treatment plant. We apply these percentages as appropriate to calculate net O&M costs, reducing total O&M costs by 40 percent at secondary treatment facilities and by 22 percent at advanced treatment facilities.[15]

[14] U.S. Environmental Protection Agency, *Analysis of Operations & Maintenance Costs for Municipal Wastewater Treatment Systems*, Office of Water, May 1978, pp. 4-35 - 4-47, 430/9-77-015.

[15] These proportions are also consistent with the constant removal efficiency baselines developed for the Mississippi and Potomac River case studies. Based on interviews with plant managers at these facilities and EPA officials, we reduced total annual O&M costs by 25 percent in the Mississippi River case study and 28 percent in the Potomac River case study to account for baseline expenditures necessary to operate the capital stock in place in 1972 at a constant removal efficiency. The facilities that were the focus of these studies are both advanced treatment facilities.

Uncertainties

Our estimates of municipal wastewater treatment costs are subject to several uncertainties. Concerning capital costs, our primary uncertainties relate to gaps in treatment level data and design flow designations for basin facilities, which affects the accuracy of the capital cost equation approach. In addition, our application of capital cost equations for very small and very large facilities may bias the results.

- **Gaps in treatment level data.** We lack data on the treatment technologies employed at 179 facilities in the basin, representing approximately 24 percent of total daily flow from all 476 facilities included in this analysis. In instances where treatment level data for a facility are not available, we apply the secondary treatment cost equation to estimate capital costs, since most facilities in the basin treat wastewater to at least a secondary level. To the extent that these facilities actually employ advanced treatment, this approach may yield cost estimates that are slightly lower than actual costs.

- **Gaps in design flow data.** We lack design flow data for 20 facilities in the basin, representing less than one percent of total daily flow from all facilities. For facilities lacking design flow information, we use actual flow figures as inputs to the cost equations. Since actual flow is generally lower than design flow, we likely underestimate capital costs for these facilities. Given the small proportion of total flow involved, however, the impact of this limitation on the total cost estimates is very small.

- **Cost equation application for small facilities.** 188 facilities in the inventory, generating less than one percent of total basin flow, have design flows of less than 350,000 gallons per day. The capital cost equations are less accurate for such facilities. To circumvent this problem, we summed the daily flows of these facilities to generate a combined facility flow of greater than 0.35 mgd and then applied the relevant cost equation. Although this approach likely understates total construction costs for these facilities, these costs represent a miniscule proportion of total construction costs incurred by all facilities in the basin.

- **Cost equation application for large facilities.** Finally, the cost equations are less accurate for facilities with design flow larger than 25 mgd, which require a larger number of customized components. The database contains 16 of these facilities, representing 55 percent of total daily basin flow. Our application of the generalized cost equations in such instances may under- or overstate total construction costs incurred by these facilities.

While these limitations suggest that our total capital cost estimates may be understated, EPA officials suggest the cost equations on average yield cost estimates that are slightly overstated.[16] Overall, therefore, the equations may yield facility-specific cost estimates that are over- or understated. The magnitude of the potential error, however, is unclear.

The lack of treatment level data for all facilities also affects our estimation of O&M costs. As with capital costs, in instances where treatment level data are unavailable, we employ the unit O&M cost estimates related to secondary treatment, which likely yield cost estimates that are slightly lower than actual costs. In addition, the unit O&M cost estimates we employ were derived from a relatively small sample of facilities located across the country, and only a few located within the Chesapeake basin. To the extent the costs faced by these facilities vary significantly from those faced by basin facilities, we may over- or understate total O&M costs in this analysis.

RESULTS

Exhibit 2-5 summarizes annual capital and O&M cost estimates for municipal facilities located within the Chesapeake Bay basin. As illustrated in this exhibit, the analysis yields net annual capital and O&M costs attributable to water pollution control investments made over the study period of $706 to $884 million. This range represents the sum of costs incurred by federal, state, and local governmental entities. Capital costs equal approximately 31 percent of lower bound total costs and 45 percent of higher bound costs. These results are discussed in greater detail below.

Exhibit 2-5

SUMMARY OF POLLUTION CONTROL EXPENDITURES BY MUNICIPAL FACILITIES IN THE CHESAPEAKE BASIN (millions $1997)

Cost Category	Lower	Higher
Net Annualized Capital	$222	$401
Net Annual O&M	$484	$484
TOTAL ANNUAL COSTS	**$706**	**$884**

Notes:
1. Totals may not sum due to rounding.
2. Lower and higher bound figures represent total net costs annualized using discount rates of two percent and seven percent, respectively.

[16] Personal communication with Leonard Fitch, EPA Office of Water, September 1, 1998.

Annualized Capital Costs

As shown in Exhibit 2-6, we estimate that capital costs related to the construction of facilities operating within the Chesapeake Basin total more than $6.7 billion. In addition, the analysis suggests that approximately 26 percent of these costs are attributable to baseline costs, yielding net capital costs of nearly $5.0 billion. Annualizing this amount using discount rates of two and seven percent yields a range of net annualized capital costs from $222 to $401 million. Costs by basin state are correlated with statewide treatment flows, with POTWs located in Maryland, Pennsylvania, and Virginia incurring the majority of capital costs.

Exhibit 2-6

CAPITAL COSTS FOR CHESAPEAKE BASIN MUNICIPAL FACILITIES (by basin state; millions $1997)

Basin State	Total Capital Costs	Baseline Costs as Percent of Total	Net Capital Costs	Annualized Net Cost	
				Lower (2% discount rate)	Higher (7% discount rate)
Delaware	$16	33%	$11	<$1	$1
District of Columbia	$1,032	16%	$862	$39	$70
Maryland	$1,913	24%	$1,462	$65	$118
New York	$297	31%	$204	$9	$16
Pennsylvania	$1,741	29%	$1,241	$55	$100
Virginia	$1,669	30%	$1,164	$52	$94
West Virginia	$38	31%	$26	$1	$2
TOTAL	**$6,705**	**26%**	**$4,970**	**$222**	**$401**

Note: Totals may not sum due to rounding.

The GICS data we collected to corroborate our capital cost estimates are consistent with the results presented above. According to the data provided by OW, total Construction Grants and state matching funds received by wastewater treatment facilities within the Chesapeake basin from 1972 through 1995 equal approximately $4.3 billion (in 1997 dollars). This figure is roughly $2.4 billion less than the $6.7 billion in capital costs estimated using the cost equations. This result is reasonable for two primary reasons: (1) the construction grants data capture only a portion of total capital investments made by basin facilities over the study period, as they exclude expenditures related to SRF loans and other federal assistance programs; and (2) according to the grants data provided by OW, a number of facilities within the basin have not received construction grants and many may have engaged in construction projects without federal assistance. Given these factors, we believe the grants data confirm that the cost equations yield reasonably accurate estimates of total capital costs.

Annual Operations and Maintenance Costs

O&M cost estimates are provided in Exhibit 2-7. Using the available flow and treatment data and applying our estimates of unit O&M costs yields a total annual O&M cost estimate of $714 million. This figure represents the total annual expenditures required to operate and maintain basin facilities active in 1997. Our analysis also suggests that baseline costs, or costs that would have been incurred in the absence of pollution control initiatives, represent 32 percent of total costs across all facilities. Subtracting this proportion from total costs yields net annual O&M costs of $484 million. As with capital costs, POTWs in Maryland, Pennsylvania, and Virginia incur the largest O&M expenditures.

Exhibit 2-7

O&M COSTS FOR CHESAPEAKE BASIN MUNICIPAL FACILITIES
(by basin state; millions $1997)

Basin State	Total Annual O&M Costs	Baseline Costs as Percent of Total	Net O&M Costs
D.C.	$137	22%	$106
Delaware	$1	40%	$1
Maryland	$148	30%	$103
New York	$24	40%	$14
Pennsylvania	$172	34%	$113
Virginia	$230	37%	$145
West Virginia	$2	40%	$1
TOTAL	**$714**	**32%**	**$484**

Note: Totals may not sum due to rounding.

CHAPTER 2 REFERENCES

Association of Metropolitan Sewerage Agencies, *The AMSA Financial Survey, 1996*, Washington, DC.

Massachusetts Water Resources Authority (MWRA), "Proposed Capital Improvement Program, Fiscal Years 1998 - 2000." December 30, 1996, p. C-1.

