Chesapeake Bay Program

Technology Transfer Report

Cost Analysis for Nonpoint Source Control Strategies in the Chesapeake Basin

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INTRODUCTION

The Chesapeake Bay is the largest estuary in the United States and one of the most productive in the world. The Chesapeake drainage basin is 64,000 square miles in size and drains portions of six states (New York, Pennsylvania, Delaware, Maryland, Virginia and West Virginia) and the District of Columbia. The Bay has the highest density of land mass per volume of water of any estuary in the United States. This makes runoff from the land very important to the health of the Bay. The Bay began a gradual decline in productivity shortly after the turn of the century. In 1975, Congress directed the U.S. Environmental Protection Agency to study the problems in the Bay and to develop solutions.

CHESAPEAKE BAY AGREEMENTS

The research phase, which was completed in 1983, brought forth findings which indicated that nutrients were the major problem, but no single source of pollution was responsible for the decline of living resources in the Bay. These studies indicated that nutrient loading to the Bay from both nonpoint source (NPS) runoff and the discharges from waste water treatment plants were equally to blame. These findings, along with the concern of citizens and elected officials, resulted in the development of the 1983 Chesapeake Bay Agreement, which was signed by the governors from Pennsylvania, Maryland, Virginia, the Mayor of the District of Columbia and the Administrator of EPA for the Federal Government. This agreement created the Chesapeake Bay Program and called for all jurisdictions and agencies to focus their existing pollution control programs on reducing the nutrient loads to the Bay. This agreement did not establish any numeric goals or time frames for action, it simply committed everyone to begin moving forward and to control pollutants entering the Bay.

A second Bay Agreement was developed and signed by the jurisdictions in 1987. The 1987 Chesapeake Bay Agreement had the benefit of several years of experience with implementation of pollution control measures in the basin and a better understanding of the major sources of pollution needing control. One of the major goals was to reduce "1985 controllable" nutrient loads to the Bay by 40 percent by the year 2000. A Basinwide Nutrient Reduction Strategy was completed in 1988 which supported the 40 percent reduction goal and called for a re-evaluation of the goal in 1991, which was to be based upon information developed from the models and monitoring data regarding the Bay.

WATERSHED MODEL

The Chesapeake Bay Program has developed models for the Bay drainage basin and the waters of the Bay. The watershed model which covers the entire 64,000 square miles of the drainage basin was initially developed during the research program and has undergone periodic updates over time. The updating of the model includes refined land use coverage, revised loads for all land uses, revised point source loads, improvements in atmospheric deposition loadings, and the load reductions expected from applied control measures (Donigian *et al.*, 1991). The watershed model was fully calibrated for the four year period (1984-1987) based on the monitoring data from the tributaries.

The watershed model simulates the pollutant loads from eight land-uses, the majority of the point sources and atmospheric deposition. Table 1. lists the distribution of 1985 watershed model land-uses for the basin.

TABLE 1. Distribution of Land Use in the Chesapeake Basin Watershed Model

Land Use	Total Acreage	% of Total Basin
Cropland*	8,237,125	20.00
Pasture	3,740,981	8.96
Forest	24,457,144	60.00
Urban	4,032,669	10.00
Water	526,115	1.00
Animal Waste	12,650	0.04

*Includes, Conventional and Conservation Tillage and Hay Land

The watershed model processes these loads through the river systems and delivers the load to the Bay for use in the Bay model. The watershed model has been used to evaluate the load reductions for several different management scenarios, to establish the "controllable" NPS source loads, to forecast the loads from a projected year 2000 land use and population growth scenario and to define a limit of technology (LOT) scenario for NPS control measures. The output from the watershed model is used to develop the input loads for the Bay water quality model.

COST OF REDUCING NPS LOADS

The NPS costs related to implementation of control programs in the Bay, are not site specific because they represent the diverse conditions over the entire basin and a limited number of land uses that the model can simulate. When developing a cost analysis of the various management measures for NPS it is important to understand the relative importance of the load from each land-use. It must be understood that the loads from each land-use are not totally controllable and that some land uses provide only a limited opportunity for implementation of control measures due to cost and the technology that is available for use. Table 2. indicates the NPS nutrient loads by the various land uses in the basin. Cropland, pasture and animal waste represent the agricultural land uses that contribute 58 percent of the total NPS nitrogen and 82 percent of the total NPS phosphorus loads to the Bay. Forest, water and urban land uses make up the remaining 42 and 18 percent respectively.

TABLE 2. Nitrogen and Phosphorus Loading Loads by Land Use
1985 Base Case Loads from Watershed Model

Land Use	Total Nitrogen	Total Phosphorus
Cropland*	107,363,945	9,579,188
Pasture	19,944,389	988,612
Forest	69,154,496	735,042
Urban	32,702,583	2,098,749
Water	5,938,403	189,542
Animal Waste	19,419,035	2,914,660
TOTAL NPS	254,522,852	16,505,793

*Includes, Conventional and Conservation Tillage and Hay Land

Land use and nutrient load data by land use provide estimates of relative load contributions for individual land uses. For example, even though forests comprise 60 percent of the land in the basin, the nitrogen load from forests are only 27 percent of the total NPS nitrogen load.

As part of the process to re-evaluate the 1988 Basinwide Nutrient Reduction Strategy, the EPA Chesapeake Bay Program Office(CBPO), along with the states, used both the watershed and the Bay models to simulate load reductions and water quality responses to management scenarios for both point and nonpoint source control activities. For the cost analysis the LOT scenario, which is better defined a best available technology (BAT) was applied to NPS land uses.

Using the results from model simulations, and NPS control technology cost data developed for the Bay Program, it is possible to determine the overall cost to reduce NPS loads within the basin.

Watershed Model Decision Rules for LOT Scenario

The decisions regarding the use of the watershed model to simulate a "LOT" or "BAT" scenario were developed by the Nutrient Reduction Task Force of the NPS Subcommittee (now the Nutrient Subcommittee). Since the model does not simulate all of the NPS best management practices (BMPs), some were combined and reduction values were developed for each grouping that was used for the scenarios. The following summarizes the ground rules that were established for making adjustments to the Watershed Model input deck for the NPS actions of the LOT scenario.

There are two types of reductions used in the scenarios, a reduction by conversion of one land use to another and a percentage reduction due to actual BMP implementation.

The application of one or both of these reductions is dependent on the NPS BMP type and the model structure. Some of the acreage categories receive both types of reductions, while others only receive one type. An explanation of the associated reductions is included with each category.

Conventional Tillage Cropland—All conventional tillage acres are converted to conservation tillage acres.

Highly Erodible Land (HEL)—HEL acres from the 1991 Soil Conservation Service (now Natural Resource Conservation Service) data base, identifying areas of highly erodible land in each county, were used to determine the HEL land areas in each county. In counties where the HEL acreage was greater than 25 percent of the total crop acres in the county, no more than 25 percent of the county cropland would be counted as HEL acres. This was for consistency with the Conservation Reserve Program (CRP) policy at the time. Total HEL acres in each model segment were aggregated up from the county level data. Highly erodible acres are removed proportionally from conservation tillage and hay land acres and placed in the pasture land use.

Structural BMP's—Structural BMP's include any physical or constructed practice, such as vegetated filter strips or waterways, implemented on cropland. This category does not include the animal waste category. Structural BMPs were applied only to conservation tillage land use. The acres treated by structural BMPs are assumed to receive a 4% nitrogen (N), 8% phosphorus (P), and 8% biological oxygen demand (BOD) reduction, representing the reductions realized from installing a "farm plan" on conservation tillage and hay land acres. "Farm plan" is defined as the additional structural BMPs necessary, when added to conservation tillage, which would bring the land into compliance with "T" or the requirements of the 1990 Farm Bill.

Nutrient Management—Nutrient management was applied to all conservation tillage and some hay land acres. These acres received the nutrient reductions calculated for each model segment from nutrient reduction data furnished by each state.

Animal Waste—Reductions of runoff load from manure acres are assumed to be controlled to the level of 75 percent. Seventy five percent of the total manure acres in each model segment are converted to pasture acres. The remaining 25 percent of the manure acres represent residual animal waste runoff loads of current animal populations after the full implementation of controls.

Pasture—Acres treated by grazing land stabilization systems, stream protection systems, or spring development are assumed to be applied to pasture land and receive a 4% N, 8% P, and 8% BOD reduction. This reduction applied to all pasture land.

Urban—Urban loads are reduced in all pervious and impervious urban land uses. Urban acres receive a 20% P, 20% N, and 25% BOD reduction based on estimated reductions for urban BMPs.

Forest—Forest BMP's provided an over all reduction in the forest loads for each state as follows: PA NH4–5%, PO4–5% and BOD–5%; MD NH4–7.5%, PO4–7.5% and BOD-7.5%; and VA NH4–10%, PO4–10% and BOD–10%.

Cost Analysis of LOT Scenario for Chesapeake Bay Program States

The NPS cost analysis is based on the decisions discussed above for the scenario simulating LOT load reductions.