Office of Management and Budget, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Circular No. A-94, October 29, 1992.

Personal communication with Leonard Fitch, EPA Office of Water, September 1, 1998.

Robert W. Hartman, "One Thousand Points of Light Seeking a Number: A Case Study of CBO's Search for a Discount Rate Policy," *Journal of Environmental Economics and Management*, vol. 18, pp. 53-57, 1990.

U.S. Environmental Protection Agency, *1996 Clean Water Needs Survey Manual*, October 1995, pp. 12-41.

U.S. Environmental Protection Agency, *Analysis of Operations & Maintenance Costs for Municipal Wastewater Treatment Systems*, Office of Water, May 1978, pp. 4-35 - 4-47, 430/9-77-015.

U.S. Environmental Protection Agency, *Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978*, Office of Water, April 1980, page 31, EPA/430/9-80-003.

U.S. Environmental Protection Agency, "Construction Grants Overview," obtained from: http://www.epa.gov/enviro/html/gics/gics_cg1.html, July 8, 1998.

U.S. Environmental Protection Agency, "State Revolving Fund System Overview," obtained from: http://mountain.epa.gov/enviro/html/gics/gics_sr1.html, July 8, 1998.

Appendix 2-A INFLATION INDICES		
Year	Plant Cost Index	GDP Deflator
1972	137.2	33.42
1973	144.1	35.30
1974	165.4	38.47
1975	182.4	42.09
1976	192.1	44.55
1977	204.1	47.43
1978	218.8	50.89
1979	238.7	55.23
1980	261.2	60.33
1981	297.0	66.01
1982	314.0	70.17
1983	316.9	73.16
1984	322.7	75.92
1985	325.3	78.53
1986	318.4	80.58
1987	323.8	83.06
1988	342.5	86.09
1989	355.4	89.72
1990	357.6	93.60
1991	361.3	97.32
1992	358.2	100.00
1993	359.2	102.64
1994	368.1	105.09
1995	381.1	107.76
1996	381.7	110.21
1997	386.5	112.40

Sources:

Plant Cost Index: "Chemical Engineering Plant Cost Index," appearing in, *Chemical Engineering*, published by the McGraw-Hill Companies, Inc., August 1998 and previous issues.

Gross Domestic Product Deflator: U.S. Bureau of the Census, *Statistical Abstract of the United States, 1997* (Washington, DC: Bureau of the Census, 1997). Table 692.

COSTS OF WATER POLLUTION CONTROL AT INDUSTRIAL FACILITIES

CHAPTER 3

INTRODUCTION

This chapter examines water pollution control expenditures made by industrial facilities in the Chesapeake basin. We begin by discussing the relevant facilities and the regulatory framework for controlling discharges. We then discuss the analytic approach used to assess water pollution control expenditures, review key analytic uncertainties, and present the resulting cost estimates. As in Chapter 2, we estimate total compliance costs as well as the net costs specifically associated with regulations introduced in 1972 and later.

BACKGROUND

The federal Clean Water Act provides the statutory framework for regulation of industrial discharges to waters of the United States, including the waters of the Chesapeake Bay watershed. The CWA governs two major categories of industrial facilities -- direct and indirect dischargers. Under the CWA's National Pollutant Discharge Elimination System (NPDES) program, industrial facilities discharging directly to surface waters must obtain a permit that establishes limits on the pollutants in their effluent and specifies monitoring and reporting requirements. The Chesapeake Bay Program point source database identifies 51 significant direct dischargers in the watershed (see Exhibit 3-1).[1] Available data suggest that these facilities discharge approximately 480 million gallons of wastewater per day.

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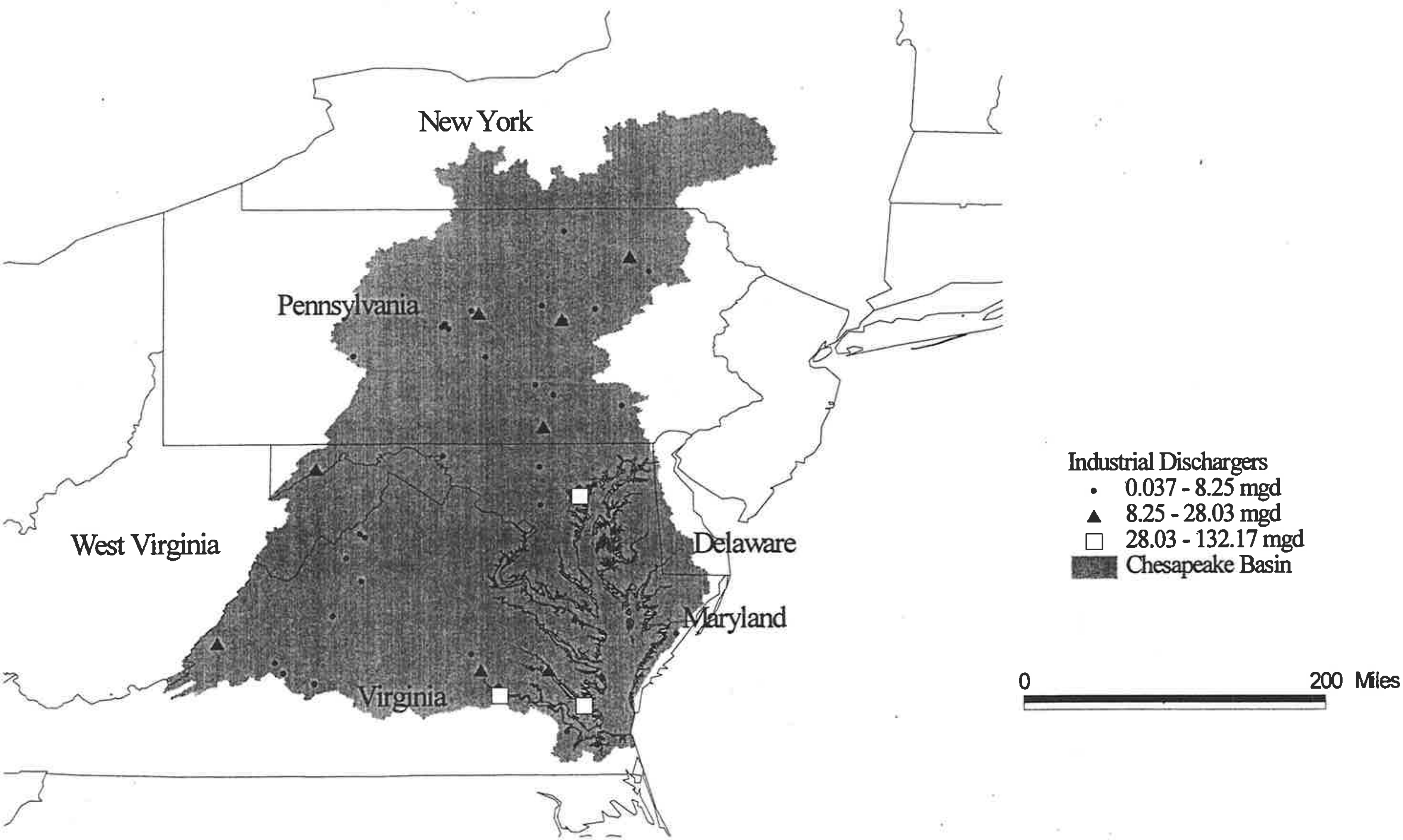
[1] Chesapeake Bay Program, Nutrient Subcommittee and Modeling Subcommittee, *Chesapeake Bay Watershed Model Application and Calculation of Nutrient and Sediment Loadings, Appendix F, Point Sources*, July 1998. For the states of Maryland and Virginia, "significant" is defined as facilities having greater than 0.5 mgd or industrial equivalent total nitrogen discharge of greater than 75 pounds per day; for Pennsylvania, the cutoff is 0.4 mgd. Facilities located outside these three states or whose discharge falls below the thresholds indicated are not included in the Bay Program's inventory.

Exhibit 3-1

SIGNIFICANT INDUSTRIAL DIRECT DISCHARGERS IN THE CHESAPEAKE BASIN



The CWA's National Pretreatment Program regulates indirect industrial discharges. Industrial facilities discharging to POTWs may be required to pretreat their wastewater to comply with national guidelines for their industry, protect POTW operations from interference, or ensure that the POTW complies with NPDES permit or biosolids management requirements. Basic pretreatment regulations apply to all POTWs nationwide. In addition, the regulations require POTWs with design capacity of more than five mgd and smaller POTWs receiving significant industrial discharges to establish local pretreatment programs. The relatively small number of major direct dischargers in the Bay Program inventory suggests that pretreatment expenditures are likely to be a significant component of the overall cost of maintaining water quality in the Chesapeake basin.

ANALYTIC APPROACH

To capture water pollution control expenditures for both direct and indirect dischargers, we apply methods that rely on the capital and operations and maintenance (O&M) costs reported in the Census Bureau's *Pollution Abatement Costs and Expenditures* (PACE) series. The basic analytic approach relies on scaling of state-level data to estimate expenditures within the Chesapeake basin and derivation of net annual expenditures attributable to post-Clean Water Act water pollution control initiatives. The approach is summarized in Exhibit 3-2. Below, we explain our derivation of capital and operating costs in more detail.

Estimating Capital Costs

From 1973 through 1994, the U.S. Department of Commerce, Bureau of Census conducted an annual survey of manufacturing facilities that tracked total capital and operating costs associated with all major forms of pollution control (air, water, and waste management).[2] The Census Bureau compiled these data annually in the series entitled *Pollution Abatement Costs and Expenditures* (PACE). The PACE data form the foundation of our capital cost analysis.

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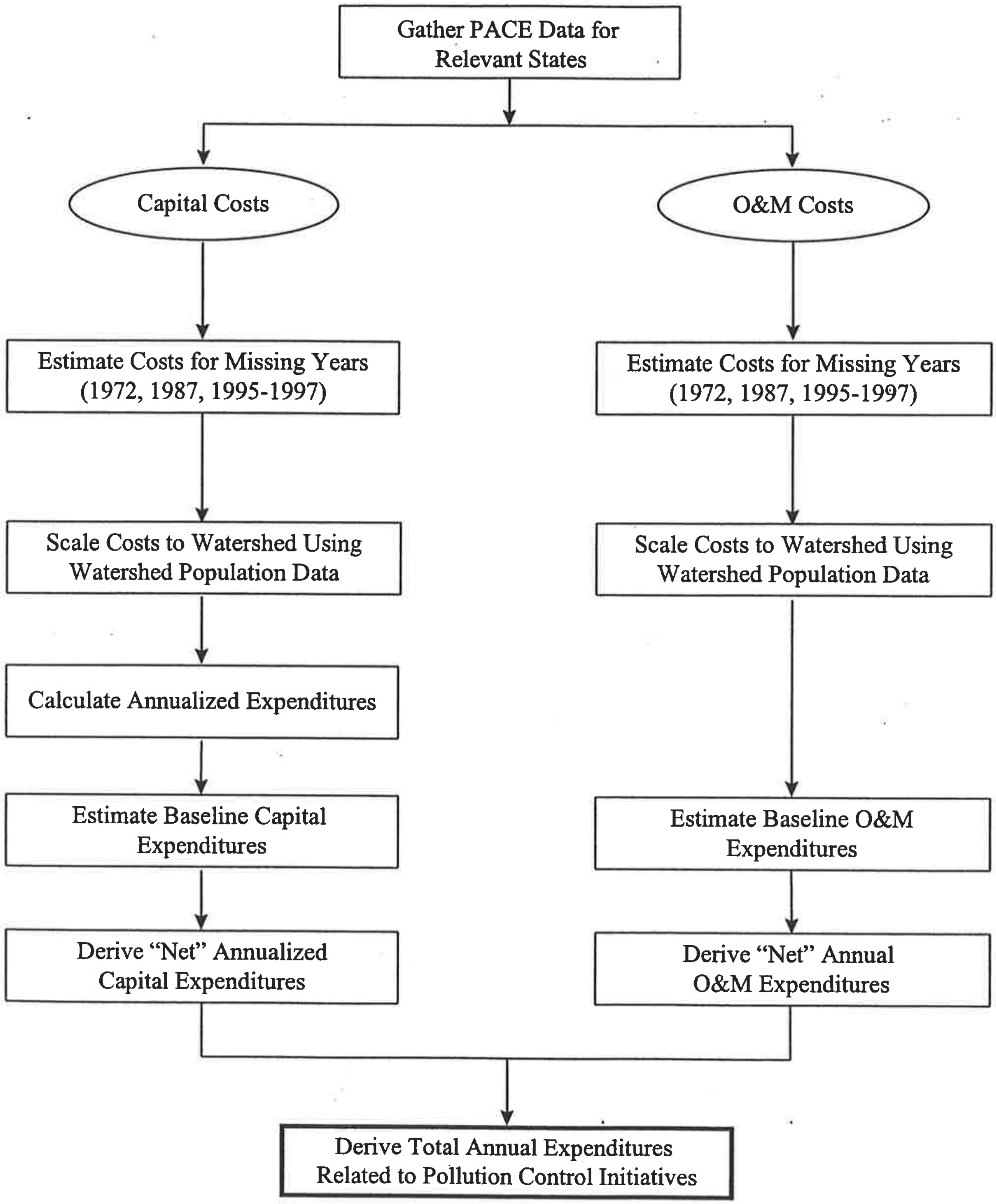
[2] Specifically, the PACE data cover establishments in SICs 2000 through 3999, the SICs for manufacturing industries. The PACE data include expenditures at all manufacturing facilities, not just the 51 direct dischargers included in the Chesapeake Bay Program's point source data base. In addition, the PACE data cover costs to control all pollutants, whereas the Bay Program's watershed model addresses only nutrient loadings. As noted in Chapter 1, these differences should be kept in mind when comparing total benefit estimates to the cost estimates reported here.

Exhibit 3-2

METHODOLOGY FOR ESTIMATING EXPENDITURES AT INDUSTRIAL FACILITIES



As noted, the PACE data do not address the full study period (1972 through 1997). To estimate capital costs for 1972, we assume expenditures equal those recorded for 1973. For the period from 1995 through 1997, we assume capital expenditures equal to the average of expenditures in the five-year period from 1990 through 1994. In addition, the Census Bureau did not gather PACE data for the year 1987; we set 1987 expenditures equal to the average of expenditures in the remaining years of the 1980s prior to and after 1987.

The PACE data are available only at the state level, and therefore must be scaled to the Chesapeake basin. Specifically, we derive the portion of the total state population that resides in the watershed (using data from 1996) and use this proportion to scale the PACE data. While we considered scaling by economic factors such as the number of commercial establishments or total employment by county (data available in the Census Bureau's County Business Patterns data base), we chose to scale by population for two reasons. First, data on population within the watershed are readily available from the Chesapeake Bay Program. These data have been adjusted to account for counties only partially located in the watershed, helping us avoid inaccuracies that could arise in using other scaling factors, for which sub-county data are not available. Second, population is almost perfectly correlated with economic activity. For example, we calculated correlation coefficients for both county population and establishments, as well as county population and employment in Maryland. In both cases the correlation coefficients were approximately 0.98.[3]

We then annualize capital costs using the same assumptions and procedures described for municipal treatment plants (see Chapter 2). In particular, we assume a 30-year useful life and use real discount rates of two and seven percent. All capital costs are inflated to 1997 dollars using the *Chemical Engineering* Plant Cost Index (see Appendix 2-A).

Estimating Operations and Maintenance Costs

The PACE data also include operations and maintenance (O&M) costs associated with water pollution control at industrial facilities in each state. We convert O&M costs to constant dollars using the Gross Domestic Product (GDP) deflator, as in the municipal treatment plant cost analysis. Because O&M costs exhibit a general upward trend over time, we interpolate missing data years using a different approach than for capital costs. Specifically, for each state's PACE data, we use ordinary least squares regression to estimate a trend line through the

[3] Overall, the approach of scaling by population may seem counterintuitive, i.e., individuals do not think of themselves as living near industrial facilities and hence may feel that population and the location of industrial facilities are likely to be poorly correlated. While this may be true at the census tract or municipal level, data at the county level suggest a high degree of correlation; not surprisingly, people live in the general vicinity of economic centers where employment opportunities exist.

available O&M data points. The slope of this trend line allows us to estimate the missing data points for the beginning and end of the O&M time series (i.e., 1972 and 1995 through 1997).[4]

Deriving Baseline Expenditures

As described earlier, the objective of the cost analysis is estimation of total annual pollution control costs in 1997, net of costs that would have been incurred without the Clean Water Act and other pollution control initiatives introduced after 1972. To develop such an estimate we must determine baseline control expenditures, i.e., expenditures at industrial facilities that would have occurred between 1972 and 1997 absent additional regulation.