The costs for LOT are determined by assigning BMP costs from the Table 2.6 of the draft cost analysis study (Camacho, 1992), to the acres treated in the LOT model simulation for the following practices: HEL-CRP, Animal Waste, Urban Cost, Conservation Tillage, Nutrient Management. Per acre costs for Forest, Pasture and Farm Plan were developed during a June 16, 1992 conference call among the States, Interstate Commission for the Potomac River Basin (ICPRB) and CBPO. The agreed upon costs per acre was applied to the total acres for Farm Plan of $15.00 and for Pasture of $2.50, the cost of treating an acre was adjusted in order to get a cost that could be applied to the total acres in the category. The cost for Forest was obtained from information presented in the South Journal of Applied Forestry (Lickman, 1990) and used in the following manner. The cost to install enhanced BMPs was 5.1% of the gross value of the harvest, in Virginia the gross value per acre is about $1,000 per acre and it was estimated that the annual harvested acres were one percent of the total forest acres.

It must be noted that the NPS costs used for this analysis are averages for the entire basin and do not represent the cost in any one river basin or tributary. These average costs represent a very wide range of costs in some cases and may be misleading when trying to relate them to a single tract of land.

Forest Cost—The total forest acres (20,333,492) were multiplied by 1% and $51.00 per acre to get the total cost of $10,370,081. The $51.00 is the cost for implementing enhanced BMPs on harvested land and is 5.1% of the gross value of the harvested timber ($1,000 per acre in Virginia).

HEL-CRP Cost—The HEL acres (528,911) were multiplied by the sum of two cost figures, the average farm plan cost, based on the average cost per acre of the examples furnished to ICPRB by Pennsylvania and the cost of permanent vegetative cover on critical areas to get the total cost of $130.00 per acre treated, resulting in a total cost of $68,758,430. A land rental rate was not factored into this analysis because the land would still be in "production" as pasture land. Therefore, once so treated, the HEL acres become part of the pasture acreage.

Animal Wast Cost—The model simulates a 75% reduction by applying BMPs to all manure acres, therefore the cost is applied to the total manure acres (12,650) used in the model scenario. This number was divided by .75 and multiplied by the cost of $8,187 per acre to get the total cost of $84,563,523. Once treated, 75% of the acres become part of the pasture acreage.

Urban Cost—The urban costs were developed by multiplying the total urban acres (3,215,863) by the cost of large scale urban retrofit BMPs at $200.00 per acre, for a total urban BMP cost of $643,172,600.

Conservation Tillage Cost—The remaining conventional tillage acres (1,909,649) were multiplied by the cost of conservation tillage, $17.43 per acre, to get a total cost of $33,285,175.

Pasture Cost—The total pasture acres (3,606,133 - which now includes the original pasture acres, plus 75% of the manure acres and the HEL acres) were multiplied by $2.50 per acre to get a total pasture cost of $9,015,332.

Nutrient Management Cost—The acres of conservation tillage (4,088,508) were multiplied by the cost of nutrient management, $2.40 per acre treated, to get a total cost of $9,812,420.

Farm Plan—The load reduction for farm plan is calculated by reducing the nitrogen load from conservation tillage and hay land acres after nutrient management has been applied. The total acres of farm plan (6,590,132 - conservation tillage plus hay land acres) were multiplied by $15.00 per acre to get a total cost of $66,169,082.

Cost Summary for the Basin

Total NPS costs and the pounds of nitrogen removed for each BMP practice or grouping are shown in Table 3., along with the cost per pound of nitrogen removed. These data provide a comparison of the various BMPs available to control NPS nitrogen. The least costly of these are nutrient management followed by animal waste control, the combination of these two practices removes about 66% of the total nitrogen load at about 10% of the total cost. The most costly is the urban category which removes about 11% of the total nitrogen load at about 70% to the total cost.

TABLE 3. NPS, "LOT" N Cost Analysis Summary by Management Practice for Agreement States—Total

Management Practice	"LOT"Cost in Dollars (000)	Pounds of N Reduced (000)	% of Total	Cost/Pound of N Reduced, $/#N
Urban	$643,172	4,509	10.64	$142.64
Forest	$10,370	150	0.35	69.13
Farm Plan	$66,169	1,462	3.44	45.27
HEL	$68,758	2,991	7.05	22.99
Pasture	$9,015	910	2.15	9.90
Lo Till	$33,285	4,476	10.56	7.44
Animal Waste	$84,563	11,801	27.84	7.17
Nutrient Mgmt.	$9,812	16,096	37.97	0.61
TOTAL	$925,144	42,395	100.00	

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