The key assumption employed in developing our baseline scenario is that post-1972 pollution control expenditures within a particular industry would have remained constant in proportion to industry output. Relying upon this assumption, we derive baseline O&M costs as follows:

- First, we divide 1973 O&M expenditures (the first year of PACE data) in each two-digit SIC by the industry's total output; for the purposes of this calculation, we use manufacturing value of shipments data from the Census Bureau's 1973 *Survey of Manufactures* as our output measure. The resulting ratio provides a measure of the pollution control expenditures that were necessary per dollar of output in order to comply with pre-CWA regulations. We develop these ratios for each of the six states.[5]

- Second, we develop a weighted average expenditure/output ratio for each state, based on the distribution of value of shipments by two-digit SIC in the 1996 *Survey of Manufactures*.[6]

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[4] The regression results for West Virginia were statistically insignificant. Therefore, we estimate the 1972 O&M value using a trend line based only on data points from the 1970s. For the period 1995 through 1997, we set O&M costs equal to the average of costs incurred in the years from 1990 through 1994.

[5] When O&M costs are disaggregated by SIC, missing data problems arise for some sectors. If the PACE data indicate that expenditures are significant, but cannot be divulged because of confidentiality concerns, we substitute the national expenditure/output ratio for the SIC in question. If the PACE data indicate that expenditures are less than $50,000 but greater than zero, we assume costs of $25,000. Because missing data problems are relatively infrequent, these assumptions have little influence on the resulting estimates.

[6] 1996 data are the most recent manufacturing output data available.

- Third, we multiply the weighted average ratio for each state by our estimate of total 1997 economic output within the state's portion of the Chesapeake basin. The output figure for activity within the Chesapeake basin is derived by multiplying total statewide manufacturing value of shipments by the same scaling factor used to scale the PACE data (see above discussion).[7] This step yields an estimate of what O&M expenditures would have been in 1997 based on the cost per dollar of output experienced in 1973, prior to the CWA and other regulatory initiatives.

- Finally, we estimate net O&M costs by subtracting the estimated baseline costs from total 1997 O&M expenditures for each state.

This approach accomplishes two key objectives. First, it allows us to correct for changes between 1972 and 1997 in the mix of economic activity within the basin. Simply assuming that pollution control expenditures would vary in proportion to changes in total manufacturing output would ignore shifts in the underlying mix of manufacturing activity over the last 25 years. For example, some areas may have experienced a shift from highly polluting heavy industry to lighter industry with less pollution. Weighting by the current manufacturing mix helps correct for these types of changes. In addition to incorporating the mix of industry, our methodology allows baseline costs to change consistent with total manufacturing output (i.e., we multiply the 1973 expenditure/output ratio by 1997 manufacturing output). In essence, the method allows us to determine what *today's* industries would be spending on pollution control if the costs per unit of output (as determined by regulatory requirements) were unchanged from 1973.

The lack of historical data on capital outlays in the 1950s and 1960s makes it difficult to determine what annual pollution abatement capital costs were in the early 1970s. Therefore, we derive net pollution abatement capital costs on a state-by-state basis using the relative proportion of net and total O&M costs estimated by the method described above. For example, for Maryland, the O&M method yields baseline O&M costs that are approximately 24 percent of total 1997 expenditures. We assume that the baseline pollution abatement capital stock would have grown similarly, i.e., that 24 percent of capital outlays would have been incurred without

[7] Manufacturing value of shipments is taken from Bureau of the Census, *Annual Survey of Manufacturers*. Note that the most recent survey data available are for 1996. We adjust 1996 output figures to 1997 dollars using the Gross Domestic Product Deflator, and then increase this this figure by 5.1 percent, the real rate of growth in manufacturing nationwide (as reported in the 1998 *Economic Report of the President*, Table B-51). We use the resulting estimate for 1997 manufacturing output in each state.

post-1972 regulatory initiatives. We then subtract the baseline cost estimate from the total 1997 annual capital cost to derive net capital costs.[8]

Uncertainties

Our estimates of industrial water treatment costs are subject to several uncertainties:

- First, certain categories of pollution control expenditures may not be adequately reflected in the PACE data. Most notably, pollution prevention efforts may not be fully incorporated into the costs reported by surveyed facilities. Furthermore, facilities may have complied with new water pollution control regulations by transferring pollutants to other media; e.g., pollutants may be managed as solid waste rather than controlled through wastewater treatment. To the extent that the PACE data do not capture such expenditures, we may understate the costs imposed by water pollution control initiatives promulgated over the study period.

- In addition, the scaling of PACE data from the state level to the watershed necessarily entails a significant degree of uncertainty. Because we scale based on 1996 population data, inaccuracies could occur if large, in-state demographic shifts have changed the proportion of the population living in the Chesapeake basin relative to the state as a whole. Comparing 1996 population data to 1980 data (the earliest year for which complete data are available) indicates that only minor population shifts (i.e., four percent or less) have occurred in the relevant states.

- Next, as we noted above, several years of PACE data are unavailable. Most notably, the lack of data for the most recent years (1995 through 1997) requires that we estimate recent O&M costs. Because these endpoints in the O&M time series play an important role in our estimation of net costs, significant uncertainty is introduced.

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[8] As discussed below, we estimate that baseline pollution control costs are about 46 percent of total 1997 pollution control O&M costs; we assume this same proportion for capital. It is noteworthy that this approach yields estimates reasonably consistent with a recent draft study of the national cost of the Clean Water Act (see Iovanna, Richard, *Cost Assessment of the 1972 Clean Water Act*, draft, March 5, 1998). This study estimated that the baseline pollution control capital costs (i.e., those net of post-1971 regulation) were about 50 percent of total pollution control capital costs. This finding appears to support our estimate that baseline capital costs equal about 46 percent of total capital costs.

- Finally, the PACE data do not include sufficiently detailed information for the District of Columbia because of the small number of industrial facilities located there. The few years of O&M data that are available indicate that O&M costs are generally less than $500,000 per year, suggesting that the resulting understatement of expenditures is minor.

Several other uncertainties are specifically associated with our method for estimating baseline and net costs:

- Our derivation of baseline and net costs is based on the ratio of pollution control expenditures to output in 1973. However, expenditures may not have kept pace with output over the last 25 years because of technological improvements that increase the efficiency of pollution control equipment, i.e., pollution control may be achieved more cheaply than in 1973. As a result, we may overstate baseline costs and understate net costs. While this is possible, it is noteworthy that technological advances in water pollution control may have been driven by the CWA and other regulation, innovation that would not have occurred in the absence of these regulations.

- In addition, the 1973 PACE data used to develop the expenditure to output ratios may include early expenditures made to comply with the CWA and other post-1972 regulation. To the extent that such early expenditures are present in the 1973 PACE data, we may overstate baseline costs and understate net costs.

RESULTS

Exhibit 3-3 summarizes the total annual capital and O&M costs estimated for industrial facilities, as well as our estimates of net costs. As shown, we estimate total annual expenditures of between $507 million and $600 million, with net costs (i.e., those attributable to post-1972 regulation) of between $272 million and $320 million per year. These results are presented in more detail in the sections below.

Exhibit 3-3 **SUMMARY OF POLLUTION CONTROL EXPENDITURES BY INDUSTRIAL FACILITIES IN THE CHESAPEAKE BASIN (millions $1997)**			
		Lower	**Upper**
Total Annual Costs	1997 O&M	$392	$392
	1997 Annual Capital	$115	$208
	TOTAL	$507	$600
Estimated Net Costs (O&M and Capital)		**$272**	**$320**

Notes:
1. These estimates do not include the District of Columbia. Capital cost data are unavailable for DC because of the small number of relevant facilities. Available O&M data suggest that industrial expenditures (capital and O&M) within DC are minor.
2. Lower and higher bound figures represent total costs annualized using discount rates of 2 and 7 percent, respectively

Total Annualized Capital Costs

We estimate that industrial facilities in the Chesapeake basin incur total annualized capital costs of between $115 million and $208 million for water pollution control. As shown in Exhibit 3-4, the majority of these expenditures are made at industrial facilities in Maryland, Pennsylvania, and Virginia.

Exhibit 3-4

TOTAL ANNUALIZED CAPITAL COSTS FOR CHESAPEAKE BASIN INDUSTRIAL FACILITIES (millions $1997)

	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia	TOTAL
Lower Bound (2% Discount Rate)	$1.4	$28.2	$3.1	$33.7	$43.8	$4.9	$115.0
Upper Bound (7% Discount Rate)	$2.5	$50.9	$5.6	$60.8	$79.0	$8.8	$207.6

Note: Capital cost data for the District of Columbia are unavailable because of the small number of relevant facilities. Available O&M data suggest that industrial expenditures (capital and O&M) within DC are minor.

Total Annual Operations and Maintenance Costs

As shown in Exhibit 3-5, we estimate total 1997 operating and maintenance costs for industrial facilities to be roughly $392 million. As with capital costs, the majority of these expenditures occur at industrial facilities in Maryland, Pennsylvania, and Virginia. We should reiterate that the lack of PACE data for 1997 requires that we estimate 1997 O&M costs; as explained, we estimate 1997 costs by plotting a trend line through the available data and extrapolating a 1997 value. The error introduced by this data gap may be significant; it would be preferable to rely on actual rather than estimated expenditure data.

Exhibit 3-5

TOTAL O&M COSTS FOR CHESAPEAKE BASIN INDUSTRIAL FACILITIES (millions $1997)

	Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia	TOTAL
O&M Costs	$8.7	$118.2	$11.0	$104.8	$137.3	$11.9	$391.9

Note: Comprehensive O&M cost data for the District of Columbia are unavailable because of the small number of relevant facilities. Available O&M data suggest that industrial expenditures (capital and O&M) within DC are minor.

Net Expenditures

As noted above, we derive baseline pollution control expenditures by examining 1973 expenditures relative to manufacturing output and assuming that post-1972 expenditures would have kept pace with output in the absence of new regulatory initiatives. Exhibit 3-6 summarizes the results of this method, presenting the net capital and O&M costs (i.e., costs attributable to regulatory initiatives since 1972). As shown, we estimate net total costs (annual capital and O&M) of between $272 million and $320 million across all states in the study area.

Exhibit 3-6

NET ANNUAL POLLUTION CONTROL COSTS FOR CHESAPEAKE BASIN INDUSTRIAL FACILITIES (millions $1997)

		Delaware	Maryland	New York	Pennsylvania	Virginia	W. Virginia	TOTAL
Total 1997 Costs	Lower (2%)	$10.0	$146.4	$14.1	$138.5	$181.0	$16.8	$506.9
	Upper (7%)	$11.2	$169.1	$16.6	$165.6	$216.2	$20.7	$599.5
Baseline Costs as Percent of Total		29%	24%	50%	61%	51%	73%	46%
Estimated Baseline Costs	Lower (2%)	$2.9	$35.8	$7.0	$84.6	$92.6	$12.3	$235.3
	Upper (7%)	$3.3	$41.3	$8.2	$101.2	$110.7	$15.2	$279.9
Estimated Net Costs	Lower (2%)	$7.1	$110.6	$7.1	$53.9	$88.4	$4.5	$271.6
	Upper (7%)	$7.9	$127.7	$8.4	$64.5	$105.6	$5.6	$319.6

Notes:
1. Cost data for the District of Columbia are unavailable because of the small number of relevant facilities. Available O&M data suggest that industrial expenditures (capital and O&M) within DC are minor.
2. Totals may not sum due to rounding error.

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COSTS OF NONPOINT SOURCE WATER POLLUTION CONTROL **CHAPTER 4**

INTRODUCTION

This chapter discusses the costs of implementing best management practices (BMPs) to reduce the flow of nonpoint source pollutants to the Chesapeake Bay. The nonpoint sources addressed in this analysis include runoff from agricultural lands, urban runoff, and effluent from marinas. The BMPs implemented to reduce nonpoint source pollution range from certain land use conversions, such as replacing cropland with a grassed buffer strip, to specific structural improvements, such as installing fences to keep livestock from damaging streambanks.

This chapter contains three sections. First, we summarize the programs governing the implementation of BMPs across the Chesapeake basin, and describe the land use practices and associated BMPs that are the focus of the study. The second section discusses the analytic approach we employ to derive cost estimates for these BMPs and uncertainties and limitations important to keep in mind when interpreting results. In the final section, we discuss the results of the analysis.

BACKGROUND

While many states had sediment and erosion control programs in place prior to the 1970s, the Federal Water Pollution Control Act of 1972 (FWPCA) established the first program addressing a broad spectrum of nonpoint source pollutants. Section 208 of the FWPCA required the development of Water Quality Management Plans, governing specific geographic areas, that account not only for point source pollution but also for runoff from agricultural and silvicultural practices.

Despite efforts stemming from the implementation of Section 208, EPA's 1983 study of the Chesapeake Bay found that nonpoint sources contributed significantly to the decline of the Bay. As a result, the Chesapeake Bay Executive Council, established pursuant to the 1983 Chesapeake Bay Agreement, made nonpoint source control a priority among its Bay cleanup efforts. The Council's efforts were supported by the Water Quality Act of 1987, which amended the FWPCA to add a new Section 319 that required states to develop programs to mitigate all nonpoint sources of pollution.

Currently, nonpoint sources of pollutants in the Chesapeake Bay watershed include runoff from several types of land uses as well as direct loadings:

- **Farms.** Runoff from cropped land contains soil and nutrients from fertilizer residues. Grazing and animal watering contribute to field and streambank erosion. In addition, runoff from animal waste storage areas contains nutrients, bacteria, and other contaminants.

- **Harvested forests.** Soil erosion associated with timber harvesting operations contributes to increased turbidity.

- **Urban areas.** Runoff from urban land contributes not only nutrients, but also toxics, oil and grease, and other pollutants. In addition, malfunctioning or improperly installed septic systems contribute to nutrient loadings.

- **Direct loadings.** Nonpoint sources not associated with land use runoff include marine septic pumpouts and shoreline erosion.[1]

A wide variety of best management practices (BMPs) are available to control pollution associated with these land uses. Examples of practices used in the Chesapeake Bay Watershed include:

- **Land use conversions.** Instituting conservation tillage practices, cultivating permanent vegetative cover instead of crops on highly erodible land, or converting portions of cropped or developed lands into grassed or forested areas (buffer strips) helps to reduce nonpoint source loadings associated with agricultural activities and urban development.

- **Stormwater controls.** Detention and retention ponds, sand filters, infiltration trenches, and other structures collect and filter urban stormwater prior to discharge into waterbodies.

- **Animal waste management systems.** Manure storage structures and ponds reduce the amount of nutrients and pathogens from animal waste that are released to waterbodies. Additionally, diversions and roof runoff controls prevent rainfall from overflowing animal waste storage structures.

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[1] Some states may regulate marine pumpouts as point sources. For convenience, we address them in this chapter rather than discussing them in a separate chapter.

- **Grazing land and streambank protection.** Rotational grazing encourages revegetation of grazing lands, thereby reducing erosion. Alternative livestock water supplies and fences or other barriers along streambanks to prevent livestock access reduce streambank damage associated with livestock watering.

- **Marine pumping facilities and shore erosion controls.** Pumping facilities and breakwaters or shoreline revegetation achieve reductions in nutrient and pathogen loadings and shoreline erosion.

ANALYTIC APPROACH

To estimate BMP costs, we obtain information on the application of BMPs in the watershed from the nutrient reduction tracking database developed for the Phase IV Chesapeake Bay Watershed Model (the Chesapeake Bay Program Office (CBPO) database); the database contains information on the total acres of land to which a BMP has been applied. We then apply BMP annual unit cost estimates, derived from a number of literature sources and conversations with CBPO and state program office staff, to the acreage data to obtain a total annual BMP cost estimate. Finally, we compare these estimates to an estimate of baseline expenditures (i.e., the costs of BMPs likely to be in place in 1997 in the absence of pollution control initiatives) to determine a net total BMP cost attributable to these initiatives.

Nutrient Reduction Tracking Database

To identify the acreage subject to BMPs in the study area, we accessed the nutrient loading reduction database developed for input into the Phase IV Watershed Model and maintained by the CBPO. This database contains an annual estimate of land use acreage in the watershed subject to various types of BMPs and the resulting nutrient loading reductions. To derive these estimates, the CBPO compiles and summarizes annual data on BMPs in operation in each state in the basin. Estimates of BMPs in operation in Maryland, Pennsylvania, Virginia, and the District of Columbia are derived from data the states or District provide, whereas estimates of BMPs established in Delaware, New York, and West Virginia are derived from USDA Farm Service data.

BMP Cost Estimates

Until 1993, the nutrient loading reductions database described above also contained data on the capital and operation and maintenance costs of each type of BMP. In 1993, as a result of a change in the inputs required for the Watershed Model, the database was altered to reflect new requirements and currently does not track BMP costs. However, several secondary sources provide cost estimates for BMPs listed in the database. These sources include:

- **Camacho (1992).** Camacho provides annual unit costs of agricultural BMPs in the Chesapeake Bay basin and urban BMPs in the District of Columbia and Maryland. Most BMPs correspond directly to BMPs listed in the CBPO database. A range of both capital and operation and maintenance costs are provided. We employ the median cost estimates presented in his report.[2]

- **Shulyer (1995).** Shulyer provides unit costs for eight broad BMP categories: Forest, Highly Erodible Land, Animal Waste, Urban, Conservation Tillage, Pasture, Nutrient Management, and Farm Plan. As appropriate, we apply these unit costs to the BMPs listed in the CBPO database.[3]

- **Riparian Forest Buffer Panel Report (1996).** This document provides cost information for certain forestry BMPs. Most BMPs discussed in this report do not correspond directly to BMPs listed in the CBPO database but encompass or constitute an element of a CBPO BMP. We apply these costs in instances where the BMP categories overlap sufficiently.[4]

- **EPA (1993).** EPA provides unit costs drawn from various sources for specific agricultural, forestry, and urban BMPs. The document reports unit costs for certain states and years, or a national or regional median; we apply these costs as appropriate. Most importantly, the BMP categories listed in this report correspond directly to BMPs listed in the CBPO database.[5]

In addition, several contacts at state environmental protection departments provided cost estimates.

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[2] Camacho, Rodolfo, *Chesapeake Bay Program Nutrient Reduction Strategy Reevaluation - Report #8: Financial Cost Effectiveness of Point and Nonpoint Source Nutrient Reduction Technologies in the Chesapeake Bay Basin*, Interstate Commission on the Potomac River Basin, December 1992.

[3] Shulyer, Lynn R., *Cost Analysis for Nonpoint Source Control Strategies in the Chesapeake Drainage Basin*, prepared for U.S. Environmental Protection Agency, Chesapeake Bay Program, May 1995.

[4] U.S. Environmental Protection Agency, *Riparian Forest Buffer Panel Report: Technical Support Document*, Riparian Forest Buffer Panel Technical Team, Chesapeake Bay Program, October 1996.

[5] U.S. Environmental Protection Agency, *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, Office of Water, January 1993.

Similar to the costs of technologies to control point source pollution, BMP costs include a capital component and an operation and maintenance (O&M) component. In cases where capital costs and O&M costs are disaggregated, we annualize these costs over the useful life of the BMP using discount rates of two percent and seven percent. In cases where costs were presented in annualized form, we applied these directly (see uncertainties below for a further discussion of the impact of discounting assumptions on the costs estimated).

To estimate total costs for a particular BMP, we multiply the units of BMP (e.g., acres) by the annual unit costs (e.g., dollars per acre per year) derived from the literature or from conversations with state representatives. The product yields the total annual cost of that BMP.

Deriving Baseline Cost Estimates

As with point source pollution control costs, we must make certain assumptions concerning "baseline" nonpoint control costs. We engage in this exercise to ensure that we are not incorrectly including control measures and costs existing in 1972 and likely to continue throughout the study period, without the enactment of the FWPCA.

As discussed above, requirements in the 1972 FWPCA spurred the first major initiative to study and address nonpoint source pollution. Prior to 1972, federal nonpoint source control efforts generally were limited to U.S. Department of Agriculture programs to reduce soil erosion on agricultural lands. These programs appear to have had limited effect on the Chesapeake region because: (1) they targeted areas subject to wind erosion, and therefore were implemented primarily in the Western U.S., and (2) they were voluntary, and federal farm support was not contingent on participation.[6,7] Moreover, the programs did not necessarily target highly erodible lands or the agricultural practices most likely to cause erosion.[7] Early state efforts to control nonpoint source discharges also focused on erosion control; these programs were instituted in 1970 or later, and therefore were not a substantial consideration in developing the baseline scenario.[8] Federal and state efforts to control urban stormwater flows generally did not appear until the 1970s, and did not address pollutants other than sediment until much later.[9] Taken

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[6] Magleby, Richard et al., *Soil Erosion and Conservation in the United States: An Overview*, U.S. Department of Agriculture, Economic Research Service, Washington, DC, October 1995, p. 21.

[7] Strohbehn, Roger, ed., *An Economic Analysis of USDA Erosion Control Programs: A New Perspective*, U.S. Department of Agriculture, Economic Research Service, Washington, DC, August 1986, p. 21. See also U.S. Department of Agriculture, *Agricultural Resources and Environmental Indicators, 1996-97,* Economic Research Service, Washington, DC, July 1997, pp. 297-309.

[8] U.S. Environmental Protection Agency, *Chesapeake Bay Nonpoint Source Programs,* Chesapeake Bay Program, Annapolis, MD, January 1988, p. 11.

[9] *Ibid.*, p. 13.

together, these findings suggest that FWPCA section 208 and the Chesapeake Bay Agreement, instituted in 1983, marked the beginning of the comprehensive strategy to implement nonpoint source controls. As a result, we estimate that the effective baseline cost of most nonpoint source controls over the study period is zero.

Uncertainties and Caveats

To provide context for interpretation of the results presented in the next section, we present below the uncertainties and caveats associated with the analysis.

- First, it is important to note that unit costs for a particular BMP may vary widely according to specific site characteristics, including soil type, land use, tillage practices, and many other conditions. To address the uncertainty associated with unit cost estimates, we provide ranges that bound the highest and lowest potential costs.

- Second, certain BMPs reported in the CBPO database reflect groups of several different practices. For example, agricultural Soil Conservation and Water Quality (SCWQ) Plans, which affect nearly 48 percent of the acres subject to BMPs within the watershed, may include diversions, cover crops, and animal waste storage systems, among others. The CBPO database does not provide detail on the frequency with which various BMPs are incorporated into these plans. Other BMPs that integrate a number of component practices include animal waste systems and timber harvesting controls. As a result, unit cost estimates for these BMPs reflect an average set of practices that may not be accurate for a specific site.

- We exclude from this analysis costs related to maintenance of onsite disposal systems (e.g., septic pumping and denitrification) to reduce leakage and homeowner connections to sewer systems (in lieu of installing onsite disposal systems). Discussions with state officials suggested that decisions about septic system maintenance and sewer connections are driven by available infrastructure, homeowner preference, and budget constraints rather than by water quality concerns.[10] As a result, we estimate that the costs associated with these activities would not vary significantly between the "with" and "without" scenarios. The incremental cost of these activities that may be attributed to FWPCA mandates or similar initiatives is therefore zero.

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[10] Personal communications with John Murtha, Pennsylvania Department of Environmental Protection, August 24, 1998, and Jane Gottfredson, Program Manager, Groundwater Permits Program, Maryland Department of the Environment, September 14, 1998.

- Wherever possible, we estimate cost ranges by annualizing capital and O&M cost data using discount rates of 2 percent and 7 percent. However, some sources provide data on an annualized basis without referencing the underlying capital and O&M data. Reported discount rates in these instances are as high as 10 percent. As a result, cost estimates may be somewhat higher relative to those that would have been generated if disaggregated capital and O&M cost data had been available for all BMPs.

- Finally, discussions with the CBPO suggest that the database may underreport the full extent of BMP activities affecting Chesapeake Bay loadings in the watershed. Although this uncertainty implies that costs are underestimated, it is important to recognize that the database will support estimates of both the costs and the benefits of water quality protection. Therefore, although the absolute value of costs and benefits may be underestimated, the nonpoint source analysis nonetheless allows for a consistent comparison of the *relative* costs and benefits.

RESULTS

Exhibit 4-1 presents the estimated annual cost for five broad categories of BMPs. Three of these categories (land use conversions, urban BMPs, and agriculture/silviculture BMPs) affect loadings to the Bay from the watershed, while the remaining two (marine pumpouts and shore erosion controls) affect direct loadings to the Bay. As Exhibit 4-1 shows, our estimate of annual nonpoint source control costs in the Chesapeake basin ranges from $99 million to $124 million; urban and agriculture/silviculture BMPs account for the majority (between 83 and 87 percent) of the costs.

Exhibit 4-1

ANNUAL COST OF BEST MANAGEMENT PRACTICES IN THE CHESAPEAKE BAY WATERSHED (millions $1997)[1]

Type of Best Management Practice (BMP)	Lower Bound Annual Cost	Upper Bound Annual Cost
Landuse Conversions	$11	$18
Urban BMPs	$45	$52
Agriculture/Silviculture BMPs	$41	$52
Marine Pumpouts	<$1	<$1
Shore Erosion Controls	$2	$3
TOTAL ANNUAL COST	$99	$124

[1] Lower and higher bound values represent low and high unit cost estimates for specific BMPs and/or total costs annualized using a discount rate of 2 and 7 percent, respectively. Columns may not sum to exact totals reported due to rounding error.

Exhibit 4-2 presents the distribution of estimated nonpoint source control costs by state. Maryland and Virginia account for the greatest proportion of total costs of water quality control (approximately 45 percent and 33 percent, respectively).

Exhibit 4-2

ANNUAL COST OF BEST MANAGEMENT PRACTICES IN THE CHESAPEAKE BAY WATERSHED BY STATE (millions $1997)[1]

State	Lower Bound Annual Cost	Upper Bound Annual Cost
Delaware	$1	$2
District of Columbia	$2	$2
Maryland	$45	$57
New York	$11	$12
Pennsylvania	$6	$9
Virginia	$33	$41
West Virginia	$1	$1
TOTAL	$99	$124

[1] Lower and higher bound values represent low and high unit cost estimates for specific BMPs and/or total costs annualized using a discount rate of 2 and 7 percent, respectively. Columns may not sum to exact totals reported due to rounding error.

The relative costs in two states are particularly noteworthy with respect to the proportions of the watershed within their borders. First, although Maryland's acreage represents only 15 percent of the watershed, the state accounts for 45 percent of total nonpoint source control costs. The high frequency of BMP application within Maryland, including the implementation of relatively expensive BMPs, accounts for the state's high nonpoint source control costs. For example, stormwater management (approximately $21 million) and erosion and sediment control (approximately $7 million), both of which feature high unit costs, alone account for between 52 and 62 percent of Maryland's annual Chesapeake Bay nonpoint source control costs. Activities associated with forestry and conservation tillage (including SCWQ plans), which are implemented on a large percentage of the state's acreage, account for an additional 27 to 34 percent of the state's costs. In addition, BMPs implemented in Maryland address direct tidal loadings and shoreline erosion, which have been implemented in only one of the other basin states (Virginia).

Second, while 35 percent of the Chesapeake Bay watershed is in Pennsylvania, the costs of nonpoint source controls in that state account for only 7 percent of the basin total. The Pennsylvania cost estimates reflect relatively low reported application rates for both urban and agricultural BMPs.

Appendix 4-A presents detailed state-by-state cost data, distributed according to BMP type and category. Unit cost estimates for each BMP are presented, together with the extent of BMP application within each state, to derive a total cost for each BMP for each state.

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Appendix 4-A

BEST MANAGEMENT PRACTICES: ANNUAL COSTS BY STATE

BMP Category	BMP Type	Level of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	7,126	acres	$4.12	$4.74	C	$29,334	$33,761
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	503	acres	$1,282.68	$1,640.44	C	$645,008	$824,909
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	0.9	acres	$29.64	$149.92	D	$26	$130
Resource Protection & Watershed Planning	Forest Harvesting Practices	6,485	acres	$71.77	$71.77	C	$465,458	$465,458
Nutrient Management Plans[1]	Nutrient Management Plans	1,788	acres	$0.21	$0.21	D	$378	$378
Nutrient Management Plans - Buffers	Grassed	291	acres	$8.47	$9.57	A	$2,466	$2,785
Nutrient Management Plans	Cover Crops (Cereal Grain)	8,028	acres	$33.02	$60.73	D	$265,107	$487,547
Subtotal							$1,407,777	$1,814,970
TOTAL							**$1,407,777**	**$1,814,970**

Notes:

Lower and higher bound values represent low and high unit cost estimates for specific BMPs and/or total costs annualized using a discount rate of 2 and 7 percent, respectively.

Row and column products and sums may not equal reported totals due to rounding error.

[1] Unit costs associated with this BMP reflect cost savings to farmers resulting from a decrease in fertilizer use.

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A Camacho, Rodolfo, *Chesapeake Bay Program Nutrient Reduction Strategy Reevaluation - Report #8: Financial Cost Effectiveness of Point and Nonpoint Source Nutrient Reduction Technologies in the Chesapeake Bay Basin*, Interstate Commission on the Potomac River Basin, December 1992.

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E IEc analysis.

F IEc estimates based on personal communication with Leonard Larese-Casanova, Maryland Department of Natural Resources, August 25, 1998.

G IEc estimates based on personal communication with Robert Pudmericky, Maryland Department of the Environment, September 2, 1998.

H Personal communication with Don O'Neill, Maryland Department of Natural Resources, August 15, 1998.

BMP Category	BMP Type	Level of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Urban BMPs								
Urban - SWM (Storm Water Management)	Extended Detention (dry)	55.0	acres	$8.95	$20.39	C,D	$492	$1,122
Urban - SWM (Storm Water Management)	Retention Ponds (Wet)	0.7	acres	$2,955.38	$2,955.38	A	$2,039	$2,039
Urban - SWM (Storm Water Management)	Sand Filters	142.0	acres	$9,851.28	$9,851.28	A	$1,398,390	$1,398,390
Urban	Underground Detention	26.5	acres	$61.16	$755.14	G	$1,618	$19,973
Urban	Water Quality Inlets	13.7	acres	$116.20	$1,132.72	G	$1,590	$15,496
Urban	Oil/Grit Separators/Stormceptors	41.6	acres	$3,166.48	$3,166.48	A	$131,821	$131,821
Urban	Infiltration Trenches	9.5	acres	$2,673.92	$2,673.92	A	$25,375	$25,375
Subtotal							$1,561,325	$1,594,216
TOTAL							**$1,561,325**	**$1,594,216**

Notes:
Lower and higher bound values represent low and high unit cost estimates for specific BMPs and/or total costs annualized using a discount rate of 2 and 7 percent, respectively.
Row and column products and sums may not equal reported totals due to rounding error.

References:
A Camacho, Rodolfo, *Chesapeake Bay Program Nutrient Reduction Strategy Reevaluation - Report #8: Financial Cost Effectiveness of Point and Nonpoint Source Nutrient Reduction Technologies in the Chesapeake Bay Basin*, Interstate Commission on the Potomac River Basin, December 1992.
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E IEc analysis.
F IEc estimates based on personal communication with Leonard Larese-Casanova, Maryland Department of Natural Resources, August 25, 1998.
G IEc estimates based on personal communication with Robert Pudmericky, Maryland Department of the Environment, September 2, 1998.
H Personal communication with Don O'Neill, Maryland Department of Natural Resources, August 15, 1998.

BMP Category	BMP Type	Level of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING LAND USE CONVERSION								
Landuse Conversions	Retirement of Highly Erodible Land	2,152	acres	$44.72	$51.41	D	$96,225	$110,630
Landuse Conversions	Forest Conservation	3,978	acres	$516.59	$1,808.07	B	$2,054,803	$7,191,810
Landuse Conversions	Tree Planting	3,066	acres	$2.81	$21.11	D	$8,629	$64,718
Landuse Conversions	Conventional -> Conservation Tillage	1,083,950	acres	$4.71	$5.67	D	$5,109,081	$6,145,706
Subtotal							$7,268,738	$13,512,864
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Urban BMPs								
Urban	Erosion & Sediment Control	6,598	acres	$985.13	$1,266.59	D	$6,499,876	$8,356,984
Urban - SWM (Storm Water Management)	SWM Conversions (Dry->Retention)	75,743	acres	$281.47	$281.47	A	$21,318,978	$21,318,978
Subtotal							$27,818,854	$29,675,962
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	1,237,636	acres	$4.12	$4.74	C	$5,094,757	$5,863,777
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	848	acres	$1,282.68	$1,640.44	C	$1,087,584	$1,390,925
Agriculture	Animal Waste Mgmt Systems (Poultry)	103	acres	$1,282.68	$1,640.44	C	$132,167	$169,030
Agriculture - Barnyard Runoff Control	Full System (Total Barnyard Control)	514	acres	$1,282.68	$1,640.44	C	$659,297	$843,184
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	9,010	acres	$29.64	$149.92	D	$267,050	$1,350,849
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/o Fencing	24,941	acres	$48.83	$102.38	D	$1,217,984	$2,553,554
Nutrient Management Plans[1]	Nutrient Management Plans	884,556	acres	$0.21	$0.21	D	$186,729	$186,729
Nutrient Management Plans - Buffers	Forested	472	acres	$107.98	$129.07	B	$50,951	$60,906
Nutrient Management Plans - Buffers	Grassed	200	acres	$8.47	$9.57	A	$1,699	$1,919
Subtotal							$8,698,218	$12,420,874
BMPs Affecting Direct Loads to Tidal Bay Waters								
Trib Model BMPs	Marine Pumpouts (installation)	125	marinas	$1,618.75	$2,011.62	H	$202,344	$251,453
Subtotal							$202,344	$251,453
Trib Model BMPs - Shoreline Protection	Structural Shore Erosion Control	17,805	feet	$20.49	$32.23	F	$364,824	$573,855
Trib Model BMPs - Shoreline Protection	Nonstructural Shore Erosion Control	35,403	feet	$7.78	$10.98	F	$275,435	$388,725
Subtotal							$640,260	$962,580
TOTAL							$44,628,413	$56,823,733

Notes:
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[1] Unit costs associated with this BMP reflect cost savings to farmers resulting from a decrease in fertilizer use.

References:

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BMP Category	BMP Type	Level Of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	127,581	acres	$4.12	$4.74	C	$525,191	$604,465
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Pasture	10,725	acres	$0.36	$0.47	C	$3,887	$4,998
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	10.6	acres	$1,282.68	$1,640.44	C	$13,609	$17,405
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	795	acres	$29.64	$149.92	D	$23,556	$119,154
Resource Protection & Watershed Planning	Forest Harvesting Practices	120,595	acres	$71.77	$71.77	C	$8,655,573	$8,655,573
Nutrient Management Plans[1]	Nutrient Management Plans	103,859	acres	$0.21	$0.21	D	$21,925	$21,925
Nutrient Management Plans - Buffers	Grassed	183	acres	$8.47	$9.57	A	$1,547	$1,747
Nutrient Management Plans	Cover Crops (Cereal Grain)	58,797	acres	$26.82	$44.10	D	$1,576,839	$2,592,988
Subtotal							$10,822,125	$12,018,254
TOTAL							**$10,822,125**	**$12,018,254**

Notes:

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BMP Category	BMP Type	Level of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING LAND USE CONVERSION								
Landuse Conversions	Forest/Grass Buffers	327	acres	$107.98	$129.07	B	$35,308	$42,207
Landuse Conversions	Tree Planting	133	acres	$2.81	$21.11	D	$374	$2,808
Subtotal							$35,683	$45,015
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Conv Tillage)	392,444	acres	$4.12	$4.74	C	$1,615,504	$1,859,354
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	273,916	acres	$4.12	$4.74	C	$1,127,581	$1,297,782
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Pasture	58,473	acres	$0.36	$0.47	C	$21,194	$27,250
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	2,479	acres	$1,282.68	$1,640.44	C	$3,179,762	$4,066,640
Agriculture - Barnyard Runoff Control	Full System (Total Barnyard Control)	85	acres	$1,282.68	$1,640.44	C	$109,028	$139,437
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	10,122	acres	$29.64	$149.92	D	$299,999	$1,517,515
Nutrient Management Plans[1]	Nutrient Management Plans	463,656	acres	$0.21	$0.21	D	$97,877	$97,877
Subtotal							$6,450,945	$9,005,855
TOTAL							**$6,486,628**	**$9,050,870**

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BMP Category	BMP Type	Level of Activity	Units	Unit Cost (1997$/unit/yr)			Annual Cost (1997$)	
				Low	High	Ref.	Low	High
BMPs INVOLVING LAND USE CONVERSION								
Landuse Conversions	Retirement of Highly Erodible Land	48,474	acres	$49.57	$56.98	D	$2,402,651	$2,762,254
Landuse Conversions	Conventional -> Conservation Tillage	128,316	acres	$7.64	$9.21	D	$979,957	$1,181,558
Subtotal							$3,382,608	$3,943,812
BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Urban BMPs								
Urban	Erosion & Sediment Control	15,771	acres	$985.13	$1,266.59	D	$15,536,458	$19,975,446
Urban - SWM (Storm Water Management)	SWM Conversions (Dry->Retention)	2,143	acres	$281.47	$281.47	A	$603,180	$603,180
Urban[1]	Nutrient Management (Residential)	2,399	acres	-$19.06	-$19.06	E	-$45,725	-$45,725
Subtotal							$16,093,913	$20,532,901
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	1,020,000	acres	$4.12	$4.74	C	$4,198,853	$4,832,642
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	423	acres	$1,282.68	$1,640.44	C	$542,573	$693,904
Agriculture	Animal Waste Mgmt Systems (Poultry)	104	acres	$1,282.68	$1,640.44	C	$133,335	$170,523
Agriculture	Grazing Land Protection (Rotational Grazing)	39,013	acres	$21.07	$25.36	A	$821,913	$989,370
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	3,245	acres	$29.64	$149.92	D	$96,176	$486,498
Resource Protection & Watershed Planning - Streambank Protection	Stream Restoration (Non-tidal)	37	acres	$149.92	$149.92	D	$5,604	$5,604
Resource Protection & Watershed Planning	Forest Harvesting Practices	68,463	acres	$71.77	$71.77	C	$4,913,838	$4,913,838
Nutrient Management Plans[2]	Nutrient Management Plans	375,597	acres	$0.21	$0.21	D	$79,288	$79,288
Nutrient Management Plans - Buffers	Forested	123	acres	$107.98	$129.07	B	$13,227	$15,812
Nutrient Management Plans - Buffers	Grassed	1,706	acres	$8.47	$9.57	A	$14,453	$16,326
Nutrient Management Plans	Cover Crops (Cereal Grain)	67,224	acres	$26.82	$44.10	D	$1,802,848	$2,964,643
Subtotal							$12,622,109	$15,168,449
BMPs Affecting Direct Loads to Tidal Bay Waters								
Trib Model BMPs - Shoreline Protection	Structural Shore Erosion Control	33,640	feet	$20.49	$32.23	F	$689,284	$1,084,217
Trib Model BMPs - Shoreline Protection	Nonstructural Shore Erosion Control	66,779	feet	$7.78	$10.98	F	$519,541	$733,233
Subtotal							$1,208,824	$1,817,451
TOTAL							**$33,307,454**	**$41,462,612**

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BMPs INVOLVING NUTRIENT REDUCTION EFFICIENCIES								
Agriculture/Silviculture BMPs								
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Cropland (Cons Tillage)	60,530	acres	$4.12	$4.74	C	$249,175	$286,786
Agriculture - SCWQ (Soil Conservation and Water Quality) Plan Implementation	Pasture	89,096	acres	$0.36	$0.47	C	$32,294	$41,521
Agriculture	Animal Waste Mgmt Systems (Dairy/Beef/Swine)	1	acres	$1,282.68	$1,640.44	C	$1,283	$1,640
Resource Protection & Watershed Planning - Streambank Protection	Stream Protection w/Fencing	3,100	acres	$29.64	$149.92	D	$91,879	$464,760
Resource Protection & Watershed Planning	Forest Harvesting Practices	6,106	acres	$71.77	$71.77	C	$438,272	$438,272
Nutrient Management Plans[1]	Nutrient Management Plans	659	acres	$0.21	$0.21	D	$139	$139
Nutrient Management Plans	Cover Crops (Cereal Grain)	5,904	acres	$26.82	$44.10	D	$158,336	$260,372
Subtotal							$971,377	$1,493,489
TOTAL							**$971,377**	**$1,493,489**

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